Burncoat Neighborhood Tree Removal/Energy Use Study
Worcester, MA

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Electricity data for 2007, 2008, 2009, and 2010 for 129 homes in the Burncoat neighborhood were provided by National Grid. They were organized into six blocks which experienced heavy tree removal prior to the summer of 2009. Homes that had either Inactive Accounts or missing data were removed from the analysis, and a total of 108 homes were analyzed.

The seasonal cooling period is defined as mid-June to mid-September. Statistical analysis proves there is a significant increase in kWh/CDD usage between the summers of 2008 and 2009, with a **98% increase in mean kWh/CDD usage during the summer of 2009 after trees were removed.** Table 1 illustrates the block-level analysis of increased cooling energy usage.

Block **(N = 6)**	Number of homes **(108 total)**	Percentage Increase (kWh/**CDD** usage) after tree removal
1	15	87
2	23	79
3	19	99.6
4	18	116
5	23	140
6	9	67

Table 1: Differences in cooling energy usage between the summers of 2008 and 2009.

A paired T-Test was conducted in order to test statistical strength of the difference in mean kWh usage between all 108 homes between the summer cooling months of 2008 and 2009. The mean kWh/CDD for 2008 is 5.7045 and the mean for 2009 is 11.3953 kWh. The standard deviation, or spread of the data, is 3.9196 for 2008 and 7.3698 for 2009. A paired T-test for 2008 and 2009 gives a T-value of -13.37 and a p-value of 0.0, which indicates that there is powerful evidence that there is an increase in mean kWh usage between 2008 and 2009.

Investigating the block as the unit analysis, and analyzing the average kWh/CDD in each block, N=6, for pre-cut (2008) and post-cut (2009) periods, a paired T-Test illustrates a 2008 mean kWh for the six blocks as 5.4376, with standard deviation of 1.5709, and a 2009 mean kWh of 10.7322, and standard deviation of 2.9159. The average kWh/CDD usage in each block is statistically greater in 2009 than in 2008 with a T-value of -7.83 and P-value of 0.001.

The total six block kWh usage increase between summer 2008 and summer 2009 is 61322.5 kWh, and the average residential home increase in kWh usage is 567.8 kWh. In

monetary terms, and assuming a retail price of 15.0 cents per kilowatt-hour, individual blocks save, on average, $1,533.00 during the cooling season when trees are present. Table 2 illustrates the block-level analysis of increased cooling energy in monetary terms.

Block **(N = 6)**	Number of homes **(108 total)**	**Dollar** Increase ($) **in cooling energy costs** after tree removal
1	15	$1,130
2	23	$2,287
3	19	$1,519
4	18	$1,447
5	23	$2,478
6	9	$334

Table 2: Differences in cooling energy costs between the summers of 2008 and 2009.

On an individual basis, residential homes pay, on average, an additional $85 over the entire cooling season as a result of using an air conditioner because of the absence of trees. The total monetary value lost in the entire 6-block Burncoat neighborhood as a result of tree canopy removal is $9,198.

Given the total increase in kWh usage between the summer of 2008 and 2009 is 61,322.49 kWh for 108 homes, an additional 38.48 metric tons of carbon dioxide is emitted. On average, the residential home will emit 0.32 more metric tons of carbon dioxide as a result of the trees being cut in the Burncoat neighborhood. Not only do trees sequester carbon dioxide from the atmosphere as a result of the photosynthesis process, but they also indirectly decrease the need for mechanical cooling during the summer months, decreasing energy use and lowering the carbon dioxide emissions per house and per block as a result of shading residential homes in the Worcester neighborhood.

Moving forward, it is necessary to acquire more residential energy usage data at both the block and individual house level. This is needed to examine other neighborhoods in Worcester that have experienced heavy tree removal, and also to more accurately examine and characterize the variation between home energy usages between homes within blocks. The block aggregation of 108 homes into six blocks does provide a powerful and significant result, illustrating that trees do have a beneficial impact as they decrease the need for mechanical cooling during the summer months. Furthermore, a more in-depth understanding of the benefits of trees for individual homeowners requires knowing the DBH of individual trees and where the tree is located relative to house orientation.

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We used Google Earth images to calculate the percentage change in canopy cover between 2008 and 2009 for the six blocks in the Burncoat Neighborhood. Google Earth images were not available for 2009. We were able to obtain clear images and full leaf coverage for 2008 and 2010. We used the 2010 images as a proxy for 2009.

More specifically, we calculated the area of each block using ImageJ and, based on this information, we used ImageJ to estimate total tree crown area. We did this for each block in each of the two years. Next, we calculated the difference in tree canopy cover for each block between 2008 and 2009 and then the percentage change.

We matched each block's percentage change in canopy cover with its average percentage change in kWh/CDD usage for each of the two years. (Houses were identified for each block. KWh usage for the cooling period (mid-June until mid-September) was calculated for each house, and the average kWh/CDD usage was determined for each block).

Table 1 below presents each block's percent canopy cover for 2008 and 2009 and the corresponding average kWh/CDD usage for each block in 2008 and 2009.

Block **(N = 6)**	kWh/CDD usage 2008	Percent Canopy Cover (%) 2008	kWh/CDD usage 2009	Percent Canopy Cover (%) 2009
1	5.5	37	10.1	3
2	8.4	35	15	5
3	5.4	40	10.7	7
4	4.6	41	9.99	9
5	5.2	42	12.4	7
6	3.7	42	6.2	5

Table 1: Average cooling energy usage and percent canopy cover between the summers of 2008 and 2009.

One-way ANOVA was used to determine if the average kWh usage over all six blocks was different between 2008 and 2009 due to percent canopy cover. (The response variable here is average kWh usage. The factor is percent canopy cover. Its two levels are canopy cover for 2008 and canopy cover for 2009).

A portion of the ANOVA table is presented in Table 2. It shows that the mean kWh usage for 2008 is 5.438, and the mean kWh usage for 2090 is 10.732. Clearly, these means appear different from each other. Not shown here are pictures of the two 95% confidence intervals that correspond with these two sets of sample statistics. When drawn, there is no overlap between the two intervals, suggesting that these two means come from two different populations.

Level	N	Mean	StDev
kWhAverage_2008	6	5.438	1.570
kWhAverage_2009	6	10.732	2.916

Table 2: Means and standard deviations for kWh/CDD in 2008 and 2009.

When conducting the formal F-test for one-way ANOVA, the null hypothesis is that mean energy usage (our response variable) is the same due to canopy cover (our one factor with two treatment levels) for 2008 and 2009. The alternative hypothesis is that the means are different. (Please note that the full one-way ANOVA table is not presented here). The F statistic (15.34) was significant at the 0.003 level. This translates into the following: we have extremely strong evidence that mean energy usage is different between the two time periods due to a change in percent canopy cover.

We also performed a simple regression analysis in which we specified the percentage increase in kWh (pikWh) between 2008 and 2009 as a function of percentage change in canopy cover (pccancov) between 2008 and 2009. (The observations used in the estimation are presented in Table 3. Please note that they can be calculated directly from the data presented in Table 1).

Block **(N = 6)**	Percentage Decrease in Canopy Cover (2008-2009)	**Percentage Increase (**kWh/CDD Usage) after tree removal
1	92	87
2	82	79
3	82	99.6
4	78	116
5	83	140
6	88	67

Table 3: Percent Canopy Cover Difference and Percent kWh Difference between 2008 and 2009.

The estimated regression equation is:

$$\text{pikWh} = 321 - 2.65\ \text{pccancov},$$

The interpretation of the slope coefficient (-2.65) on pccancov is as follows: If the percentage change in canopy cover goes down by 1, the percentage change in kWh/CDD increases by 2.65 percent.

We must point out the limitations to the estimated equation. We have not presented any statistics of fit. Importantly – and not shown here – is the standard error on the slope coefficient. The standard error was such that the p-value on the slope coefficient was significant at the 0.38 level; that is, the results were not significant when regressing one percentage change variable on another percentage change variable. (This type of result is typical with percentage-change variables. The problem could possibly be ameliorated by

introducing more variability in the data and increasing the number of observations. However, the cost for this remedy is usually a well-designed experiment).

Given the limitation of the regression equation in the present context, one simple calculation can be done using the data presented in Table 3 directly. We averaged the six calculations in the second column and the six calculations in the third column. These are 84.16 and 98.13, respectively. The ratio of the latter to the former is 1.17. The interpretation is as follows: the average percentage increase in kWh/CDD is 1.17 due to an average one-percentage decrease in canopy cover.