The Effect of Urban Tree Canopy on Residential Energy Use

A Worcester Polytechnic Institute Interactive Qualifying Project

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Sponsor: Executive Office of Energy and Environmental Affairs

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Abstract

Our project aims to verify that tree canopy can help reduce residential utility levels. The loss of over 30,000 trees in Worcester due to the Asian Longhorn Beetle became the motivation for determining tree canopy’s economic value. Unfortunately, the correlation between the tree canopy and energy usage is ambiguous. The challenges encountered from this project have aided the team in developing recommendations for better conditions for future teams to continue research of this kind.
Acknowledgements

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Executive Summary

To address the causes and anticipated consequences of global climate change, Massachusetts passed the Global Warming Solutions Act in late 2008. The legislation requires that statewide emissions of greenhouse gasses (GHG) be reduced from 1990 levels by 80% by 2050, and 25% by 2020. Of the three major CO2 emitting sectors identified for emission level reductions, the building sector represents a particularly major emission source, with heating, ventilation and air conditioning (HVAC) comprising nearly 70% of total household energy use. In order to substantially reduce the high level of energy consumption in the residential sector, an alternative energy reduction strategy will need to be implemented that does not require a tremendous investment by the state.

Over the past term, the Urban Tree Cover Interactive Qualifying Project (IQP) team has been working under the guidance of the Executive Office of Energy and Environmental Affairs to produce measured data that would either support or refute the belief of the possible economic benefit provided by tree canopy to urban residencies. Widely believed to reduce heating and cooling costs in buildings, tree cover is seen as a possible low-cost and low-maintenance strategy to reduce the energy usage in the residential sector of the state. In order to produce measured data of the impact of tree canopy, the team set out to measure the changes in energy consumption from residents in Worcester who had lost trees on their property due to the Asian long-horned beetle.

To measure the impact of tree canopy on energy consumption, the team set out to acquire willing participants for the study to measure the electricity and fuel levels from before and after the removal of trees from their respective properties. Due to most of the trees having been removed in early 2009, utility levels were calculated for 2008 and 2010, to measure the change (if any) in consumption levels. By normalizing each gathered monthly rate with each year’s heating and cooling degree days, any variance in temperature for those years would be accounted. Diagrams of each property were also constructed to illustrate the number of trees on each property, as well as their location on the property and estimated canopy size.

Throughout the entire data gathering process, the project team faced many unanticipated challenges that influenced the overall results of the research. The extremely low resident response rate during the initial stages of research not only demonstrated the lack of interest in the potential benefits the project could produce, but also forced the project team to lower the expected number of willing participants from 30 to 10. Though 10 participants were interviewed, they frequently provided the team with inconsistent utility rates. Often to make up for missing monthly usage rates, estimates for fuel or electricity levels would have to be made based upon whatever information each resident was able to provide upon the appointment.

Due to the challenges faced during the entire data collection process, the project team shifted the central focus of the research from the results of the research, to the
construction of the proper methodological approach. By modifying each data collection process to account for the unanticipated challenges faced during research, the team produced a working data collection strategy to aid any and all future research of this type.
1. Introduction

1.1 Climate change indicators

The U.S Environmental Protection Agency states that “Climate change represents the state of certain environmental conditions in an area and a specified period of time. Examples of climate change indicators include temperature, precipitation, sea level, and greenhouse gas concentrations in the atmosphere (EPA, 2010).”

Carbon dioxide is one of the primary greenhouse gas emissions that are stored in our atmosphere. It is produced, along with other emissions, as a result of the widespread industry on which our national economy relies. A build-up of these emissions causes radiation from the sun to become trapped in our atmosphere, known as the “greenhouse effect”. The resulting entrapment of the suns energy causes the overall increase in average worldwide temperatures (WWF, 2010).

Trees, green plants and certain species of algae essentially serve as the lungs of our planet. Through the process of photosynthesis, trees absorb carbon dioxide and expel breathable oxygen (EPA, 2010). By storing CO2 within their living structure, trees actively reduce the level of emissions in the atmosphere. This characteristic, which every plant that undergoes photosynthesis possesses, represents a necessary and important role in the environment and is vital for all aerobic life on earth.
The benefits provided by trees to the environment and developed communities stretch beyond the reduction of atmospheric CO2 concentrations. While no statistical data exists to prove so, it is widely believed that the existence of trees in residential and urban communities produces a considerable and measurable reduction in levels of energy consumption.

1.2 Background of the Asian longhorn beetle

On August 7th, 2008, Asian Long-horned Beetles were discovered in Worcester, MA (MIPOP, 2010). Native primarily to China and Korea, the Asian long-horned beetle (ALB) is an invasive species of insect that has caused the destruction of trees on a massive scale. The beetle destroys deciduous hardwood trees, such as maple, elm and poplar by cutting off the flow of nutrients between the trunk, roots, and stem. Since the discovery, ALB’s have caused the destruction of over 30,000 trees in Worcester alone, leaving once lush neighborhoods completely bare. The neighborhoods of Burncoat and Greendale were the most severely affected. A quarantine zone of about 94 square miles has been established around the area, prompting efforts to remove the beetle and control any further damage that it may cause to the city (MIPOP, 2010).

Below are images demonstrating clear examples of the damage caused as a result of the ALB. Both shots were taken from the same location on Hillcroft Avenue before and after the trees were removed by the city to control further infestation.
Figure 1: Hillcroft Avenue before trees were removed

Figure 2: Same location on Hillcroft Ave. after removal
1.3 Project purpose

The purpose of this research project is to investigate the influence of tree canopy cover in order to obtain empirical data that will support or refute an existing theory. Evidence from other climates has suggested that tree canopy reduces energy demand. A study of this type has never been conducted before, and if successful, will provide valuable information concerning the economic benefits of trees, as well as the proper methodology for future research of this type.

Much of the research for the project will include conducting interviews with willing residents who have lost trees on their property as a result of the ALB. During the interviews the team will be gathering important structural information of the house, utility figures, and details of the particular trees that were removed. With this collection of empirical data, the mostly qualitative research that the team will undergo will be supplemented by practical quantitative research as well. The objective is to analyze the effected residents’ energy usage before and after the Asian Longhorn Beetle infestation to further prove how important the economic benefit provided by trees is to urban communities.

1.4 Project methods

Continuing upon research from a previous project, the data the team will need to obtain and analyze will either support or refute the existing theory of tree canopy as an energy reduction strategy. These claims of course, were made based on research measuring the perception that residents of the Burncoat and Greendale areas have on the
economic value of trees in their community. While these assertions provided a useful understanding of how residents felt about their energy consumption, they still lacked solid evidence showing that in fact, tree canopy does have an effect upon consumption levels. The resulting data will be utilized to formulate a solid claim of the impact of tree cover on urban residential energy consumption throughout the state and general region. Worcester of course, is only a subset of the entire urban population, but the information gathered would provide accurate representations of other residential areas with similar characteristics.
2. Background

2.1 Global Warming Solutions Act

In August of 2010, Massachusetts passed the Global Warming Solutions Act, making it one of the first states to develop a comprehensive regulatory program to address the growing climate change issue (Mass, 2008). The program requires the state to reduce greenhouse gas emissions by 80% from 1990 levels, by 2050, as well as a 25% reduction by 2020. In Massachusetts, the building sector is one of the three major areas identified in the Draft Climate Implementation Plan as being crucial for meeting these mandated emission reduction levels (MassDEP, 2008).

2.2 Statewide energy use and residential energy use

In the United States, fossil fuel burning is the largest source of carbon dioxide emissions. The consumption of energy in the United States is approximately 89.4% from the burning of fossil fuels. Among this percentage, 39.1% comes from oil, 25.9% from natural gases, and 24.4% from coal (Stewart, 2009). Annually, residential energy use is 18% of total energy use statewide, accounting for 16% of greenhouse gases emissions. Heating, ventilation, and air conditioning systems comprise the largest portion of residential energy demand; 66% of household energy use goes to heating alone (EEA, 2010). Residential energy consumption is increasing because houses are getting larger central air conditioning systems are increasingly prevalent, and air conditioning systems are being run with greater frequency. Residential building electricity consumption for cooling is one of the few energy uses that are projected to grow in the future, despite improving technology (EEA, 2010).
2. 3 Massachusetts’ housing problem

One characteristic that many houses in Massachusetts share is their age. Nearly 75% of homes were built before 1980, with 44% having been built before 1940 (EEA, 2010). Generally, this means that the homes have poor or almost no insulation, as well as older and much less efficient HVAC systems. With these current circumstances, there is considerable room for increasing the temperature control efficiency of these homes, which would be a significant step in reducing statewide emissions. Whether or not such upgrades can be undertaken however, is another consideration. The means by which old houses can be made efficient is extremely expensive. The costs of upgrading these houses would require a substantial investment from the state, as well as the owner (EEA, 2010).

2.4 New energy solution

There is a need for a residential energy-reduction strategy that is both low-cost and low-maintenance. The solution must have the ability to be implemented across residential neighborhoods that can minimize the obligations of landlords and capitalize on the capacities of the tenants. Properly planting trees in strategic positions in these residential areas may be that solution.

2.5 Tree canopy

Tree canopy cover is a very effective way to reduce heating and cooling costs in many buildings. A study at Florida International University has shown that 50-60% of energy needed for air conditioning can be eliminated by planting trees in a specific way
Evapotranspiration, which is a combination of water evaporating into the atmosphere and trees releasing water through respiration (Lydersen, 2009) is responsible for preventing heat exchange by reducing temperatures in the building envelope (EEA, 2010). Not only can trees prevent warm air from getting in during the summer, but also prevent cold air from getting in during the winter (EEA, 2010).

Tree canopy is estimated to provide approximately 15% savings in energy costs for cooling and heating (EEA, 2010). The mechanisms for savings on cooling costs are: preventing solar heat absorption through direct shading of windows and walls; and, when adopted on a widespread basis, lowering ambient air temperatures in the urban areas by 1-3 °C (i.e. reducing the Urban Heat Island effect). Large deciduous trees placed within 15 feet of the Southeast and Southwest walls of a house have been shown to achieve somewhat optimal energy savings. The primary means by which heating energy is reduced is by reducing infiltration of cold outdoor air. This is especially relevant to the high number of older, less insulated homes in Worcester. This is best achieved by conifer trees planted on the North or Northwest side of the house. All of these techniques reduce the amount of work required by heating and cooling systems (EEA, 2010).

2.6 Sponsor and background

The sponsor of the research project, the Executive Office of Energy and Environmental Affairs (EEA) has presented the team with the challenge that, if carried out successfully, could help neighborhoods across the state reduce energy costs and the
state to meet its mandated GHG emissions reduction goals. The EEA is charged with preserving the land, air, water, and other natural resources of the Commonwealth, regulating energy resources and sustainability, among other things. Last year, with the aid of the EEA, students at WPI worked on a research project entitled “Assessing Ecosystem Service Values Provided by Urban Trees”, where they assessed the values that ecosystems provide and local resident’s knowledge of such. The particular neighborhoods they focused on were the Greendale and Burncoat areas of Worcester, both of which were severely damaged by the Asian long-horned beetle.

The extent of the damage caused by the Asian long-horned beetle is still very difficult to determine, but its effects are made chillingly clear every day. According to Clint McFarland, manager of the U.S. Department of Agriculture’s ALB Eradication Program, about 75% of the trees between the Faulkner Hospital in Boston and Route 70 will have to come down (Crowley, 2010). Residents of the Burncoat and Greendale areas of Worcester witnessed firsthand the destructive nature of the ALB, having lost almost every deciduous tree in the area to the unfortunate infestation. The investigation of the project will focus on these two neighborhoods, because the team believes that the extent of the ALB damage goes far beyond aesthetical considerations.

2.7 Significance

While the removal of so many trees has taken its emotional and financial toll on the residents of Worcester and the state of Massachusetts, it does present a unique scenario that could provide evidence for a new energy reduction strategy in the state.
This project will be a natural case study to support or refute the theory that tree canopy cover benefits energy conservation. This project will not only serve to educate locals’ alternative energy conservation strategies, but will also produce measured energy savings data and appropriate research methodology for research initiatives of this kind.
3. Research Methods

The project team’s objectives will be the collection of relevant data to support the task of determining the economic value provided tree canopy. As the team carries this process out, they must keep in mind the ultimate results that this information will help achieve. Maintaining sufficient tree canopy cover around houses may significantly decrease heating and cooling expenditures as well as increasing air quality and property value. In order for the team to determine the impact of the ALB on energy demand, they need to measure any major differences in levels of energy consumption in the Worcester, as a subset of other urban populations. If the findings support this existing theory, it would shed new light on an energy reduction strategy that could potentially help the state of MA lower GHGs.

There is no question of the damaging effects that the ALB has caused to the residents of Worcester. For almost two years, residents have been ‘fighting’ the insect in a losing battle that has taken its toll not only on the hearts of the people, but also their wallets (Telegram, 2010). The type of information that the team will to collect, among many other measurable land variables, will include electric and fuel consumption levels from before and after the trees were removed, household temperature settings, and the specifics on each tree lost to the ALB for individual properties. After the team gathers sufficient data for analysis, they will be able to present a valid response to the question of how tree canopy cover affects residential energy use.
3.1 Research Questions

3.1.1 Research question 1

Question: Have energy levels changed as a result of removal of trees due to the Asian long horned beetle?

In order to prove the legitimacy of tree canopy as an alternative energy conservation strategy, measured changes in utility costs will need to be gathered from a diverse set of properties. Naturally, the team will have to visit individual properties at the residents’ convenience in order to obtain reliably sets of data for analysis.

3.1.2 Research Question 2

Question: Can we attribute the change in energy to tree loss/orientation/type?

The most important variable in this question is energy levels of homes in Worcester, and if they have increased or decreased since the infestation of Asian Long-Horned Beetles. In order to accurately determine whether or not the Asian Long-Horned Beetle infestation had a significant effect on a home’s energy levels, the project team will first have to find data of the house’s energy levels at some point before the infestation; and also measure the energy usage at its present level. However, the team will have to take note of other variables which may have altered the energy level, such as: age of the house (construction and last major renovation), when/how many trees have been planted/cut down (not necessarily due to the ALB), which/how many appliances were used in the house, if the family took vacations, or if they used their appliances more/less for different reasons. Naturally, to find out most of this information, the team will have to go to the
homes of the residents. To find out these variables, the team will either have to ask the residents of the house or make a personal measurement on their property. A full list of these variables, as well as the methods of discovering them, is found in section 3.5.

3.2 Description and justification for methods

In order for the project team to be successful in acquiring the information necessary to support the economic value of trees, they will need to plan out proper research acquiring methods as well as goals to meet prior to our research.

The first objective would be informing the residents of the Burncoat and Greendale areas of Worcester of our intentions and the purpose of our research. It is understandable that due to the nature of the project and the type of information we’re gathering, many residents would be hesitant to freely provide private billing information. The team will need to conduct research respectably and professionally in order to increase the overall rate of success and efficiency of the data collection process. Early notification of the residents will be made through a number of flyers which we will posted in and around the neighborhoods, providing basic introductory information of who they are, what the project is, and the purpose for our research.

The following is a short list of the initial steps to take in our data gathering process.

- Inform residents of the team’s identity, what the project is, and how it would benefit them.
• Meet residents in person for formal introduction
• Discuss project in detail
• Schedule future day and time for data collection on that property
• Ensure resident is able to obtain electrical and heating information

After the team makes introductions and inform the residents of the data they’re gathering, they will need to set up a schedule for us to follow which would be given to the residents. This master schedule would inform them of the specific date and time the team would be visiting their property to take all the necessary measurements for analysis. This would also give the residents the date by which to have the electrical and other energy information available for the team to record. Depending on the difficulty of obtaining past and present energy consumption information, it is assumed that we would not need to inform the residents of how to acquire this information for the project team.

When the team finally begins the process of visiting properties for data collection, it will be very important to include as many different types of variables as possible that could influence the results. Once this data is recorded for the first few houses, and the team becomes proficient at gathering data, they will split up into two teams in order to visit more houses in less time, to maximize efficiency.

3.3 Interview Questions
• Have you noticed an increase/decrease in your heating/cooling bills since the removal of trees on your property?
• When was your house built, and when was the last major renovation?
• When were the trees destroyed by the beetles removed from your property?
• What major appliances do you own? How often do you use them?
• What is the size of your house lot?
• What type of HVAC system do you use? Has it ever had to be repaired?
• Are there any other factors which may affect your household energy levels?
• Is it okay if the team measures the aspects of your house, and if they look around your yard and record the type/size/location of your trees? Could you also possibly walk around your yard with us to point out locations of stumps which may not be obvious?
• For our next visit, could you please have your electric and heating bills ready?

3.4 AutoCad

Besides providing 3-D plots, the team will also provide drawings of the properties around the house by using the computer program AutoCad. In order to provide more clarified information, drawings will contain some elements, such as street outside of the house, sidewalk, driveway, walkway between driveway and house, house with dimensions, trees with numbers (circles with estimated area where branches can spread out), distances between centers of trees and the house, types of trees, and estimated height of trees. The AutoCad drawings will provides clear ideas of where the removed trees were. Having these drawings can help the team to have more accurate determinations of the significance of tree canopy to the energy change, if there are changes in energy expenses.
3.5 Checklist for completion during resident survey

**Red = found by resident inquiry  Black = found by personal measurement**

- age of the house (construction and last renovation)
- aspect of the house: windows, walls
- size of lot
- type of HVAC system
- frequency of appliance use
- temperature settings
- energy source
- Energy usage by month and fuel type
- type, size, location of trees
- date of tree removal
- other possible explanatory variables, e.g. vacation dates, behavior change, other major appliance purchases/changes
- Anecdotal evidence: Do people notice change before and after ALB removals?

Upon the conclusion of the Burncoat and Greendale residential interviews and tree study, it will be time to analyze our data and determine the important considerations in determining the impact of tree canopy. At this point in our study we have 4 participants in total, almost half of the expected quota of ten surveys. Data from every property has varied considerably, so it is important for us to clearly define the most important variables that are consistent with each location.
4. Data Collection

4.1 Stimulating local interest

Initially, in order to expedite the overall process of gathering participants for research the team took several steps to ensure that the residents of the Burncoat and Greendale neighborhoods were aware of our presence, as well as the overall purpose of our research in their community. In response to a recommendation from a particular enthusiastic local, part of the team made an appearance on the Jordan Levy News Program on FM 94.1. Jordan Levy was originally the mayor of Worcester but now hosts a radio program where he discusses local and statewide issues in depth. Being familiar with all the damage caused by the ALB, Mr. Levy allowed us to discuss our project in depth on the air in order to further inform the public of our objectives. While the experience in itself stimulated local interest, demonstrated by the phone calls received in the studio, it did not fulfill its purpose of inciting locals to contact us for participation.

4.2 Raising project awareness

To raise local awareness of our presence in the community, the team posted flyers in and around the Burncoat and Greendale areas. The purpose of which was to introduce ourselves and inform the residents of our project and intentions. Despite leaving contact information for any and all interested in the study, only two responses were received and no appointments were actually scheduled.
With little feedback received from the posted flyers, a more direct approach was taken by delivering personalized letters to individual properties explaining in detail the purpose of the project and requesting participation.

Over 150 personalized letters requesting participation were delivered to residencies known to have lost trees due to the ALB. Unfortunately, due to an unperceived general lack of interest in this type of research, the letters only yielded four responses, two of which actually chose to schedule appointments. At this point in the project, it became all too clear that obtaining willing participants for research would be one of the most difficult aspects of the entire study. Due to this unfortunate drawback, the target number of participants for the study, which was set to thirty residencies, was lowered to a more realistic goal of ten.

4.3 Contacting residents personally

At this point in time suitable options for garnering willing participants in the project were dwindling, posing the question of how much interest (or lack of), that those affected by the ALB possessed. The team began contacting residents by phone, utilizing the public directory to obtain resident home numbers. By following a flexible script to increase resident interest in the research being conducted; a considerable increase in participation was obtained for every house that was dialed. This strategy proved to be much more efficient, inciting nearly half of every local called into participating.
Good morning, my name is _________. I am a student at Worcester Polytechnic Institute working on a project that is assessing the damage caused by the Asian long-horned beetle in your community.

Our team is working with the Massachusetts Executive Office of Energy to determine the importance of trees and how they can be utilized to considerably lower energy consumption in the state. The damage caused by the Asian long-horned beetle presents a unique opportunity to study the perceived benefits that residential trees provide.

How many trees have you lost on your property as a result of the Asian long-horned beetle?

Would you be interested in participating in our study? If you were to schedule an appointment it would not take more than an hour

In developing the phone script, it was important to consider the expected reactions of each person willing to listen to our proposal. Many residents have developed strong emotions toward the ALB and the damage it has caused to their community. Placing the focus of each conversation on the ALB, rather than the benefits of tree canopy, was crucial for building interest in the research being conducted. Each resident that was dialed generally had varying levels of enthusiasm in the research, making it important to format each call based upon their own level of interest.

Despite a higher rate of acceptance by dialed participants, the number still remained relatively low considering the time frame we would normally make each call. Most of the calls made were dialed during normal working hours, causing a high number of voicemails to be reached, which occurred roughly 75% of the time. After the first week of calls, not a single voicemail left that was left warranted a reply. Taking this response rate into account, it was decided to skip leaving a voicemail and to simply re-try
at a more suitable time. By the end of the fifth week of the study, over one hundred calls had been made; making contact with only eighteen residents and scheduling eight appointments as a result.

4.4 Appointment Procedure

Despite limited success from the proposed methods of gathering participants, the appointments with those who were willing to contribute to the study generally followed the same procedure:

1. Team would sit down with the resident and obtain varies household structural information by a simple question and answer method.
2. Resident would provide whatever past electric and fuel bills (or alternative record) for the team to document.
3. One member would record the figures of households heating system, measuring its efficiency by input and output of British Thermal Units (BTUs)
4. Team would determine the number of trees that were removed, and the specific type of trees that they were.
5. One member would use a pre-measured sketch of the property obtained from real-estate maps online to note the location of each tree and estimated size of the canopy.

4.5 Unexpected difficulties

With each appointment, unforeseen complications tended to occur that would influence the data collection process. Most common of these would be the resident’s lack of certain utility information, or even knowledge of such. In a case where insufficient
energy records were available the team would need to make monthly estimates of fuel
collection or electricity usage based on whichever information residents were able to
provide.

This particular winter produced a considerable amount of snowfall, demonstrated
by consistent weekly blizzards. On a regular basis, poor and unsafe conditions not only
affected standard methods of travel, but also indirectly affected the project team’s
research. Due to the extreme weather conditions faced during the entire data collection
process, appointment cancellations were fairly common. During a two week period, half
of the scheduled appointments were cancelled, many of which chose not to re-schedule
due to unsafe conditions on their properties.

4.6 Normalizing data for heating and cooling degree days

Due to the fact that two separate yearly usage rates for energy are being
calculated, it is important to account for any possible differences in the yearly
temperature differences. Since no two years share the exact same pattern of temperature
change, each monthly usage rate will need to be normalized to account for the possible
degree differences. Due to most of the energy usage data we have gathered is in the time
period from 2007 to 2010, so the team decided to obtain monthly information about the
heating and cooling degree days in the past 4 years (NCDC, 2007) (NCDC, 2008)
(NCDC, 09-10) (NCDC, 2007) (NCDC, 08-09) (NCDC, 2010).
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<td>490</td>
<td>246</td>
<td>100</td>
<td>18</td>
<td>5</td>
<td>147</td>
<td>503</td>
<td>569</td>
<td>1091</td>
<td>6200</td>
</tr>
<tr>
<td>2010</td>
<td>1193</td>
<td>992</td>
<td>729</td>
<td>427</td>
<td>163</td>
<td>21</td>
<td>0</td>
<td>6</td>
<td>57</td>
<td>404</td>
<td>630</td>
<td>1098</td>
<td>5636</td>
</tr>
</tbody>
</table>

Table 1 shows the heating degree days data of each month in 2007-2010. Note that the “Total” column represents the total heating degree days in the heating season in the each year (the highlighted months are calculated into the total).

We originally decided to group months of January through April, November and December into the heating season. However, as shown in Table 1, there are also some significant inputs in the May and October; and the fact that winters last longer than summers in the New England area, so the team decided to group months of January through May and October through December into the heating season. Therefore, months of June through September are the group of cooling season. As shown in Table 1, the highest total heating degree days occurred in 2009, that means it is expected more energy is used for heating. Meanwhile, the total in 2007 is slightly less than the total in 2009, so it would have the same expectation on the heating energy usage. The lowest total heating degree days occurred in 2010, which means that if there are not any changes in the house, it is expected to use less energy for heating.

**Table 2: Cooling degree days**

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>72</td>
<td>189</td>
<td>174</td>
<td>49</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>484</td>
</tr>
<tr>
<td>2008</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>109</td>
<td>257</td>
<td>122</td>
<td>34</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>522</td>
</tr>
<tr>
<td>2009</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>26</td>
<td>111</td>
<td>210</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>360</td>
</tr>
<tr>
<td>2010</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>19</td>
<td>114</td>
<td>300</td>
<td>178</td>
<td>65</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>657</td>
</tr>
</tbody>
</table>

Table 2 shows the cooling degree days data of each month in 2007-2010. Note that the “Total” column represents the total cooling degree days in the heating season in the each year (the highlighted months are calculated into the total).
The team decided to group months of June through September into the cooling season because these months provide most of the significant inputs. As shown in Table 2, the highest total cooling degree days occurred in 2010, which means that it is expected to use more energy for cooling. The total cooling degree days in the 2007, 2008 and 2009 are much lower than the total in 2010. Therefore, ideally, it is expected to use less energy for cooling in 2007, 2008 and 2009 if there are not any changes in the house.
5. Findings

5.1 Heating and cooling comparisons

During the initial assessment of resident energy consumption, our plan was to record the monthly fuel consumption in terms of dollar amount as well as fuel type. We decided to change this approach due to the fact that the information we gathered from our initial visits could not be accurately compared. Oil prices have changed considerably over the past several years, making a comparison of costs unreliable unless each resident possessed their annual fuel bills from the exact same years, (which was not the case). It eased the process to simply calculate the annual usage in Kilo British Thermal Units.

As presented in our primary research question, our objective is to determine how utility levels have changed (if at all), as a result of the removal of trees in the Burncoat and Greendale neighborhoods. Household levels of fuel consumption are calculated annually, with oil levels measured in gallons and natural gas measured in cubic feet. Below is a comparative chart indicating the difference in annual consumption. Issues in obtaining reliable fuel records from particular residents are the reason for only recording two individual properties.
The chart above clearly demonstrates contrasting data from what we had originally hypothesized. Annual levels of natural gas on both properties actually *decreased* from previous levels before the tree removal.
Electricity levels, which remained consistent with each household, were measured in Kilowatt hours (KWh). The same process was followed for calculating electrical consumption in the actual cost was disregarded for the amount of wattage. A comparative chart can be read below.

![Figure 5: Electrical Usage](image)

While the Data fail to support our task of determining the benefit of tree canopy, it cannot be considered conclusive data at this point in time. Many more surveys are still required, as well as the consideration of other variables such as HVAC efficiency and additional insulation installments.
5.2 Normalized fuel and electrical comparisons

5.2.1 Normalized fuel usage comparison

According to the data of heating and cooling degree days in Section 4.6, the total heating degree days are different in each year, which means the temperatures are different in each year. In a colder winter, it is reasonable to have higher fuel usage for heating. It is hard to determine how much of it is due to the weather and how much of it is due to other changes around the property. For a more accurate comparison, we normalized the data by using the total winter fuel usage, which is calculated by data from months of January-May and October-December and converted to KBTU (Kilo British Thermal Units), divided by the total heating degree days. What information can a normalized data set provide to us? Basically, the normalized data set of each property is expected to be at the same level if there are no changes around the property. During the interviews, we also asked residents about other changes around the house, such as behavioral changes, temperature setting changes, insulation changes in the period of 2008 to 2010, HVAC system changes, etc. None of the residents mentioned there are any changes in these aspects, so we assumed the only change around the house is the tree removal. Since tree canopy is believed to provide savings in energy usage, so the graph of the comparison between the normalized data in 2008 and 2010 is expected to increase.
Figure 6: Normalized fuel usage in winter

Data is normalized by using the total fuel usage in months of January-May and October-December to divide the total heating degree days in those months in 2008 and 2010.

In Figure 6, the blue columns represent the normalized data in each individual property in 2008 and the purple columns represent the normalized data in each individual property in 2010. As mentioned before, tree removal is considered to be the only change around the house, so the changes in the normalized data set would be considered as the effect of tree canopy removals. In the prospective of the project, it is expected to have increments in the normalized data set in the year after trees were removed. However, as shown in Figure 6, the changes in the normalized data set are not consistent, some of them increase and some of them decreased. There might be some other significant factors we did not put into our considerations, so the graph is not conclusive to determine the relationship between trees and energy usage.
5.2.2 Electrical usage comparisons

As shown in section 4.6, the cooling degree days are different in each year. However, most of the cooling degree days are from the months from June to September. So it is reasonable to separate the comparison in the heating season and the cooling season.

In Figure 7, the winter season is including the months from January to May and October to December. Blue columns represent the total electrical usage in each property in 2008 winter. The red columns represent the total electrical usage in each property in 2010 winter. Due to the Property 1 and Property 10 were only able to provide the annual electrical usage, so we are not able to obtain the monthly electrical usage to calculate the total in winter or summer for these two properties. Other total usage of each property is converted to the unit of Mega British Thermal Units. As shown in Figure 7, some of the
electrical usage went up after trees were removed and some of them went down. The sequence of changes in the winter electrical usage is not transparent.

Since the cooling degree days are different in each year, a set of normalized data is needed for a more accurate comparison. As shown in section 4.6, most of the total cooling degree days come from the months of June to September, so these months are considered as the cooling season of the year. The total summer usage of each property is converted to Kilo British Thermal Units. We normalized the data by using the total the electrical usage in the cooling seasons in 2008 and 2010 to divide the total cooling degree days in 2008 and 2010.

![Figure 8: Normalized electrical usage in the cooling season](image)

Data in Figure 8 is normalized by using the total electrical usage in the cooling season, which is from June to September, to divide the total cooling degree days in those months.

Due to the fact of some people have air conditioners at home, and some people do not, we group these residents into two groups, which are within or without air
conditioners at home. Property 1 and Property 2 do not have air conditioners and the rest of these properties do have air conditioners. Due to the issue that Property 1 and Property 10 were not able to provide the monthly usage, we cannot put them into comparison. As tree canopy is believed to provide savings on the electrical usage by providing direct shades in the summer. The normalized data after trees were removed is expected to increase. However, surprisingly, almost all of the normalized data decreased after trees were removed. There might be some other changes around the property besides the tree removals. The relationship between tree canopy and electrical usage is not determined yet.

5.3 AutoCad Drawings

In order to evaluate our secondary research question, AutoCad was chosen as the suitable program to properly display the characteristics and orientation of the properties and the removed trees. Each property was accurately measured and proportioned to display each trees cardinal location and distance from the house. By displaying the proper locations of each tree, estimating the size and distance of the canopy to the house would be expedited. Below is the AutoCad diagram for 93 Airley Street, of the Burncoat Neighborhood.
This particular house only had three trees removed due to the ALB, which is a relatively low amount compared to others. Each tree location was measured in relation to the house with the height estimated based upon the residents own recollection. Green circles, as indicated, represent the estimated canopy size. Due to the age and height of the tree removed in the backyard, the canopy was estimated to be larger than the house itself. The electrical graphs above show that this property lowered its Kwh consumption between the years that the trees were removed. Due to the size of the maple that was removed, and the fact that we were informed no type of AC unit was ever used, we
assumed that the extra sunlight was the cause for such a minimal increase. Natural sunlight would eliminate the need for additional unnecessary household lighting that would keep Kwh levels above normal.

Having obtained AutoCad diagrams from each property visited to date, the visual significance of canopy in relation to each household can be made without much further investigation. The only drawback as of late is the unexpected reductions in energy consumption, which raises several new questions on its own.
6. Discussions and Recommendations

Throughout the research portion of this research project, the team faced many unforeseen obstacles that hindered overall research and forced us to adjust our approach for gathering data. Despite these consistent complications, the team was able to set up appointments with the expected quota of ten participants. While the results of each study vary considerably and fail to support the theory of measuring the economic benefit provided by tree canopy, the experiences undergone by the research team during this pilot study will be put forth to ensure the success of future research endeavors of this kind. The team has re-assessed the original data gathering process and has determined the most efficient methods for carrying out this type of research.

6.1 Acquiring Participants

The most unexpected obstacle during the research process was the inability of the team to find willing residents to participate in the study. Despite the numerous flyers and personalized letters delivered in and around the neighborhoods, as well promoting the study on a popular local radio program, scheduling appointments was the most challenging and difficult portion of the project. A graphical representation of the response rate can be read below.
Table 3 Summary data collection

<table>
<thead>
<tr>
<th></th>
<th>Flyers</th>
<th>Letters</th>
<th>Answered phone calls</th>
<th>Missed phone calls</th>
<th>Total interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered/called</td>
<td>100</td>
<td>150</td>
<td>20</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Responses</td>
<td>2</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Scheduled</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

As shown in Table 3, a numerical summary of the data collection process is provided. Roughly one-hundred flyers were distributed around the Burncoat and Greendale neighborhoods, with only two responses. During the next step, which was delivering appointment request letters to properties know to have been affected by the ALB, only two appointments were scheduled as a result. These extremely low response rates prompted a much more direct method calling each resident personally in order to present them with our project and request an appointment on the spot.

6.2 Direct Contact

Contacting each resident directly proved much more successful, inciting nearly half of each respondent to participate. The success of this strategy over the original methods prompted consideration of what was done differently. The original methods of seeking locals to participate left the decision in their own hands. Many would not take the time to make contact with us simply due to the fact that it requires them to go out of their way to do so. By contacting each household directly, as done with the phone method, many more appointments could be scheduled simply due to the fact that the decision would be made right then and there. A strong recommendation that the team
stresses for future studies would be to utilize this strategy over less indirect methods such as posting flyers or distributing letters.

6.3 Weather complications

During the entire data collection process one of the most unpredictable and detrimental factor was the weather. Frequent snow storms would not only hinder the ability to travel to scheduled appointments, but would also prompt appointees to cancel pre-scheduled visitations out of fear for their safety or our own. For one, there were many snowstorms throughout the course of the term. The excessive snowfall also hindered the team’s ability to accurately measure the locations of specific trees on each property. With averages of up to 4 feet of snow on each property, the team had to rely heavily on estimates for determining distances of trees from each household. Holding research of this type during the fall or spring seasons would be most efficient to prevent any weather related cancelations or complications.

6.4 Varying data levels

With each property visit, the accumulated data remained inconsistent with the original hypothesis. In many cases, levels of energy consumption decreased with the loss of trees, reflecting a result polar opposite to the proposed theory. With such varying levels in the research, aside from the excessive number of variables for consideration, the team felt an alternative research method should be followed for future studies to follow.
For consideration by future researchers, the project team recommends that in order to severely lower variation in data by unforeseen factors, is be to considerable condense the target population for study. Though the Greendale and Burncoat neighborhoods generally share the same geographical characteristics, many smaller factors such as arrangement of properties, location of hills, and differences in elevation considerably affect the overall results. This would affect the amount of warm air/cold air which enters their home, and therefore affect their household energy levels, which is the main data the team had to collect. If the survey was limited to a single street of one of the neighborhoods, much of the geographical factors would be eliminated, causing any changes resulting from the loss of trees to be much more conclusive.

The actions and methods undergone during this pilot study have been met with equal accomplishments and setbacks. Despite the constant road-blocks that caused research to come to a grinding halt, the actions taken in this study will only serve to improve the overall approach for future researchers. By improving upon the original methods, this project team has formulated the most successful and efficient process to follow in order to ensure the smoothest acquisition of necessary data.
7. Conclusion

The actions and methods undergone during this pilot study have been met with equal accomplishments and setbacks. Despite the constant roadblocks that caused research to come to a grinding halt, the actions taken in this study will only serve to improve the overall approach for future researchers. By improving upon the original methods, this project team has formulated the most successful and efficient process to follow in order to ensure the smoothest acquisition of necessary data.

Success can be measured by one’s personal standard. The theory of whether or not tree canopy has a measurable benefit on energy consumption is still unclear. Only by taking every step into consideration and improving upon them can we make a valid contribution to the statewide effort to lower energy consumption and GHGs. We hope that the information we gather and the conclusions we make that result from this experience will serve to help future studies of this nature.
## Appendix I: Project Milestone

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Schedule appointment with WTAG producer</td>
<td>1 day</td>
<td>Tue 1/4/11</td>
</tr>
<tr>
<td>2</td>
<td>Attend Jordan Levy Show</td>
<td>1 day</td>
<td>Wed 1/5/11</td>
</tr>
<tr>
<td>3</td>
<td>Schedule visit appointments with Worcester residents</td>
<td>10 days</td>
<td>Thu 1/13/11</td>
</tr>
<tr>
<td>4</td>
<td>Distribute flyers around Greendale and Burncoat neighborhoods</td>
<td>1 day</td>
<td>Sat 1/15/11</td>
</tr>
<tr>
<td>5</td>
<td>Write up milestone</td>
<td>1 day</td>
<td>Sat 1/15/11</td>
</tr>
<tr>
<td>6</td>
<td>First weekly meeting</td>
<td>1 day</td>
<td>Tue 1/18/11</td>
</tr>
<tr>
<td>7</td>
<td>Type up interview checklist</td>
<td>3 days</td>
<td>Wed 1/19/11</td>
</tr>
<tr>
<td>8</td>
<td>Revise milestone</td>
<td>1 day</td>
<td>Wed 1/19/11</td>
</tr>
<tr>
<td>9</td>
<td>Review comments on proposal</td>
<td>1 day</td>
<td>Tue 1/18/11</td>
</tr>
<tr>
<td>10</td>
<td>Revise proposal and accomplish first 3 chapters of the IOP report</td>
<td>6 days</td>
<td>Wed 1/19/11</td>
</tr>
<tr>
<td>11</td>
<td>Write up letter to Worcester residents</td>
<td>1 day</td>
<td>Fri 1/21/11</td>
</tr>
<tr>
<td>12</td>
<td>Get signatures for the letter</td>
<td>1 day</td>
<td>Mon 1/24/11</td>
</tr>
<tr>
<td>13</td>
<td>Send out letters to the Greendale and Burncoat neighborhoods</td>
<td>1 day</td>
<td>Tue 1/25/11</td>
</tr>
<tr>
<td>14</td>
<td>Look up Worcester open community meetings</td>
<td>1 day</td>
<td>Mon 1/24/11</td>
</tr>
<tr>
<td>15</td>
<td>Attend Worcester Planning Board Meeting</td>
<td>1 day</td>
<td>Wed 1/26/11</td>
</tr>
<tr>
<td>16</td>
<td>Second weekly meeting</td>
<td>1 day</td>
<td>Tue 1/25/11</td>
</tr>
<tr>
<td>17</td>
<td>First interview with resident</td>
<td>1 day</td>
<td>Wed 1/26/11</td>
</tr>
<tr>
<td>18</td>
<td>Summarize collected data</td>
<td>1 day</td>
<td>Thu 1/27/11</td>
</tr>
<tr>
<td>19</td>
<td>Revise ID2050 final presentation</td>
<td>1 day</td>
<td>Wed 1/26/11</td>
</tr>
<tr>
<td>20</td>
<td>First half of IOP final presentation</td>
<td>1 day</td>
<td>Fri 1/28/11</td>
</tr>
<tr>
<td>21</td>
<td>Interviews with residents</td>
<td>15 days</td>
<td>Mon 1/31/11</td>
</tr>
<tr>
<td>22</td>
<td>Summarize and analyze collected data</td>
<td>14 days</td>
<td>Tue 2/1/11</td>
</tr>
<tr>
<td>23</td>
<td>Third weekly meeting</td>
<td>1 day</td>
<td>Tue 2/1/11</td>
</tr>
<tr>
<td>24</td>
<td>Attend Worcester economic development meeting</td>
<td>1 day</td>
<td>Wed 2/2/11</td>
</tr>
<tr>
<td>25</td>
<td>Write up outline findings draft</td>
<td>3 days</td>
<td>Wed 2/2/11</td>
</tr>
<tr>
<td>26</td>
<td>Fourth weekly meeting</td>
<td>1 day</td>
<td>Tue 2/8/11</td>
</tr>
<tr>
<td>27</td>
<td>Add in new data collections</td>
<td>2 days</td>
<td>Wed 2/9/11</td>
</tr>
<tr>
<td>28</td>
<td>Revise outline finding with updated data collection</td>
<td>1 day</td>
<td>Fri 2/11/11</td>
</tr>
<tr>
<td>29</td>
<td>Give discussion and recommendations based on data collection</td>
<td>1 day</td>
<td>Fri 2/11/11</td>
</tr>
<tr>
<td>30</td>
<td>Fifth weekly meeting</td>
<td>1 day</td>
<td>Tue 2/15/11</td>
</tr>
<tr>
<td>31</td>
<td>Add in new data collections</td>
<td>2 days</td>
<td>Wed 2/16/11</td>
</tr>
<tr>
<td>32</td>
<td>Revise data analysis with updated data collection</td>
<td>1 day</td>
<td>Fri 2/18/11</td>
</tr>
<tr>
<td>33</td>
<td>Complete draft of report</td>
<td>1 day</td>
<td>Fri 2/18/11</td>
</tr>
<tr>
<td>34</td>
<td>Schedule additional interviews (if needed)</td>
<td>4 days</td>
<td>Tue 2/15/11</td>
</tr>
<tr>
<td>35</td>
<td>Additional interviews with residents (if needed)</td>
<td>5 days</td>
<td>Mon 2/21/11</td>
</tr>
<tr>
<td>36</td>
<td>Add in new data collections</td>
<td>4 days</td>
<td>Tue 2/22/11</td>
</tr>
<tr>
<td>37</td>
<td>Sixth weekly meeting</td>
<td>1 day</td>
<td>Tue 2/22/11</td>
</tr>
<tr>
<td>38</td>
<td>Review comments on draft of report</td>
<td>1 day</td>
<td>Mon 2/21/11</td>
</tr>
<tr>
<td>39</td>
<td>Revise draft of report</td>
<td>4 days</td>
<td>Tue 2/22/11</td>
</tr>
<tr>
<td>40</td>
<td>Practice final presentation</td>
<td>1 day</td>
<td>Fri 2/25/11</td>
</tr>
<tr>
<td>41</td>
<td>Final presentation</td>
<td>1 day</td>
<td>Wed 3/2/11</td>
</tr>
<tr>
<td>42</td>
<td>Review comments on revised draft of report</td>
<td>1 day</td>
<td>Mon 2/28/11</td>
</tr>
<tr>
<td>43</td>
<td>Finalize the entire IOP report</td>
<td>3 days</td>
<td>Tue 3/1/11</td>
</tr>
<tr>
<td>44</td>
<td>Final report due</td>
<td>1 day</td>
<td>Fri 3/4/11</td>
</tr>
</tbody>
</table>
February 2011

Dear Residents,

We are a team of Worcester Polytechnic Institute students investigating how the loss of trees due to the Asian Long-Horned Beetle has affected your heating and cooling utility expenses. This is part of our Interactive Qualifying Project, which applies science and technology to a community project. The Massachusetts Executive Office of Energy and Environmental Affairs is sponsoring our research in order to help direct climate change mitigation and adaptation strategies across the state.

Over the next seven weeks we will be visiting residents of the Greendale and Burncoat neighborhoods who have agreed to let us visit their properties to gather data on the trees they have lost as a result from the Asian long-horned beetle. We will also be conducting interviews to obtain utility information before and after losing trees around your home, and to learn more about your experience. Our goal is to properly analyze the impact of residential tree cover on heating and cooling energy usage, and to estimate the economic value provided by trees in urban communities.

If you are interested in participating in this study or have any questions or concerns please contact James at 203-770-6243

You may also contact our team at alb@wpi.edu or our advisor, Professor Robert Krueger, at Krueger@wpi.edu

Thank you,

Eric Petrini
WPI Students

James Post

Zhichao Liao

Cella Riechel
Project Sponsor
Appendix III: Interview Checklist

Economic Value of Trees Checklist

Participant name:
Participant address:
Date of survey:
Time of survey:

<table>
<thead>
<tr>
<th>House Information</th>
<th>Brick</th>
<th>Wood</th>
<th>Cement</th>
<th>Stone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Built</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area (sq. Feet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of floors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of rooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height of Ceiling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Primary Materials:

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Additional Insulation Installed? Type?

Notes:
# Heating, Ventilation, Air Conditioning

**Heating System:**
- **Yes**
- **Fuel:** (Circle one)
  - Natural gas, Propane, Oil

**Forced Air (Furnace):**
- Natural gas, Propane, Oil

**Boiler:**
- Natural gas, Propane, Oil

**Number of Floors heated:**

**Average Temperature Setting Day and Night:**

**Irregular Use? (seasonal, vacation):**

**Annual fuel consumption before tree removal**

**Annual fuel consumption after removal**

**Cooling System:**
- **Yes**
- **Notes:**

**Central AC / Manufacturing Year Size/Capacity:**

**Window Unit:**

**Annual electric (kWh) usage before tree removal**

**Annual usage after removal**

**Notes:**

[Type text]
Tree Information

Number of trees removed
% of all trees on property
Date(s) of removal

Number each tree removed, including the type of tree, estimated size and height:

Make an above view sketch of the property, noting each removed tree location with its corresponding number above and estimated canopy size:

Additional notes:

[Type text]
Appendix IV: AutoCad Drawings for each visited property

House is in red
1. Maple H: 30 ft; D: 32 ft
2. Maple H: 30 ft; D: 32 ft
3. Hawthorn H: 20 ft; D: 10 ft
4. Ash H: 40 ft; D: 14 ft
5. Maple H: 35 ft; D: 30 ft
○ Stump
H = Estimated height
D = Estimated Diameter
Scale: 1/4" = 1'

105 Kendrick Ave
9 Hillcroft Ave

House is in RED
All green circles are removed MAPLE trees
H = Estimated height
D = Estimated Diameter
○ Stump
Scale 1/4" = 1'
1. H: 22 ft; D: 20 ft
2. H: 20 ft; D: 20 ft
3. H: 18 ft; D: 20 ft
4. H: 18 ft; D: 14 ft
5. H: 18 ft; D: 14 ft
6. H: 18 ft; D: 14 ft
7. H: 18 ft; D: 20 ft
8. H: 20 ft; D: 20 ft
9. H: 20 ft; D: 20 ft
10. H: 24 ft; D: 30 ft
11. H: 35 ft; D: 35 ft
12. H: 35 ft; D: 35 ft
House is in RED
All green circles are removed trees
H = Estimated height
D = Estimated Diameter
○ Stump
Scale 1/4" = 1'
1. Maple (100 yrs)
   D: 45 ft; H: 55 ft
2. Red Maple
   D: 25 ft; H: 30 ft
3. Maple
   D: 35 ft; H: 40 ft

93 Airley St
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
○ Stump
Scale 1/4" = 1'
1. D: 30 ft; H: 55 ft
2. D: 30 ft; H: 55 ft

All circles without number approximately have the same size
D: 20 ft; H: 40 ft

138 Hillcroft Ave
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
• Stump
Scale 1/4" = 1'
1. D: 34 ft; H: 55 ft
2. D: 30 ft; H: 55 ft
3. D: 30 ft; H: 50 ft
4. D: 30 ft; H: 50 ft
5. D: 40 ft; H: 65 ft
6. D: 40 ft; H: 65 ft

27 Coventry St
House is in RED
All green circles are removed trees
H = Estimated height
D = Estimated diameter
○ Stump
Scale 1/4" = 1'
1. Ash D: 25 ft; H: 45 ft
2. Ash D: 25 ft; H: 45 ft
3. Maple D: 30 ft; H: 40 ft

Circle in black is London Tree
did not get infected

114 Whitmarsh Ave
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
○ Stump
Scale 1/4" = 1'
1. D: 45 ft; H: 55 ft
2. D: 35 ft; H: 45 ft
3. D: 32 ft; H: 45 ft

37 Thorndyke Rd
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
° Stump
Scale 1/4" = 1'
1. D: 45 ft; H: 55 ft
2. D: 40 ft; H: 50 ft
3. D: 40 ft; H: 50 ft

25 Monterey Rd
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
  ◦ Stump
Scale 1/4" = 1'
1. D: 45 ft; H: 55 ft
2. D: 35 ft; H: 45 ft

37 Monterey Rd
House is in RED
All green circles are removed maple trees
H = Estimated height
D = Estimated diameter
gment
Scale 1/4" = 1'
1. D: 40 ft; H: 55 ft
2. D: 35 ft; H: 50 ft

59 Granville Ave
### Appendix V: Summary of Basic Property Information

<table>
<thead>
<tr>
<th>Properties</th>
<th>Area (Sq. ft)</th>
<th>Stories</th>
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## Appendix VI: Fuel and electrical usage

### Appendix VI.1 Fuel usage

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<th>2008 Usage</th>
<th>2010 Usage</th>
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### Appendix VI.2 Electrical usage

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Appendix VII: Normalized data

Appendix VII.1 Normalized fuel data

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Appendix VII.2 Normalized electrical data

Monthly Electrical Usage In 2008

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## Monthly Electrical Usage In 2010

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<table>
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<tr>
<th>Properties</th>
<th>Total in Cooling season (KWH)</th>
<th>In (KBTU)</th>
<th>Total Electrical usage in heating season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property 1</td>
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<td>Property 2</td>
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<td>810</td>
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<td>3196</td>
<td>10905.71</td>
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</table>
Normalized Cooling Season Electrical Usage

<table>
<thead>
<tr>
<th>Properties</th>
<th>KBTU/CDD 2008</th>
<th>KBTU/CDD 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property 1</td>
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</tr>
<tr>
<td>Property 2</td>
<td>5.824443103</td>
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<td>Property 3</td>
<td>5.209967625</td>
<td>4.206945205</td>
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<tr>
<td>Property 4</td>
<td>12.25682471</td>
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<tr>
<td>Property 5</td>
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<td>Property 6</td>
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<td>22.19956092</td>
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<td>Property 10</td>
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</tbody>
</table>

Appendix VII.3: Heating season electrical usage comparison

<table>
<thead>
<tr>
<th>Properties</th>
<th>2008 Winter (MBTU)</th>
<th>2010 Winter (MBTU)</th>
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</thead>
<tbody>
<tr>
<td>Property 1</td>
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<td>Property 2</td>
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<td>Property 4</td>
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<td>Property 5</td>
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<tr>
<td>Property 10</td>
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<td>0</td>
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</tbody>
</table>
Appendix VIII: Power point presentation

Urban Tree Cover and Residential Energy Use
Sponsor: Massachusetts Executive Office of Energy and Environmental Affairs (EEA)
Advisors: Professor Nancy Burnham, Professor Robert Krueger, Professor Verna DeLauer, EEA Rep. Celia Reichel
Participants: James Post, Eric Petrin, Zhichao Liao

Global Warming Solutions Act
- Reduce statewide emissions by 2020 and 2050
- Three sectors to meet required levels
- Our project: Building sector - residential
  - Heating, Ventilation, Air Conditioning (HVAC)
Can utilizing tree cover lower carbon production?

Role Of The Asian Long-Horned Beetle
- Provided context for a natural experiment
  - Over 30,000 trees removed
  - Burncoat and Greendale neighborhoods

Greendale Before ALB Damage

Greendale After ALB Damage

Tree Canopy: An Experiment
- Simple & inexpensive
- Already exists throughout Worcester
- Reduce energy costs

Tree Canopy: An Experiment
- Simple & inexpensive
- Already exists throughout Worcester
- Reduce energy costs
Research Questions

Did the tree removal have an affect on resident energy consumption?

Did the size and location of tree canopy affect energy costs?

Modifying the Approach

- Initial: Determine impact of canopy on residential energy use
  - Drawbacks in variables and data acquisition
- Adjusted: Construct appropriate methodology
  - Account for inconsistent data and proper investigative approach

Data Acquisition

Step 1: Identify 30 participants

Step 2: Determine any change in energy consumption

Step 3: Map removed trees

Step 1: Identifying Participants

- Posted flyers
- Distributed letters
- Contacted residents by phone
- Goal lowered to 10

<table>
<thead>
<tr>
<th>Flyers</th>
<th>Letters</th>
<th>Answered phone calls</th>
<th>Missed phone calls</th>
<th>Total interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivered: 100</td>
<td>150</td>
<td>20</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Responses: 2</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Interviewed: 0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

Step 2: Determine Change in Energy Consumption

- 2008 and 2010
- Fuel and electricity
- Normalized for temperature variance
- Estimates for missing data
- Results inconsistent

Step 3: Mapping Removed Trees

- Property diagrams:
  - Identify location of removed tree on property
  - Measure distance of trees to house
  - Estimated canopy size
  - Confirm canopy estimates

27 Coventry St
Observations

- Resident
  - Tree removal provided garden sunlight
  - Needed many more air conditioners the following summer
  - Water usage increased due to lawn upkeep

- Researcher
  - Geographical variation
  - Neighboring properties

Data Collection Issues

- Low resident response rate
- Lack of consistent utility records
- Weather related logistical problems
- Cancellations or missed appointments

Process modifications needed!

Step 1: Identifying Participants

Original Approach:
- Radio promotion
- Send letters to original study participants by phone
- Send letter explaining purpose directly
- Schedule appointments
- Accumulate 30 participants

Step 2: Determine Change in Energy Consumption

Original Approach:
- Inform residents that their electricity bills will be used in research
- Obtain consumption data and feedback on the study
- Record monthly usage for both years
- Compare monthly rates to determine any change

Step 3: Mapping Removed Trees

Original Approach:
- Determine natural coverage of property online
- Request resident provide location of removed trees
- Measure distance of each tree to house
- Estimate tree volume
- Estimate tree health

Recommendations

- Change to more appropriate season
- Obtain neighborhood energy records from respective utility companies prior to research
- Utilize neighborhood associations/watch groups
- Limit study to individual streets
  - Less variation in general surroundings and geographical location
Conclusions

- Unable to verify tree canopy as alternative carbon reduction strategy
- Challenges faced during this project will serve to improve upon future research of this kind

Questions?

Step 2: Fuel Consumption

Calculated for January May and October December

Step 2: Winter Electrical Usage

Calculated by the data in months from January May and October December

Step 2: Summer Electrical Usage

Calculated by the data in months from June to September

Property 1 Comparison
Works Cited

Crowley, J. (2010, October 26). CROWLEY, WEINER APPLAUD USDA FUNDING TO COMBAT ASIAN LONGHORNED BEETLE IN NEW YORK. States News Service.

EEA. (2010). Background. Mass EEA.


