Using Cluster Analysis to Assess the Adoption of Energy Star Ratings by the Commercial Buildings in the United States

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Abstract

As of December 2013, approximately 5,200 building managers and owners in the commercial building sector in the United States have decided to retrofit their buildings and seek qualification for the Energy Star rating administered by the U.S. Environmental Protection Agency. I have sampled the buildings that have scored high enough, at least 75 on a scale of 100, and sent out surveys asking various questions regarding the decision factors to retrofit their buildings. I then used principal components analysis to factor out the primary reasons why building managers/owners implement various clean energy projects and what factors contribute to making that decision. After that I used cluster analysis to explain how homogeneous and heterogeneous the decision-making processes are. Finally, I used regression analysis to find the relationships between the principal components and size variables such as the size of the buildings and the total number of full-time employees. The results show that, in general, the majority (56%) of the managers/owners in the commercial building sector are not concerned about the energy efficiency of their buildings, 27% of them are low or moderately concerned and only 17% of them are highly concerned about energy efficiency and energy conservation. The results also show that when the building size or the total number of employees goes up then the concern for energy efficiency, insulation upgrade, and resource conservation go down. In addition, the result shows an interaction effect of the building size and total number of employment. It shows that when these variables are multiplied together then the resultant value is positively related to concern for energy efficiency, insulation upgrade, and resource conservation.

Taxonomy

energy conservation; energy efficiency; low-carbon building; climate change policy; energy economics; building energy analysis; united states

Keywords

cluster analysis; principal components analysis; regression analysis; Energy Star rating; building retrofit; low carbon; energy efficiency, U.S.A

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Foreword

My interest for alternative and low-carbon energy technology was intensified when I started working as an Energy Economist at University of Alaska in 2011. As a fresh college graduate, the opportunity to move to an arctic community to conduct financial analyses of renewable energy projects was too good to pass on. There I was exposed to different kinds of renewable and low-carbon energy technologies such as hydro kinetic energy, sea water heat pumps, wood pellet boilers, and retrofitting existing buildings. I was also introduced to energy-related government policies during my work at the university.

One of the policies that really amazed me was the Home Energy Rebate Program (HERP). In this program, the residential customers get rebates from the government up to a certain amount if they decide to retrofit their houses for energy efficiency. The residents of Alaska have embraced the program because it has quite a few benefits. One of the benefits is that it reduces the energy bills for the residential customers since their buildings are now more energy efficient and use less energy. On the other hand, less demand for energy helps the government since they do not have to invest money on costly infrastructure updates, especially for peak demand load. I have talked to few people in rural Alaska where the energy bill is high and fossil fuel is the main source of energy. From the conversation with those people I realized that the program had helped them a lot financially by reducing their energy bills.

Energy-retrofit in the residential building sector encouraged me to further investigate whether the retrofits in the other building sectors such as commercial building sector or academic building sector can also have financial and environmental benefits. Once I enrolled myself in the MES program I certainly wanted to explore more about energy policies and energy retrofits in the building sectors. I started meeting different professors in the faculty who conduct energy-related research to talk about my interest. I finally met Professor Hoicka who encouraged me to conduct research on energy efficiency in the commercial building sector. She suggested that I sign up for various courses that would enhance my research skills. She also suggested that I work in the government agencies or not-for-profit organizations to understand how the energy market functions in the province and in the nation. Following her suggestions, I took various qualitative and quantitative courses and worked in the Ontario Ministry of Energy and Friends of Greenbelt Foundation in last two years. By taking those courses and working for different agencies I have gained valuable research skills that have helped me to conduct my own research and to write this paper.

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1. Introduction

Energy use in buildings is a major source of CO_2 emissions globally since a third of global CO_2 emissions come from buildings (Ürge-Vorsatz and Novikova, 2008). According to the Intergovernmental Panel on Climate Change (IPCC) reports, buildings cause 19% of the world's greenhouse gas (GHG) emissions (IPCC, 2007, 2014). In 2007, US commercial buildings consumed 18% of total US energy (Andrews and Krogman, 2009), and three years later, in 2010, commercial buildings consumed almost 20% of total energy in the country (Bin, 2012). Also, commercial buildings had the highest rate of growth for energy consumption compared to other sectors (Bin, 2012). The European Commission's Energy Efficiency Plan has also identified the building sector as one of the critical sectors for climate change mitigation (Energy Efficiency Plan, 2011). In addition, since buildings and some of their retrofits have long lifespans, sometimes over 100 years (Natural Resources Canada, 2017), they can get locked-in with existing energy performance and associated GHG emissions. That is why it is important to investigate this sector for the implementation of new and improved energy efficient technology in both new and older buildings so that energy demand can be reduced in future (IPCC, 2007).

It is worthwhile to look into the building sector as a possible target for the climate change mitigation because addressing this sector has some potential benefits. One of the benefits is that the technology to reduce energy demand from the building sector is already available and mature enough to be trusted (IPCC, 2014). The co-benefits can be significant enough to make it a very low-cost or negative-cost[1] mitigation sector (IPCC, 2014). Also, the lower demand for energy can bring energy security to building owners and reduce unemployment (IPCC, 2014). Ma et al. (2012) have shown that retrofitting existing buildings for energy efficiency can lead to annual energy conservation up to 49.3% of total energy consumption of the buildings that do not get retrofitted for energy conservations.

[1] Negative costs may occur when the cost generates private benefits for which the consumers and businesses do not pay and when the benefit is higher than the cost of project implementation

To benefit from this sector, various agencies in the United States have been implementing different energy policies. One of the policies is to implement a rating program, called Energy Star, by the United States Environmental Protection Agency (EPA) to encourage building owners and managers[2] to conserve energy and reduce GHG emissions. It is a voluntary program (EPA, 2017-b) and the building owners or managers who qualify by retrofitting their buildings to the standard set by the EPA can be considered early adopters of the technology. The rating ranges from 1 to 100 and shows how energy efficient a building is compared to its peers (EPA, 2017-a). The Energy Star rating program benefits property owners by increasing the sales and rental values of their properties by 16% on average (Environmental Protection Agency, 2017-a). The rating program also benefits the environment because Energy Star-rated buildings use 35% less energy compared to their peers (Environmental Protection Agency, 2017-a). Also, to motivate owners/managers to make their properties energy efficient, the Federal National Mortgage Association (Fannie Mae) and Federal Home Loan Mortgage Corporation (Freddie Mac), both in the United States, offer discounted loans for the retrofits (Environmental Protection Agency, 2017-a).

To reduce the amount of GHG emissions from buildings, they need to be retrofitted to make them more energy efficient. Even though technologies for the retrofits are already available, along with the incentives, some building owners and managers are reluctant to take on projects that will make their buildings more energy efficient. That is why researchers are working to identify the range of influences that affect energy consumption and energy conservation. Identifying the influences can help accelerate the uptake of low-carbon technology by the building owners or managers. *To contribute to the existing research, in this study I have tried to identify the primary reasons (i.e. economic/financial, regulatory, etc.) why commercial buildings implement clean energy projects. I have also tried to aggregate the managers/owners into different groups based on the decisions they make before doing any kind of energy-retrofit.* The analysis

[2] Building owners and managers were surveyed instead of the building tenants because those two groups of population have different incentives to do the energy-retrofits. Also, in a commercial building the manager/owner have more decision-making power for energy-retrofit than the tenants. My research focused on the group who have better decision-making power. Further research can be conducted to find the incentives of the tenants of the commercial buildings.

was done by collecting Energy Star data, administered by Environmental Protection Agency, for commercial buildings that have done energy retrofits to qualify for Energy Star ratings.

This paper begins with a literature review (Section 2) that explains the commercial building sector as a potential candidate for climate change mitigation, Energy Star rating system to measure buildings' energy use, and the statistical tools to measure the energy-retrofit decision factors. Section 3 is the 'methods and materials' section that describes how the data have been collected and how statistical tools such as principal components analysis and cluster analysis have been used to carry out the analysis. I then move on to Section 4 which is called 'results and discussion' and it describes the results I have found in the previous section and section 5 is the 'conclusion' section.

2. Literature Review

2.1 Commercial Buildings for Climate Change Mitigation

Even though the building sector is a large contributor to climate change, this sector can be challenging to be considered for climate change mitigation. The reasons for this include conservative attitudes in the building industry, deficiencies in public policy to stimulate the building energy efficiency programs, and limited regulations from governments to make buildings more energy efficient (Ryghaug and Sørensen, 2008). Other reasons may also include the number of stakeholders of buildings (i.e., owners, investors, tenants and others); leaseholders' agreements; and heterogeneity of buildings in terms of age, design and structure (Axon et al. 2012). If various obstacles are overcome, energy efficiency improvements in existing buildings and a new energy efficiency standard in new buildings can play an important role in climate change mitigation, reducing the energy consumption of the existing buildings and their short-term and long-term energy demand (Janda, 2014).

Once the obstacles are overcome, several steps can be taken to implement a clean energy project in a commercial building. Ma et al. (2012) have shown that five steps can be followed to implement a successful energy efficiency retrofit that can reduce energy consumption for a building. The stages are: project set-up and retrofit, energy auditing and performance assessment, identification of retrofit options, site implementation and commissioning, and validation and verification of the retrofit.

2.2 Energy Star Rating System to Measure Buildings' Energy Use

To reduce GHG emissions by adopting energy-efficient products and services, the US Department of Energy (DOE) and US Environmental Protection Agency (EPA) have jointly started a program named Energy Star ('ENERGY STAR®, Department of Energy', 2017). This program encourages business owners, including commercial building owners and managers, to conserve energy by retrofitting their buildings. The program started in 1992, when only computers and computer equipment were allowed to get the Energy Star label (Environmental Protection Agency, 2017-b). The label was later extended to new residential buildings in 1993 when they started to qualify for the Energy Star rating by using energy efficient construction methods (Eichholtz et al., 2010). Commercial buildings started to qualify for the Energy Star ratings from 1999 ('ENERGY STAR Major Milestones', 2016). The Energy Star Portfolio Manager, which is an online tool to track and measure energy performance, has been used by almost half a million commercial buildings in the US (EPA, 2017-b). Commercial buildings can qualify for the Energy Star rating by being retrofitted or newly constructed to a certain energy efficiency standard set by the program. The rating ranges from 1 to 100, indicating the energy efficiency of the buildings compared to similar buildings in the nation. The program has helped commercial buildings in the US to save almost eight billion dollars of energy costs in 2015. The total cumulative savings including commercial buildings since 1992 is over $144 billion ('ENERGY STAR by the Numbers', 2017). As of 2016 approximately 29,500 buildings have qualified for Energy Star ratings, including 7,500 buildings alone in 2016 ('ENERGY STAR by the Numbers', 2017).

In 2001 Canada has become an international partner in the Energy Star program. Natural Resources Canada (NRCan) administers the program and promotes energy-efficient equipment and appliances. NRCan also designs guidelines for the Energy Star ratings for the products that are used in Canada ('About ENERGY STAR', 2013). In July of 2013 NRCan has adopted the ENERGY STAR Portfolio Manager to score the energy efficiency standard of commercial buildings in Canada ('ENERGY STAR Major Milestones', 2016)

2.3 Cluster Analysis to Analyse Decision Factors for Energy Retrofits

Researchers have already used cluster analysis in energy-related social science research to better understand how to influence energy decisions in order to reduce greenhouse gas emissions, so I have also decided to use this tool to analyse decision factors for energy retrofits. This analytical tool has been used previously to find relationships among energy conservation behaviours (Barr et al., 2005), to categorize different energy consumer segments (Sütterlin et al., 2011), to determine occupant behaviours on building energy consumption (Yu et al., 2011), to find public preferences for energy sources in the USA (Greenberg, 2009), to uncover trade-offs between fuel-efficient traffic and fuel-efficient cities (Newman and Kenworthy, 1988), and to identify 'green consumers' who like to purchase environmentally friendly products, including the products that help to conserve energy (Paço et al., 2008).

Barr et al. (2005) have shown that cluster analysis can be used to find similarities and dissimilarities between two kinds of energy consumption behaviours: purchase-oriented behaviours and habitual action behaviours. Purchase-oriented behaviours require to make financial investment and alteration of the house structure. The action typically includes installing technologically advanced and energy efficient products such as installing smart thermostats and double-glazing windows and buying energy efficient refrigerators or other electronics, With habitual action behaviours, energy conservation can be accomplished by changing the daily habits of energy consumption such as switching the lights off of the unoccupied rooms, opening the windows in hot summer days, and setting the thermostat to room temperature. Habitual behaviours do not require any structural change of the household to conserve energy. They have analyzed the similarity of people's energy consumption behaviours by creating four clusters: committed environmentalists, mainstream environmentalists, occasional environmentalists, and non-environmentalists. Barr et al. (2005) have found that 'committed environmentalists' (23% of consumers) engage in purchase-oriented behaviours as well as habitual action behaviours. Mainstream environmentalists' (33%

of consumers) energy conservation pattern is almost similar to the committed environmentalists except that the former group consists of a different group of people with respect to socioeconomic variables such as education, sex, age, and income. Occasional environmentalists (40% of consumers) engage in energy conservation that requires minimal effort and almost no financial investment. Non-environmentalists (3% of consumers) barely engage is energy conservation. They are the ones are more likely to ignore energy efficiency of products when they make purchases and distance themselves from participating in habitual action that require minimal to moderate efforts.

Paço et al. (2008) have used factor analysis to reduce the number of variables, then used Ward's method and squared Euclidean distance to find clusters based on demographic and environment data. Their analysis has discovered three different groups of consumers – the uncommitted (36% of consumers), green activists (35% of consumers), and the undefined (29% of consumers). Members of the uncommitted group have negative ideas about recycling and environmentally friendly buying patterns. They are also unwilling to pay extra to preserve and protect the environment. On the other hand, members of the green activist group favour environmentally friendly buying patterns such as buying energy efficient products. They also support resource conservation. Finally, the members of the undefined group have mixed attitudes toward environmentally friendly behaviours. They have less knowledge about environmental issues compared to the previous two groups. They favor recycling but have negative or neutral views on other environmental issues.

Yu et al. (2011) have used K-means clustering with Euclidean distance to find the occupants who behave similarly in terms of building energy consumption. In their analysis they found four clusters of residential buildings. Cluster-1 represents the residents who tend to live in detached houses and have a small number of occupants. They also use non-electrical kitchen equipment and hot water supplies. Cluster-2 represents the households with a high number of occupants who tend to use electrical kitchen equipment and electrical space cooling and heating systems. Members of the Cluster-3 use non-electrical hot water supplies. Finally, Cluster-4 consists of household members who tend to use electrical kitchen equipment and non-electrical space cooling and heating systems.

Sutterlin et al. (2011) have used hierarchical cluster analysis with Ward's method and squared Euclidean distance to find different consumer segments based on energy conservation behaviours and motives. They have found segments (clusters) of consumers – idealistic, selfless inconsequent, thrifty, materialistic, convenience-oriented indifferent, and problem-aware well-being-oriented. Greenberg (2009) has also used hierarchical cluster analysis to find the clusters of customers who are similar to each other in terms of their choices of energy sources, but unlike Paço et al. Greenberg used factor analysis to verify the clusters he found in cluster analysis. Greenberg found that three clusters existed in terms of energy sources that people prefer. The first cluster represented the people who prefer fossil fuel, the second cluster preferred renewable energy sources, and the third cluster preferred nuclear energy sources.

In my research I have used cluster analysis to explain the homogeneity and heterogeneity of the decision factors to implement clean energy projects by different commercial building managers and owners. This statistical tool can be used to find the similarity (and dissimilarity) among individual cases in the dataset. This is an exploratory data analysis method that can be used to solve classification problems (Willis et al., 2011). The members of the same group have specific properties in common (they are homogeneous within the group) but the properties are different from other groups (they are heterogeneous across groups) (Yim and Ramdeen, 2015). Cluster analysis can also be used as data reduction technique. Unlike factor analysis or principal components analysis which are used to reduce the number of variables, cluster analysis reduces the number of cases by grouping them into homogeneous clusters (Yim and Ramdeen, 2015).

In cluster analysis the similar cases can be joined together using the squared Euclidean distance. The concept is, as the distance between two cases increases, the similarity between the two cases decreases and they are most likely to fall into different clusters. One of the methods to group the cases into different clusters is to treat all cases separately and independently in the beginning. Then the second case is clustered together with the first case based on how similar the second case (or candidate) has responded to the questions (Gilg and Barr, 2006; Barr et al., 2005). Theoretically, all the cases can be clustered together into one single cluster but in that situation, all cases would be homogeneous with each other. In practice, the cases are clustered together based on how similarly the respondents answer the questions. The graphic tool that is used to find the number of clusters is the dendogram. One needs to find the number of stages, which is one less than the number of cases, to find the number of clusters. A scree plot can be used to find the number of stages (Yim and Ramdeen, 2015). The two essential parts of cluster analysis are finding the number of clusters and then defining each cluster by looking at each cluster's characteristics (Willis et al., 2011).

3. Materials and Methods

3.1 Data Quality and Data Clean-up

Data for commercial property owners/managers who have participated in the Energy Star program and also achieved scores of at least 75 were collected from the EPA website. The information for 19,413 buildings' property managers were available as of December 2013 and of these 19,413 managers, 5,239 managers were found as unique managers. Out of those 5,239 unique managers, 2000 were randomly chosen and contacted for the survey; of these, 240 managers responded, and of those surveys, 178 were completely filled out by the respondents, making them useful for the final analysis.[3] The response rate for the completed survey was 9% which is typical to electronic surveys in the United States (Gliedt and Hoicka 2015).

The survey asked various questions: what kind of clean energy project was implemented and how the project was financed; the primary reasons the clean energy project was implemented; what factors contributed to the investment; whether the property pursued an energy audit or not; if the property did not pursue the energy audit then why they decided not to pursue an energy audit; and if the energy audit was performed then whether it was helpful or not. The survey sample data represents the population data with the exception of California (under-represented by 1%) and Missouri and Texas (over-represented by 1%) (Gliedt and Hoicka 2015). In the case of one manager managing multiple buildings that have achieved high scores (more than 75) in

[3] SurveyMonkey was used to collect the data

Energy Star ratings, the managers were instructed to give information about the highest achieving building (Gliedt and Hoicka 2015), so I am examining the possible subgroups in the sample of high scoring buildings.

To analyze the primary reasons for implementing clean energy projects the responses were classified as economic, regulation, and other. The 'economic' responses, such as shareholder value or financial investment, were given the highest value since most of the respondents mentioned 'economic' as the main reason for implementing a clean energy project. The 'regulation' responses such as compliance with regulations or corporate social responsibility were given the second highest value, and 'other' was given the lowest value. The economic/financial reasons got a score of 3, the regulatory reasons got a score of 2, and the other reasons got a score of 1.

The dataset had two continuous variables: (i) approximately how many full time equivalent employees work for your organization?; and (ii) in square feet, what is the total area of this building? Normality tests showed that none of the variables was normally distributed. To test for normality of those variables, I used Kolmogorov-Smirnov and Shapiro-Wilk tests. I also checked the histogram and Normal Q-Q plot. To make the variables normal I took the log (10-based log) of the variables and tested for normality again. The tests showed that taking log of the variables had normalized the variables. After that, I used 'linear interpolation' in SPSS-24 to impute any missing values. Then I checked again for normality of the continuous variables and the tests showed that the imputed variables were normal. Then I checked for the balancing of the categorical variables (after imputation for missing values) by running the frequency distribution. If a variable has more than or equal to 70% similar responses, then that variable is considered unbalanced and excluded from the analysis.[4]

3.2 The Analytical Approach

The analysis was done in three steps: principal components analysis (PCA), cluster analysis, and regression analysis. PCA enabled me to summarize the decision factors that were taken into consideration before doing energy-retrofits. It also allowed me to

[4] The balancing decision is subjective. Researchers may choose other numbers, such as 80% or 85%, of the similar responses instead of 70%

discover new latent properties that influenced the decisions to do the retrofits. The latent factors were measured by combining or summarizing (with linear combinations) different decision factors already presented in the dataset. These new factors are described in the ‘Results and Discussions’ section. PCA was used to get the component scores for the variables.[5] The principal component method extracts the components from the matrix (Abdi & Williams, 2010) known as the correlation matrix where the components are uncorrelated or orthogonal to each other (Groth, Hartmann, Klie, & Selbig, 2013). The components are also known as factors. Each variable in the analysis contributes to the component scores[6] so the components represent the consistent aspects of the variables (Cliff, 1987, page 311). Initial eigenvalue[7] (total, % of variance) and the scree plot[8] were used to determine how many components can be used for the cluster analysis in the next step. The characteristics of each principal component are described in the ‘Results and Discussion’ section.

The second step of the analysis was to use cluster analysis with the principal component scores found in the previous step. Cluster analysis allowed me to group the managers and owners whose decisions to energy-retrofit their buildings are based on general efficiency concerns (Principal Component – 1 or PC-1), insulation upgrade (Principal Component – 2 or PC-2), and resource conservation (Principal Component – 3 or PC-3). Two essential steps suggested by Willis et al. (2011) were followed in the analysis: (a) determining the number of clusters; and (b) describing the characteristics of each cluster. Since the number of clusters was unknown and the principal components were orthogonal to each other, hierarchical cluster analysis (instead of K-means cluster analysis) with squared Euclidean distance was used for the analysis.[9]

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[5] Component scores are the linear combinations of the variables that construct the components for each case or building

[6] Extraction score of each variable in the Communality matrix was checked to determine the extent to which the variable is contributing to the solution. Low score (<0.5) is an indicator that the variable is not contributing enough to form the principal components and therefore may be omitted from the analysis

[7] PCA accounts for total variance of the variables used in the analysis. Eigenvalue is the numeric representation of that variance

[8] Scree plot shows the eigenvalue for each component

[9] SPSS 24 statistical package was used to run the cluster analysis. For method, Ward’s cluster method with Squared Euclidean Distance was used. Values were not transformed to standard scores because the responses were categorical variables and they were measured on the same scale for each question.

The dendogram[10], scree plot, and number of stages were used to find the optimum number of clusters (Yim and Ramdeen, 2015). Once the clusters were identified then univariate analysis of variance[11] (ANOVA) was used to identify group differences in means in order to characterize the groups or clusters.

The final step of the analysis was to use linear regression to find relationships among the three principal components and the size variables such as the size of the buildings and the total number of full-time equivalent employees. I developed three regression models, one for each principal component (PC). PC was the dependent variable and size variables were the independent variables. It can be said that, in my model, each PC was a function of building size, number of full-time employees, and a new variable. The new variable represents the multiplication of the two size variables. This was done to find the interaction effect – how the combination of the size variables affects each principal component.

3.3 Finding the components in Principal Components Analysis

I used principal components analysis to analyze the primary reason why an organization implements a clean energy project. The first three components had eigenvalues (total) greater than one and they account for cumulative 59.95% of variance among the variables (Appendix 1). The scree plot also showed that the major break in the curve happened after three components (Appendix 2), so the first three components were used for cluster analysis in the next step.

3.4 Finding the Number of Clusters in Cluster Analysis

I used the three components that were extracted to group the buildings in order to find how homogenous or similar the decision factors are to retrofit the buildings. Since the number of clusters were unknown, I used the hierarchical clustering method.

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[10] The distance between two points, when they are merged, is represented by the height of the dendogram-bar of those two points. Usually the long horizontal lines that combine the clusters represent the dissimilar clusters. The longest the horizontal lines, the more dissimilar (heterogeneous) the clusters are. The rule of thumb to find the optimal number of clusters is to subtract the number of stages (may also be found in the scree plot) from the number of cases.

[11] One-way ANOVA with Bonferroni equal variance and 0.05 significance level

To find the number of clusters I used the methodology described by Yim and Ramdeen (Yim and Ramdeen, 2015). The total number of cases was 191 and total number of stages in the Agglomeration Schedule[12] was 190 (Appendix 3). I stopped clustering at stage 187 because there was a big jump from stage 187 to stage 188 in the scree plot (Appendix 4), so I left out 3 stages (stage 188, stage 189 and stage 190). Then I drew an imaginary line after three vertical lines (check the dendogram in Appendix 5 from right to left). This imaginary vertical line crossed 4 horizontal lines, so I have decided to use four-cluster solution for this analysis. I used the Univariate Analysis of Variance to find the homogeneity and heterogeneity among the clusters. The scree plot[13] (Appendix 4) shows the stage where the jump for the coefficients occurred.

4. Results and Discussions

Four clusters have shown distinctive characteristics for three different principal components: general efficiency concerns (PC-1), insulation upgrade (PC-2), and resource conservation (PC-3). Cluster-1 was the main discriminatory factor for PC-1 which means that Cluster-1 showed some distinctive characteristics (explained in Appendix 11.2.1) that separated it from other clusters. These characteristics demonstrated that the members of this cluster were ‘least concerned’ for general efficiency in PC-1. Cluster-2 was the main discriminatory factor for PC-2 (explained in Appendix 11.2.2) that separated it from other clusters. These characteristics revealed that the members of this cluster were ‘least concerned’ for insulation upgrade in PC-2. Cluster-4 was the main discriminatory factor for PC-3 (explained in Appendix 11.2.3) that separated it from other clusters. These characteristics demonstrated that the members of this cluster were ‘most concerned’ for resource conservation in PC-3.

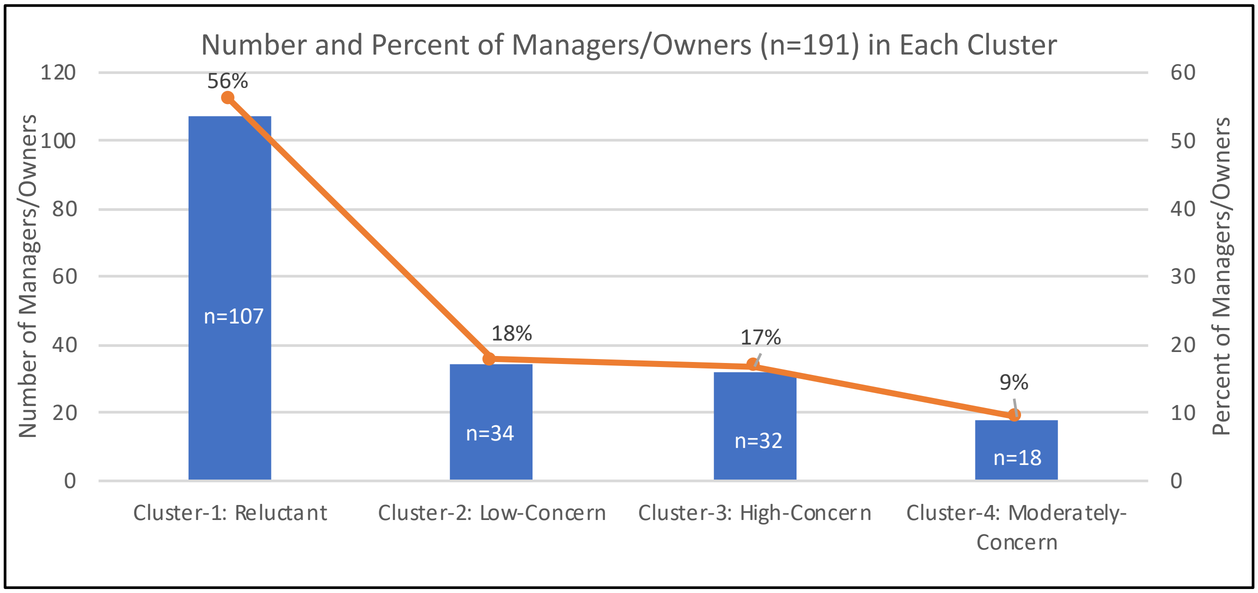
[12] Agglomeration schedules shows which unit, in this case building managers/owners, gets joined with which cluster. It is an evident way to show how far the input cases are from each other.
[13] A scree plot for cluster analysis is just a graphic representation of the Agglomeration Schedule where X-axis is the number of stage and Y-axis is the coefficient score

Table 1. General Characteristics of Each Cluster for Each Component

Cluster	PC-1 General Efficiency Concern	PC-2 Insulation upgrade	PC-3 Resource Conservation
Cluster-1 (n=107)	Not concerned about general efficiency	Indifference for insulation upgrade	Indifference for resource conservation
Cluster-2 (n=34)	More concern about general efficiency than Cluster-1 and Cluster-4	Not concerned about insulation upgrade	Not concerned about resource conservation
Cluster-3 (n=32)	Most concerned group of managers/owners about general efficiency.	Most concerned about insulation upgrade	Not concerned about resource conservation
Cluster-4 (n=18)	More concerned about general efficiency than Cluster-1 but less concerned than Cluster-2 and Cluster-3	More concerned about insulation upgrade than Cluster-1 and Cluster-2 but less concern than Cluster-3	Most concerned about resource conservation

From my analysis I have found that the managers/owners in Cluster-1 are not very concerned in terms of general efficiency upgrade, are indifference to insulation upgrade and indifferent to resource conservation, so I renamed this cluster as the *reluctant group*. The members in Cluster-2 are somewhat concerned about general efficiency, but not very enthusiastic about insulation upgrade or resource conservation such as heat or water conservation, so I renamed this cluster the *low-concern group*. The members in Cluster-4 are moderately concerned in terms of general efficiency and insulation upgrade and very concerned about resource conservation such as heat conservation with green roof, so I renamed this cluster the *moderately-concern group*. Cluster-3 has the most concerned group of managers/owners in terms of general efficiency and insulation upgrade but they are not very concerned about resource conservation such as green roofs installations or water conservation technology improvements, so I renamed this cluster the *high-concern group*. The new names give the general characteristics of the clusters and will not always fit the clusters exactly.

__Figure 1. Cluster Memberships__



56% of surveyed managers/owners fall into Cluster-1 or the Reluctant Group which means that, in general, the majority of managers/owners are not concerned about the energy efficiency of their buildings. 18% and 9% of manager/owners have low concern and moderate concern, respectively for energy efficiency, and only 17% of manager/owners have high concern for energy efficiency of their buildings.

Managers and owners of the Reluctant Group (Cluster-1) tend to be quite unenthusiastic to retrofit their commercial buildings for energy efficiency.

__Table 2. Energy-Retrofit by the Members of the Reluctant Group__

Type of Energy-Retrofit by Reluctant Group (Cluster-1)	Actions Taken by Managers/Owners		
	Implemented for Economic Reason	Implemented for Regulatory Reason	Not Implemented
Add water conservation technologies	2%	30%	68%
Add weather stripping or air-sealing	6%	9%	85%
Implement an automated energy management system	15%	51%	34%
Implement an energy information and tracking system	7%	29%	64%
Improve the insulation in the attic/ceiling	1%	1%	98%
Improve the main interior or exterior walls	0%	2%	98%
Improve the operating efficiency or resizing motors to conserve energy	3%	15%	82%
Increase the operating efficiency of the cooling system	14%	32%	54%

Increase the operating efficiency of the heating system	10%	31%	59%
Increase the operating efficiency of the interior or external lighting	17%	39%	44%
Increase the operating efficiency of the ventilation system	6%	55%	39%
Increase the operating efficiency of the water heating system	0%	18%	82%
Install a green roof	0%	2%	98%
Upgrade the windows	0%	7%	93%

The analysis shows that 64% managers/owners of this group either did not implement any energy information tracking system, 82% managers/owners did not improve the operating efficiency/resize motors to conserve energy, 93% did not upgrade windows, 98% did not improve the main interior/exterior wall. The results also show that economic reasons played no role in decisions to improve the main interior or exterior walls, install a green roof, upgrade the windows or increase the operating efficiency of the water heating system. Appendix 7 has more details about the decisions to retrofit the commercial buildings and what factors influenced the managers/owners to make those decisions.

Managers and owners of the Low-concern Group (Cluster-2) tend to have low interest in retrofitting their commercial buildings for energy efficiency, but the level of interest was generally higher than the Reluctant Group.

Table 3. Energy-Retrofit by the Members of the Low-Concern Group

Type of Energy-Retrofit by Low-Concern Group (Cluster-2)	Actions Taken by Managers/Owners		
	Implemented for Economic Reason	Implemented for Regulatory Reason	Not Implemented
Add water conservation technologies	68%	15%	18%
Add weather stripping or air-sealing	18%	3%	79%
Implement an automated energy management system	82%	3%	15%
Implement an energy information and tracking system	68%	18%	15%
Improve the insulation in the attic/ceiling	0%	0%	100%
Improve the main interior or exterior walls	0%	0%	100%
Improve the operating efficiency or resizing motors to conserve energy	79%	0%	21%
Increase the operating efficiency of the cooling system	88%	3%	9%

Increase the operating efficiency of the heating system	88%	3%	9%
Increase the operating efficiency of the interior or external lighting	94%	3%	3%
Increase the operating efficiency of the ventilation system	88%	3%	9%
Increase the operating efficiency of the water heating system	50%	3%	47%
Install a green roof	0%	0%	100%
Upgrade the windows	18%	0%	82%

The analysis shows that 100% of managers/owners of the Low-concerned Group did not improve the insulation in the attic/ceiling, 100% of managers/owners did not improve the main interior or exterior walls, 79% did not add weather stripping or air-sealing. The analysis also shows that 85% of managers/owners implemented automated energy management systems and 91% increased the operating efficiency of the heating and cooling systems, and 97% increased the operating efficiency of the interior or external lighting. None of the managers/owners installed any green roof. The results also show that none of the regulatory or economic reasons influenced the managers/owners to improve the insulation in the attic or improve the main interior/exterior walls. For further information please check Appendix 8.

Managers and owners of the Moderately-concern Group (Cluster-4) were more eager to retrofit their commercial buildings compared to the Reluctant Group and Low-concerned Group.

Table 4. Energy-Retrofit by the Members of the Moderately-Concern Group

Type of Energy-Retrofit by Moderately-Concern Group (Cluster-4)	Actions Taken by Managers/Owners		
	Implemented for Economic Reason	Implemented for Regulatory Reason	Not Implemented
Added water conservation technologies	17%	28%	56%
Added weather stripping or air-sealing	44%	0%	56%
Implemented an automated energy management system	50%	11%	39%
Implemented an energy information and tracking system	50%	11%	39%
Improved the insulation in the attic/ceiling	44%	0%	56%
Improved the insulation in the main interior or exterior walls	39%	6%	56%
Improved the operating efficiency or resizing motors to conserve energy	28%	6%	67%
Increase the operating efficiency of the ventilation system	61%	22%	17%

Increased the operating efficiency of the cooling system	67%	22%	11%
Increased the operating efficiency of the heating system	61%	6%	33%
Increased the operating efficiency of the interior or external lighting	83%	17%	0%
Increased the operating efficiency of the water heating system	44%	0%	56%
Installed a green roof	44%	44%	11%
Upgraded the windows	33%	0%	67%

100% of managers/owners of this group increased the operating efficiency of the interior or the external lighting, 89% increased the operating efficiency of the cooling system, 61% implemented automated energy management system or energy information tracking system. On the contrary to low-concern group, 89% members of this group installed green roof but 67% restrained from upgrading windows. The results also show that none of the regulatory reasons influenced the managers/owners to add weather stripping/air-sealing or to improve the insulation in the attic/ceiling. Appendix 9 has more information about what factors contributed the decisions.

On the contrary to previous groups, members of the High-concern Group (Cluster-3) were very concerned and enthusiastic about energy efficiency and energy conservation of their commercial buildings.

Table 5. Energy-Retrofit by the Members of the High-Concern Group

Type of Energy-Retrofit by High-Concern Group (Cluster-3)	Actions Taken by Managers/Owners		
	Implemented for Economic Reason	Implemented for Regulatory Reason	Not Implemented
Add water conservation technologies	25%	56%	19%
Add weather stripping or air-sealing	47%	38%	16%
Implement an automated energy management system	31%	41%	28%
Implement an energy information and tracking system	28%	41%	31%
Improve the insulation in the attic/ceiling	41%	44%	16%
Improve the main interior or exterior walls	28%	41%	31%
Improve the operating efficiency or resizing motors to conserve energy	41%	34%	25%
Increase the operating efficiency of the cooling system	50%	44%	6%
Increase the operating efficiency of the heating system	47%	50%	3%

Increase the operating efficiency of the ventilation system	25%	59%	16%
Increase the operating efficiency of the water heating system	50%	41%	9%
Increased the operating efficiency of the interior or external lighting	50%	50%	0%
Install a green roof	0%	25%	75%
Upgrade the windows	38%	31%	31%

100% managers/owners who belong to this group increased the operating efficiency of the interior or external lighting, 97% increased the operating efficiency of the heating system, and 94% increased the operating efficiency of the cooling system. The analysis also showed that 31% did not upgrade their windows and 75% did not install any green roof. For further information please see Appendix 10.

After estimating the characteristics of each cluster, I developed a regression model with the number of full-time equivalent employees and total area of the building as independent variables and each principal component (general efficiency concerns, insulation upgrade, and resource conservation) as dependent variables. The regression output showed that there is a negative relationship between the number of full-time employees and general efficiency concern; a negative relationship between the total area of the buildings and general efficiency concern; and a positive relationship when an interaction happens between the two independent variables. It shows that the interaction (by multiplication) of number of full-time employees and total area of the building is positively related to general efficiency concern. Even though the result was not statistically significant (except the total building area for principal component - 2) the model shows that when the number of full-time employees increases, the general efficiency concerns decreases; when the total area of the building increases, the general efficiency concerns decreases; but when the multiplication of number of full-time employees and total area of the building increases, then general efficiency concerns increases too. Further research needs to be conducted to address this seemingly contradictory output of the regression analysis. One hypothesis is that when the sizes of the buildings go up, the number of employees go up too. An example would be that a building that houses call center help desks tend to have more employees than a similar building that houses a warehouse. Business operations in the building might be an indicating factor of the contradictory regression results.

Table 6. Regression Coefficients for General Efficiency Concern, Insulation Upgrade and Resource Conservation

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Principal Component-1 or General Efficiency Concern	(Constant)	0.558	1.546		0.361	0.719
	number of full-time equivalent employees	-0.230	0.259	-0.564	-0.887	0.376
	total building area	-0.099	0.132	-0.122	-0.745	0.457
	Interaction Variable	0.028	0.022	0.854	1.265	0.208
Principal Component-2 or Insulation upgrade	(Constant)	4.252	1.542		2.758	0.006
	number of full-time equivalent employees	-0.348	0.258	-0.853	-1.345	0.180
	total building area	-0.350	0.132	-0.434	-2.650	0.009
	Interaction Variable	0.028	0.022	0.849	1.261	0.209
Principal Component-3 or Resource Conservation	(Constant)	2.101	1.587		1.324	0.187
	number of full-time equivalent employees	-0.391	0.266	-0.960	-1.470	0.143
	total building area	-0.200	0.136	-0.248	-1.473	0.142
	Interaction Variable	0.037	0.022	1.125	1.624	0.106

A similar kind of relationship was discovered for the other two principal components (insulation upgrade and resource conservation). If the number of full-time employees increases then the concern for insulation upgrade decreases and when the total area of the building increases then the concern for insulation upgrade decreases, but when the two independent variables interact then the concern for insulation upgrade increases too. Finally, if the number of full-time employees increases then concern for resource conservation decreases and when the total area of the building increases then the concern for resource conservation decreases, but when the two independent variables interact then the concern for resource conservation increases too. The interaction effect may be an indicator that when a building gets bigger in terms of both size and number of employees, the building managers/owners become more concerned about energy and resource conservation. Further research needs to be conducted to find the actual reason of this relationship.

The results of my analyses were somewhat different from the previous researchers. Paço et al. (2008) found three groups of consumers (the uncommitted, the green activists and the undefined) in terms of how much they care about the environment. On the other hand, my research found four groups of managers/owners in terms of how much they care about energy efficiency in their commercial properties. In contrast to their results where they found 35% of consumers are 'green activists', my research found only 17% of managers/owners are 'highly concerned' about energy efficiency and resource conservation. Also, Barr et al. (2005) found that 23% of consumers were committed environmentalists and 33% were mainstream environmentalists who actively participated in energy conservation activities by making financial investment and by adjusting their daily life-styles. According to their findings, only 3% of consumers were non-environmentalists and did not participate in energy conservation behaviours. Their research contradicts my findings where the results showed that as much as 56% of managers/owners were reluctant to participate in energy conservation behaviours and only 17% of managers/owners were highly concerned about energy and resource conservation in their commercial buildings. Further research needs to be conducted to understand this discrepancy. It might be, among other factors, that the people are more engaged in household level energy conservation than in commercial level because high energy bills are more evident to household consumers as it directly affects their expenditures.

Even though cluster analysis was used to group the consumers like previous researchers, my analytical method was somewhat different from them. I used a similar method to Paço et al. (2008) and Barr et al. (2005). The main difference between our methods was that they used factor analysis to reduce the number of variables but I used principal components analysis to reduce the number of variables.[14] My analytical method was also different from that of Greenberg (2009) who first used hierarchical cluster analysis to find different segments of consumers and then used factor analysis to verify the clusters. On the contrary, I used principal components analysis to reduce the number of variables and to find the component loadings. I then used the first three components with high loadings to conduct a hierarchical cluster analysis to find different groups of building managers/owners. My method was also different from that of Yu et al. (2011). They have used K-means clustering where the number of clusters is pre-determined whereas I used hierarchical clustering where the number of clusters was determined *after* running the cluster model.

For the characteristics of the principal components, different clusters and regression analysis please see Appendix 11.

5. Conclusion

The survey for this study was conducted to find the primary reasons why the managers/owners of commercial buildings in the United States invest in energy-retrofit projects and this research labeled those reasons as economic or financial reasons. My analysis found that there were mainly four groups of managers/owners in terms of energy efficiency concerns: Reluctant, Low-concern, Moderately-concern, and Highly-concern. The groups were formed by taking into account what kind of retrofits they had completed for their buildings and what motivated (e.g., financial/economic gain, regulation by the governments, corporate social responsibilities) them to invest in energy-retrofit projects where they used clean energy technologies. Principal components analysis was used to factor out the primary reasons or motivating factors to implement energy-retrofits. After that, cluster analysis was used group the

[14] Principal components analysis is a kind of factor analysis with commonality set to zero

managers/owners based on what kinds of retrofits they had implemented and what influenced them to do those retrofits.

My analysis has found that only 17% of managers/owners are highly concerned and as much as 56% of managers/owners are not concerned about energy efficiency and resource conservation. The managers/owners of the latter groups are the ‘laggards’ in terms of general efficiency concern. My analysis has also found that the members of the Reluctant Group are typically influenced by the regulatory reasons to retrofit their buildings for energy efficiency. The members of the Low-Concern and Moderately-Concern groups are generally (but not always) motivated by the financial reasons. Finally, the members of the High-Concern group are typically influenced by both regulatory and financial reasons to retrofit their buildings. There is a policy implication of this finding since the policymakers can use both financial and regulatory incentives to motivate the managers/owners to invest in energy-retrofit projects.

Here it is worth mentioning that all these 191 managers in all four clusters have already done some kind of energy retrofits and scored high in the Energy Star rating system. I have tried to find the level of efficiency concern among the managers who have already taken measures to improve efficiency of their buildings for economic, regulatory, or other reasons. Since both economic and regulatory reasonings play important roles on decision-making for different kinds of energy-retrofits, policymakers need to be aware which incentive (economic or regulatory) works for different retrofits when they make their policies to encourage low-carbon technologies on commercial buildings.

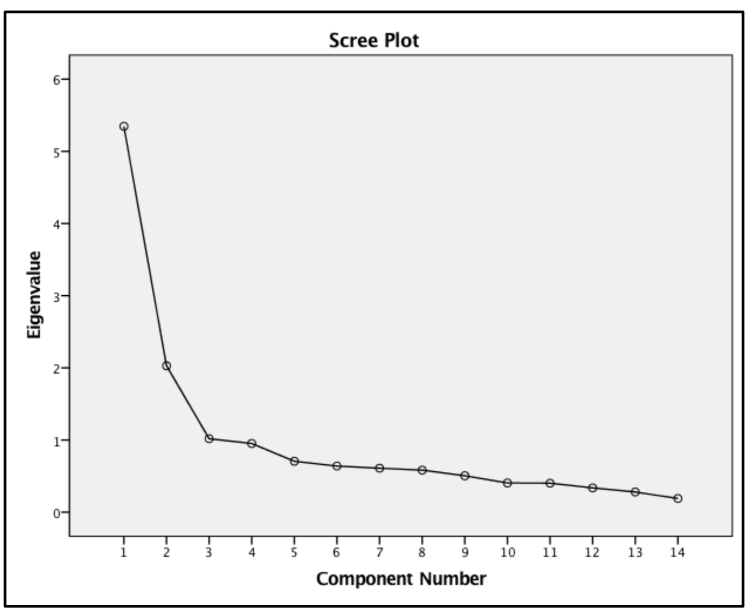
The analysis also discovered that size variables such as the size of the buildings and the total number of full-time employees are negatively related to the concern for general efficiency, concern for insulation upgrades and concern for resource conservation. It also found an interaction effect of the size variables. The result shows that when both the building size and the total number of full-time employee go up together then the concern for energy efficiency, insulation upgrades and resource conservation go up too. Further research needs to be conducted to find why the size variables are individually negatively related but the interaction effect is positively related with the concern for energy efficiency.

Appendices

Appendix 1. Total Variance Explained for Principal Components Analysis

Total Variance Explained						
		Initial Eigenvalues		Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.347	38.189	38.189	5.347	38.189	38.189
2	2.028	14.488	52.678	2.028	14.488	52.678
3	1.018	7.271	**59.95**	1.018	7.271	59.948
4	0.952	6.799	66.748			
5	0.706	5.04	71.788			
6	0.639	4.565	76.353			
…	…	…	…			
14	0.19	1.357	100			
Extraction Method: Principal Components Analysis.						

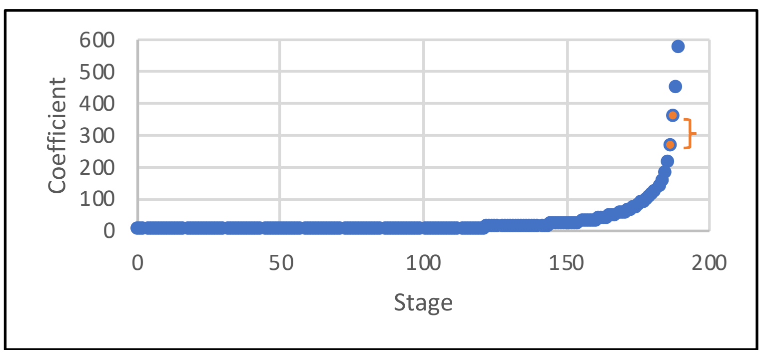
Appendix 2. Scree Plot for Principal Components Analysis



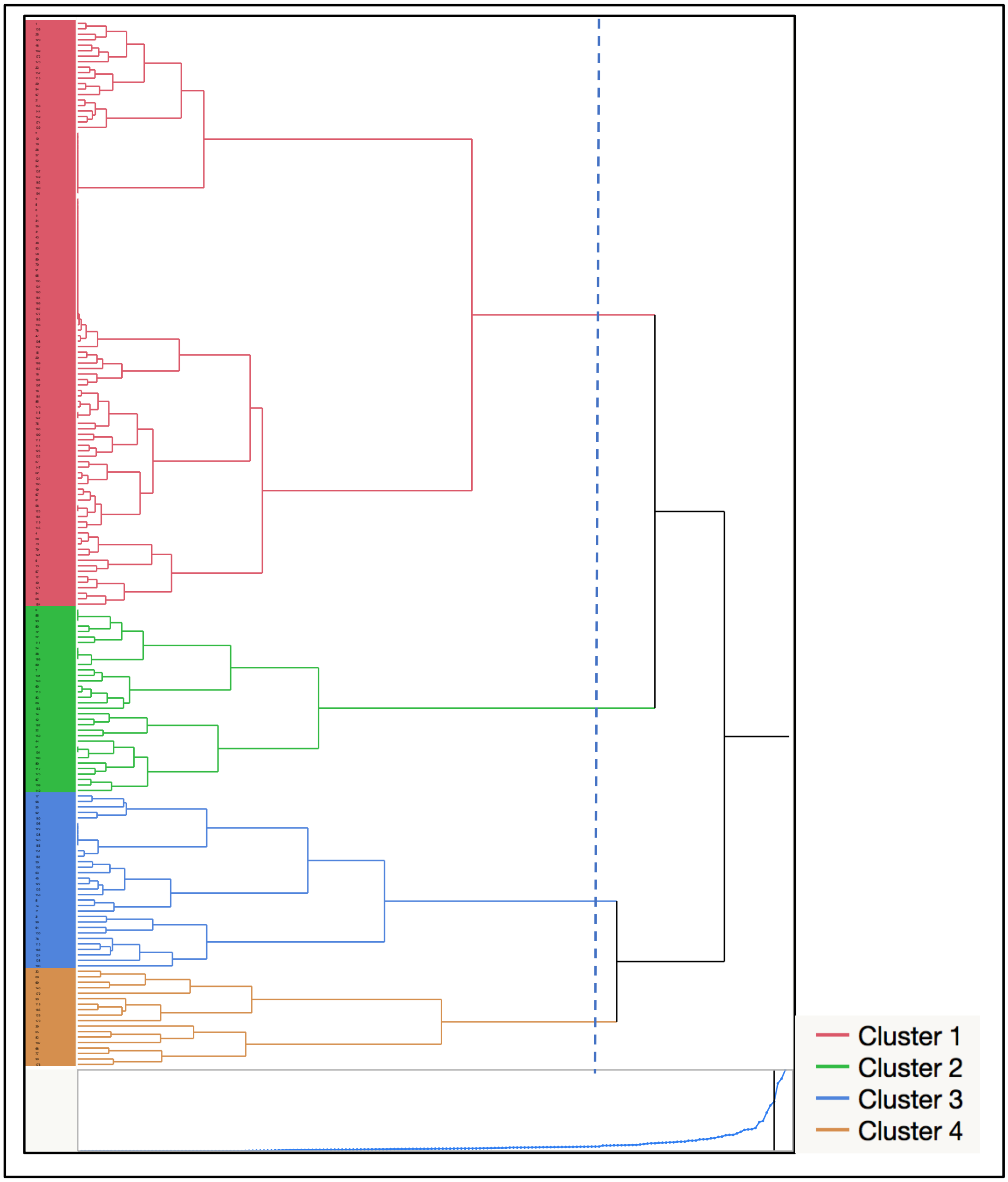
Appendix 3. Cropped version of Agglomeration Schedule

Stage	Cluster Combined			Stage Cluster First Appears		
	Cluster 1	Cluster 2	Coefficients	Cluster 1	Cluster 2	Next Stage
1	190	191	0	0	0	2
2	2	190	0	0	1	12
3	38	186	0	0	0	35
4	177	183	0	0	0	5
5	3	177	0	0	4	7
6	166	167	0	0	0	7
7	3	166	0	5	6	10
8	160	164	0	0	0	10
9	149	162	0	0	0	12
10	3	160	0	7	8	20
…	…	…	…	…	…	…
185	17	31	182.083	183	175	188
186	33	39	213.065	181	176	188
187	1	3	258.18	174	182	189
188	17	33	351.779	185	186	190
189	1	6	448.463	187	184	190
190	1	17	570	189	188	0

Appendix 4. Scree Plot for Agglomeration Schedule



Appendix 5. Dendogram for a Four-Cluster Solution



Appendix 6. Component Matrix for Principal Components Analysis

Clean Energy Project	Component 1	Component 2	Component 3
Increased the operating efficiency of the heating system	0.715	-0.192	-0.022
Increased the operating efficiency of the cooling system	0.749	-0.233	0.129
Increased the operating efficiency of the ventilation system	0.737	-0.309	0.235
Increased the operating efficiency of the interior or external lighting	0.742	-0.195	0.151
Increased the operating efficiency of the water heating system	0.676	0.153	-0.143
Improved the insulation in the attic/ceiling	0.574	0.677	-0.080
Improved the insulation in the main interior or exterior walls	0.525	0.660	0.033
Added weather stripping or air-sealing	0.480	0.541	-0.193
Upgraded the windows	0.566	0.395	-0.121
Installed a green roof	0.240	0.306	0.766
Added water conservation technologies	0.567	-0.27	-0.411
Improved the operating efficiency or resizing motors to conserve energy	0.639	-0.237	-0.251
Implemented an energy information and tracking system	0.639	-0.286	0.070
Implemented an automated energy management system	0.610	-0.366	0.139
Extraction Method: Principal Components Analysis. 3 components extracted.			

Appendix 7. Cluster Characteristics for Cluster-1 and PC-1, PC-2 and PC-3

PC# and Cluster #	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-1 Cluster-1	Increase the operating efficiency of the heating system		
		Not implemented or not applicable	35%
		Implemented for regulatory reason	31%
		No mention of anything	24%
		Implemented for economic reason	10%
PC-1 Cluster-1	Increase the operating efficiency of the cooling system		
		Not implemented or not applicable	28%
		Implemented for regulatory reason	32%
		No mention of anything	26%
		Implemented for economic reason	14%
PC-1			

PC# and Cluster #	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
Cluster-1	Increase the operating efficiency of the ventilation system	Not implemented or not applicable	39%
		Implemented for regulatory reason	55%
		Implemented for economic reason	6%
PC-1 Cluster-1	Increase the operating efficiency of the interior or external lighting		
		Not implemented or not applicable	18%
		Implemented for regulatory reason	39%
		No mention of anything	26%
		Implemented for economic reason	17%
PC-1 Cluster-1	Increase the operating efficiency of the water heating system		
		Not implemented or not applicable	51%
		No mention of anything	31%
		Implemented for regulatory reason	18%
PC-1 Cluster-1	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	1%
		Implemented for economic reason	1%
PC-1 Cluster-1	Improve the main interior or exterior walls		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	2%
PC-1 Cluster-1	Add weather stripping or air-sealing		
		Not implemented or not applicable	50%
		No mention of anything	35%
		Implemented for regulatory reason	9%
		Implemented for economic reason	6%
PC-1 Cluster-1	Upgrade the windows		
		Not implemented or not applicable	61%
		No mention of anything	32%
		Implemented for regulatory reason	7%
PC-1	Install a green roof		

PC# and Cluster #	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
Cluster-1		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	2%
PC-1 Cluster-1	Add water conservation technologies		
		Not implemented or not applicable	36%
		No mention of anything	32%
		Implemented for regulatory reason	30%
		Implemented for economic reason	2%
PC-1 Cluster-1	Improve the operating efficiency or resizing motors to conserve energy		
		Not implemented or not applicable	49%
		No mention of anything	34%
		Implemented for regulatory reason	15%
		Implemented for economic reason	3%
PC-1 Cluster-1	Implement an energy information and tracking system		
		Not implemented or not applicable	34%
		No mention of anything	31%
		Implemented for regulatory reason	29%
		Implemented for economic reason	7%
PC-1 Cluster-1	Implement an automated energy management system		
		Not implemented or not applicable	34%
		Implemented for regulatory reason	51%
		Implemented for economic reason	15%
PC-2 Cluster-1	Increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	39%
		Implemented for regulatory reason	55%
		Implemented for economic reason	6%
PC-2 Cluster-1	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	1%
		Implemented for economic reason	1%

PC# and Cluster #	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-2 Cluster-1	Improve the insulation in the main interior or exterior walls		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	2%
PC-2 Cluster-1	Add weather stripping or air-sealing		
		Not implemented or not applicable	50%
		No mention of anything	35%
		Implemented for regulatory reason	9%
		Implemented for economic reason	6%
PC-2 Cluster-1	Upgrade the windows		
		Not implemented or not applicable	61%
		No mention of anything	32%
		Implemented for regulatory reason	7%
PC-2 Cluster-1	Install a green roof		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	2%
PC-2 Cluster-1	Implement an automated energy management system		
		Not implemented or not applicable	34%
		Implemented for regulatory reason	51%
		Implemented for economic reason	15%
PC-3 Cluster-1	Install a green roof		
		Not implemented or not applicable	66%
		No mention of anything	32%
		Implemented for regulatory reason	2%
PC-3 Cluster-1	Installed water conservation technology		
		Not implemented or not applicable	36%
		No mention of anything	32%
		Implemented for regulatory reason	30%
		Implemented for economic reason	2%

Appendix 8. Cluster Characteristics for Cluster-2 and PC-1, PC-2 and PC-3

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-1 Cluster-2	Increase the operating efficiency of the heating system		
		Not implemented or not applicable	9%
		Implemented for regulatory reason	3%
		Implemented for economic reason	88%
PC-1 Cluster-2	Increase the operating efficiency of the cooling system		
		Not implemented or not applicable	9%
		Implemented for regulatory reason	3%
		Implemented for economic reason	88%
PC-1 Cluster-2	Increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	9%
		Implemented for regulatory reason	3%
		Implemented for economic reason	88%
PC-1 Cluster-2	Increase the operating efficiency of the interior or external lighting		
		Not implemented or not applicable	3%
		Implemented for regulatory reason	3%
		Implemented for economic reason	94%
PC-1 Cluster-2	Increase the operating efficiency of the water heating system		
		Not implemented or not applicable	44%
		No mention of anything	3%
		Implemented for regulatory reason	3%
		Implemented for economic reason	50%
PC-1 Cluster-2	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-1 Cluster-2	Improve the main interior or exterior walls		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-1 Cluster-2	Add weather stripping or air-sealing		
		Not implemented or not applicable	74%
		No mention of anything	6%
		Implemented for regulatory reason	3%
		Implemented for economic reason	18%
PC-1 Cluster-2	Upgrade the windows		
		Not implemented or not applicable	76%
		No mention of anything	6%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
		Implemented for economic reason	18%
PC-1 Cluster-2	Install a green roof		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-1 Cluster-2	Add water conservation technologies		
		Not implemented or not applicable	15%
		No mention of anything	3%
		Implemented for regulatory reason	15%
		Implemented for economic reason	68%
PC-1 Cluster-2	Improve the operating efficiency or resizing motors to conserve energy		
		Not implemented or not applicable	21%
		Implemented for economic reason	79%
PC-1 Cluster-2	Implement an energy information and tracking system		
		Not implemented or not applicable	12%
		No mention of anything	3%
		Implemented for regulatory reason	18%
		Implemented for economic reason	68%
PC-1 Cluster-2	Implement an automated energy management system		
		Not implemented or not applicable	15%
		Implemented for regulatory reason	3%
		Implemented for economic reason	82%
PC-2 Cluster-2	increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	9%
		Implemented for regulatory reason	3%
		Implemented for economic reason	88%
PC-2 Cluster-2	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-2 Cluster-2	Improve the insulation in the main interior or exterior walls		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-2 Cluster-2	Add weather stripping or air-sealing		
		Not implemented or not applicable	74%
		No mention of anything	6%
		Implemented for regulatory reason	3%
		Implemented for economic reason	18%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-2 Cluster-2	Upgrade the windows		
		Not implemented or not applicable	76%
		No mention of anything	6%
		Implemented for economic reason	18%
PC-2 Cluster-2	Install a green roof		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-2 Cluster-2	Implement an automated energy management system		
		Not implemented or not applicable	15%
		Implemented for regulatory reason	3%
		Implemented for economic reason	82%
PC-3 Cluster-2	Install a green roof		
		Not implemented or not applicable	91%
		No mention of anything	9%
PC-3 Cluster-2	Installed water conservation technology		
		Not implemented or not applicable	15%
		No mention of anything	3%
		Implemented for regulatory reason	15%
		Implemented for economic reason	68%

Appendix 9. Cluster Characteristics for Cluster-3 and PC-1, PC-2 and PC-3

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-1 Cluster-3	Increase the operating efficiency of the heating system		
		Not implemented or not applicable	3%
		Implemented for regulatory reason	50%
		Implemented for economic reason	47%
PC-1 Cluster-3	Increase the operating efficiency of the cooling system		
		Not implemented or not applicable	6%
		Implemented for regulatory reason	44%
		Implemented for economic reason	50%
PC-1 Cluster-3	Increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	16%
		Implemented for regulatory reason	59%
		Implemented for economic reason	25%
PC-1 Cluster-3	Increased the operating efficiency of the interior or external lighting		
		Implemented for regulatory reason	50%
		Implemented for economic reason	50%
PC-1 Cluster-3	Increase the operating efficiency of the water heating system		
		Not implemented or not applicable	6%
		No mention of anything	3%
		Implemented for regulatory reason	41%
		Implemented for economic reason	50%
PC-1 Cluster-3	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	13%
		No mention of anything	3%
		Implemented for regulatory reason	44%
		Implemented for economic reason	41%
PC-1 Cluster-3	Improve the main interior or exterior walls		
		Not implemented or not applicable	25%
		No mention of anything	6%
		Implemented for regulatory reason	41%
		Implemented for economic reason	28%
PC-1 Cluster-3	Add weather stripping or air-sealing		
		Not implemented or not applicable	9%
		No mention of anything	6%
		Implemented for regulatory reason	38%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
		Implemented for economic reason	47%
PC-1 Cluster-3	Upgrade the windows		
		Not implemented or not applicable	28%
		No mention of anything	3%
		Implemented for regulatory reason	31%
		Implemented for economic reason	38%
PC-1 Cluster-3	Install a green roof		
		Not implemented or not applicable	72%
		No mention of anything	3%
		Implemented for regulatory reason	25%
PC-1 Cluster-3	Add water conservation technologies		
		Not implemented or not applicable	16%
		No mention of anything	3%
		Implemented for regulatory reason	56%
		Implemented for economic reason	25%
PC-1 Cluster-3	Improve the operating efficiency or resizing motors to conserve energy		
		Not implemented or not applicable	22%
		No mention of anything	3%
		Implemented for regulatory reason	34%
		Implemented for economic reason	41%
PC-1 Cluster-3	Implement an energy information and tracking system		
		Not implemented or not applicable	28%
		No mention of anything	3%
		Implemented for regulatory reason	41%
		Implemented for economic reason	28%
PC-1 Cluster-3	Implement an automated energy management system		
		Not implemented or not applicable	28%
		Implemented for regulatory reason	41%
		Implemented for economic reason	31%
PC-2 Cluster-3	Increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	16%
		Implemented for regulatory reason	59%
		Implemented for economic reason	25%
PC-2 Cluster-3	Improve the insulation in the attic/ceiling		
		Not implemented or not applicable	13%
		No mention of anything	3%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
		Implemented for regulatory reason	44%
		Implemented for economic reason	41%
PC-2 Cluster-3	Improve the insulation in the main interior or exterior walls		
		Not implemented or not applicable	25%
		No mention of anything	6%
		Implemented for regulatory reason	41%
		Implemented for economic reason	28%
PC-2 Cluster-3	Add weather stripping or air-sealing		
		Not implemented or not applicable	9%
		No mention of anything	6%
		Implemented for regulatory reason	38%
		Implemented for economic reason	47%
PC-2 Cluster-3	Upgrade the windows		
		Not implemented or not applicable	28%
		No mention of anything	3%
		Implemented for regulatory reason	31%
		Implemented for economic reason	38%
PC-2 Cluster-3	Installed a green roof		
		Not implemented or not applicable	72%
		No mention of anything	3%
		Implemented for regulatory reason	25%
PC-2 Cluster-3	Implemented an automated energy management system		
		Not implemented or not applicable	28%
		Implemented for regulatory reason	41%
		Implemented for economic reason	31%
PC-3 Cluster-3	Installed green roof		
		Not implemented or not applicable	72%
		No mention of anything	3%
		Implemented for regulatory reason	25%
PC-3 Cluster-3	Installed water conservation technology		
		Not implemented or not applicable	16%
		No mention of anything	3%
		Implemented for regulatory reason	56%
		Implemented for economic reason	25%

Appendix 10. Cluster Characteristics for Cluster-4 and PC-1, PC-2 and PC-3

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-1 Cluster-4	Increased the operating efficiency of the heating system		
		Not implemented or not applicable	33%
		Implemented for regulatory reason	6%
		Implemented for economic reason	61%
PC-1 Cluster-4	Increased the operating efficiency of the cooling system		
		Not implemented or not applicable	11%
		Implemented for regulatory reason	22%
		Implemented for economic reason	67%
PC-1 Cluster-4	Increase the operating efficiency of the ventilation system		
		Not implemented or not applicable	17%
		Implemented for regulatory reason	22%
		Implemented for economic reason	61%
PC-1 Cluster-4	Increased the operating efficiency of the interior or external lighting		
		Implemented for regulatory reason	17%
		Implemented for economic reason	83%
PC-1 Cluster-4	Increased the operating efficiency of the water heating system		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for economic reason	44%
PC-1 Cluster-4	Improved the insulation in the attic/ceiling		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for economic reason	44%
PC-1 Cluster-4	Improved the insulation in the main interior or exterior walls		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for regulatory reason	6%
		Implemented for economic reason	39%
PC-1 Cluster-4	Added weather stripping or air-sealing		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for economic reason	44%
PC-1 Cluster-4	Upgraded the windows		
		Not implemented or not applicable	61%
		No mention of anything	6%
		Implemented for economic reason	33%
PC-1 Cluster-4	Installed a green roof		
		Not implemented or not applicable	11%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
		Implemented for regulatory reason	44%
		Implemented for economic reason	44%
PC-1 Cluster-4	Added water conservation technologies		
		Not implemented or not applicable	56%
		Implemented for regulatory reason	28%
		Implemented for economic reason	17%
PC-1 Cluster-4	Improved the operating efficiency or resizing motors to conserve energy		
		Not implemented or not applicable	61%
		No mention of anything	6%
		Implemented for regulatory reason	6%
		Implemented for economic reason	28%
PC-1 Cluster-4	Implemented an energy information and tracking system		
		Not implemented or not applicable	39%
		Implemented for regulatory reason	11%
		Implemented for economic reason	50%
PC-1 Cluster-4	Implemented an automated energy management system		
		Not implemented or not applicable	39%
		Implemented for regulatory reason	11%
		Implemented for economic reason	50%
PC-2 Cluster-4	Increased the operating efficiency of the ventilation system		
		Not implemented or not applicable	17%
		Implemented for regulatory reason	22%
		Implemented for economic reason	61%
PC-2 Cluster-4	Improved the insulation in the attic/ceiling		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for economic reason	44%
PC-2 Cluster-4	Improved the insulation in the main interior or exterior walls		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for regulatory reason	6%
		Implemented for economic reason	39%
PC-2 Cluster-4	Added weather stripping or air-sealing		
		Not implemented or not applicable	50%
		No mention of anything	6%
		Implemented for economic reason	44%
PC-2 Cluster-4	Upgraded the windows		
		Not implemented or not applicable	61%
		No mention of anything	6%
		Implemented for economic reason	33%

PC# and Cluster#	Type of Energy-Retrofit	Actions Taken by Managers/Owners	Percent of Building Manager/Owner
PC-2 Cluster-4	Installed a green roof		
		Not implemented or not applicable	11%
		Implemented for regulatory reason	44%
		Implemented for economic reason	44%
PC-2 Cluster-4	Implement an automated energy management system		
		Not implemented or not applicable	39%
		Implemented for regulatory reason	11%
		Implemented for economic reason	50%
PC-3 Cluster-4	Installed green roof		
		Not implemented or not applicable	11%
		Implemented for regulatory reason	44%
		Implemented for economic reason	44%
PC-3 Cluster-4	Installed water conservation technology		
		Not implemented or not applicable	56%
		Implemented for regulatory reason	28%
		Implemented for economic reason	17%

Appendix 11. Statistical Summary

11.1 Characteristics of the Principal Components Analysis

PCA provides me with the component matrix (Appendix 6) with component scores. The scores describe the characteristics of the components or the strength of the linear combinations of the variables. Each component represents the summarized version of decision factors that the commercial building owners and managers use before deciding to invest in energy-retrofit. Below are the characteristics of each component.

11.1.1 General Efficiency Concerns(PC-1)

All clean energy projects for PC-1 have component loadings higher than 0.3 (except the green roof project). Increased operating efficiency of heating system, cooling system, ventilation system, and interior/external lighting have high component loadings (>0.7) so this component is defined as *General Efficiency Concerns* (Table 7).

Table 7. Component Scores for General Efficiency Concerns (PC-1)

Clean Energy Project	PC- 1 Component Loadings
Increased the operating efficiency of the heating system	0.715
Increased the operating efficiency of the cooling system	0.749
Increased the operating efficiency of the ventilation system	0.737
Increased the operating efficiency of the interior or external lighting	0.742
Increased the operating efficiency of the water heating system	0.676
Improved the insulation in the attic/ceiling	0.574
Improved the insulation in the main interior or exterior walls	0.525
Added weather stripping or air-sealing	0.480
Upgraded the windows	0.566
Installed a green roof	0.240
Added water conservation technologies	0.567
Improved the operating efficiency or resizing motors to conserve energy	0.639
Implemented an energy information and tracking system	0.639
Implemented an automated energy management system	0.610

11.1.2 Insulation Upgrade (PC-2)

PC-2 shows that insulation upgrades such as improved insulation in the attic/ceiling, main interior/exterior walls, and weather stripping/air-sealing have the highest loadings (>0.5), so this component is defined as *Insulation upgrade*. The negative loadings are the indicators for either those building managers are, in general, reluctant to increase the operating efficiency of the ventilation system by insulating their buildings or the main reason for retrofitting their buildings are neither economic nor regulatory The managers whose responses were neither economic nor regulatory have been recoded with ‘other’ in the analysis and ‘other’ was given the lower score than ‘economic’ and ‘regulation’.

Table 8. Component Scores for Insulation upgrade (PC-2)

Clean Energy Project	PC-2 Component Loadings
Increased the operating efficiency of the ventilation system	-0.309
Improved the insulation in the attic/ceiling	0.677
Improved the insulation in the main interior or exterior walls	0.660
Added weather stripping or air-sealing	0.541
Upgraded the windows	0.395
Installed a green roof	0.306
Implemented an automated energy management system	-0.366

11.1.3 Resource Conservation (PC-3)

PC-3 shows that installing green roof and adding water conservation technology have moderate component loadings (in absolute terms it is > 0.4), so this component is defined as *Resource Conservation*. The negative component loading for ‘added water conservation technology’ means either these building managers, in general, are reluctant to use water conservation technology or the main reason for retrofitting their buildings are neither economic nor regulatory. I have also noticed that there is a little bit of factor straddling for the green-roof with PC-2 (Insulation upgrade, see Table 7), so green roof is also regarded as being an insulation factor. This factor splitting means that green roofs are an insulation measure to conserve energy. Also, the green roof is a minor concern (because the component loading is low, 0.240) in terms of general efficiency concerns (PC-1, see Table 7).

Table 9. Component Scores for Resource Conservation (PC-3)

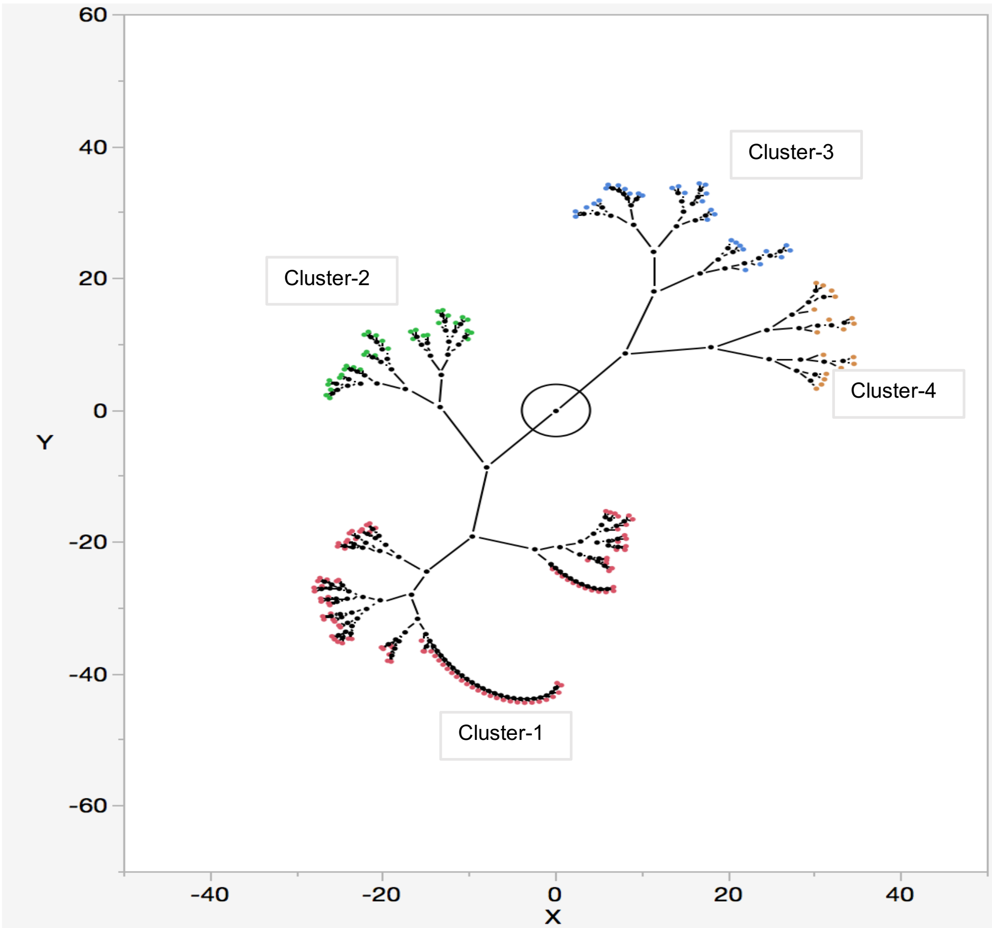
Clean Energy Project	PC-3 Component Loadings
Installed a green roof	0.766
Added water conservation technologies	-0.411

11.2 Characteristics of the Four-Cluster Solution

As I have mentioned earlier (in Section 3.4) that I have decided to use the four-cluster solution to group the building managers/owners. The membership is not equal for each cluster. 56% of building managers/owners belong in Cluster-1, 17.8% and 16.8% of building managers/owners belong in Cluster-2 and Cluster-3, respectively, and 9.4% of building managers/owners belong in Cluster-4.

The Constellation plot also shows the same pattern for the clusters. This plot reveals similar information to a dendogram (see Appendix 5). Here the lines represent the membership of the clusters and the length of the line represents the distance between the clusters. Length of the line should be interpreted by comparing with each other since shorter length means the similarity of the clusters and longer length means the dissimilarity of the clusters. Other aspects of the plot such as orientation and thickness of the dots and angles of the lines are arbitrarily set to make the plot look neat and less cluttered (‘Hierarchical Cluster Options’, 2018)

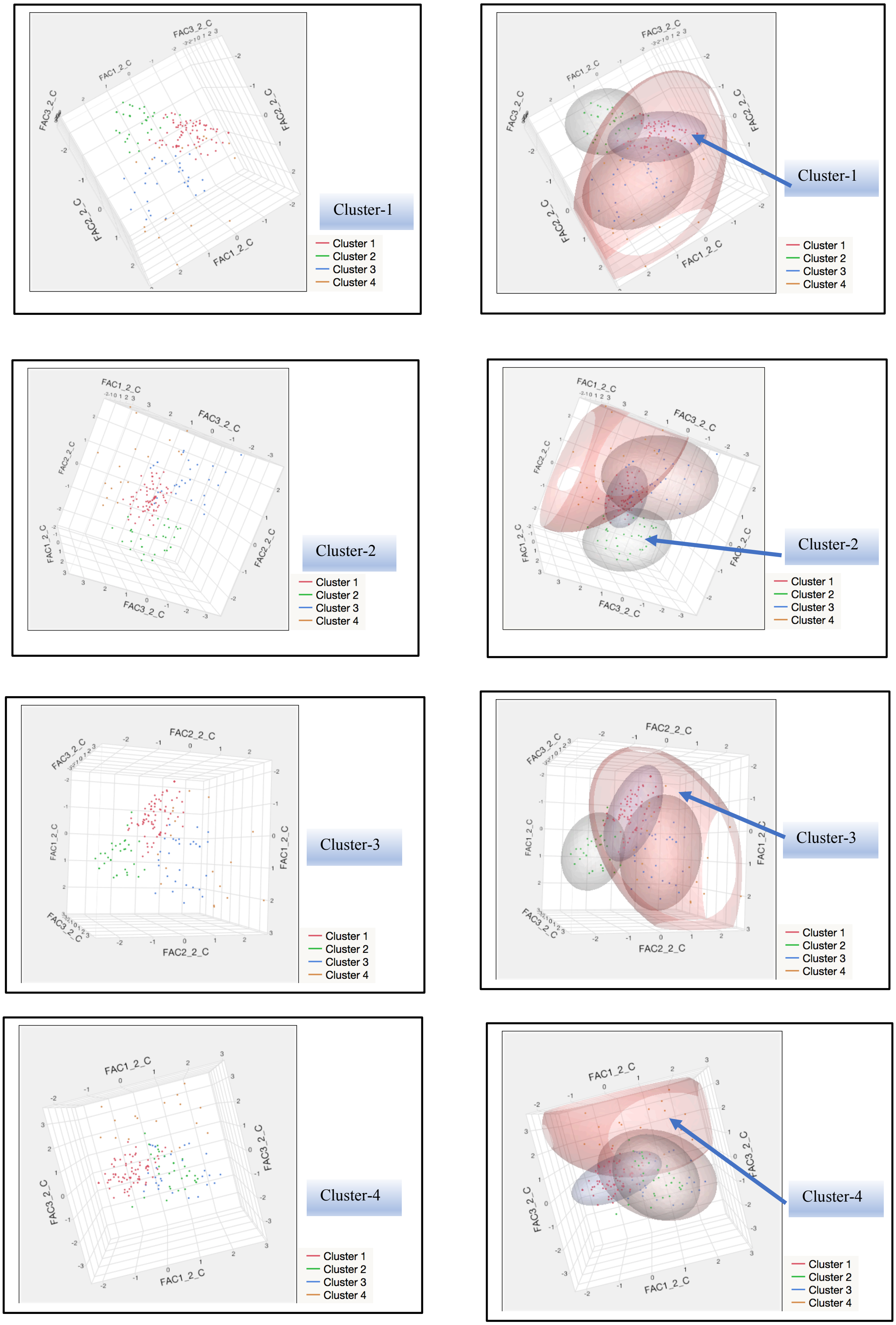
Figure 2. Constellation Plot of the Clusters



Since all clusters are not explicit from one particular angle, I have provided several graphs from different angles to make them more evident. The graphs show how the four clusters are aligned for three components: PC-1, PC-2, and PC-3 in a three-dimensional (3-D) space. Here in the graph FAC1_2_C is PC-1, FAC2_2_C is PC-2, and FAC3_2_C is PC-3. Each dot in the graphs shows one manager or owner that has three characteristics for why he/she has decided to energy-retrofit the building. These characteristics are general efficiency concerns(PC-1), insulation upgrade (PC-2), and resource conservation (PC-3). The graphs on the left side shows how clusters are spread-over in a 3-D space and the graphs on the right side shows the normal contour ellipsoids[15] of four clusters to make the clusters look more evident and observable.

[15] The ellipsoids are the functions of variances, means and correlations of the variables for each cluster

Figure 3. Cluster Memberships in a Three-Dimensional Space



11.2.1 Four Clusters for Principal Component – 1 (PC-1: General Efficiency Concerns)

The interpretation of PC-1 is 'general efficiency concerns'. This the general component that does not have much discrimination in terms of component loadings for the variables. All loadings here have positive values. The Boxplot for the four-cluster solution of PC-1 shows that case number 150 is an outlier in comparison to all members in Cluster-2. Cluster-1 is the only one whose median is below zero which means that the members in Cluster-1 are low in general efficiency concern. The error bars for Cluster-2, Cluster-3, and cluster-4 are overlapping which can be interpreted as they are not vastly different from each other. Low general efficiency concerns for Cluster-1 becomes more evident when I examine the table for means (***Table 10***). It shows that Cluster-1 is the discriminating cluster since it has low 'mean' (only mean that is negative), so generally speaking, the members of Cluster-1 are not good conservers.

Figure 4. Box-plot for PC-1 (General Efficiency Concern)

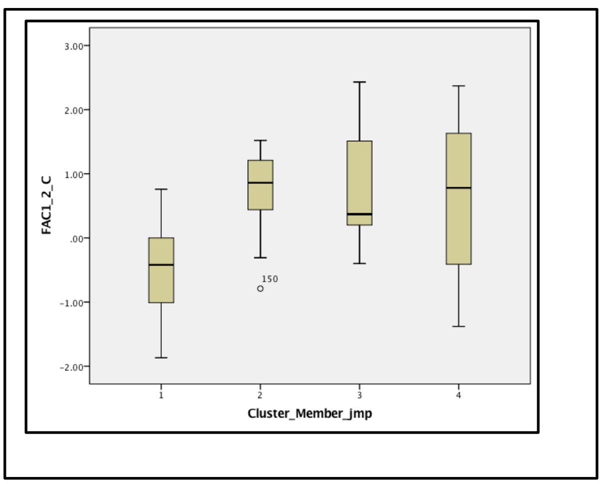


Table 10. Cluster Means for PC-1 (General Efficiency Concern)

Dependent Variable: FAC1_2_C (PC-1)			
Cluster_Member	Mean	Std. Deviation	N
1	-0.597	0.671	107
2	0.788	0.524	34
3	0.802	0.817	32
4	0.636	1.223	18
Total	0.000	1.000	191

Table 11. Characteristics of Four Clusters for PC-1

Cluster #	Cluster Characteristics
1	Not concerned about general efficiency (mean is negative)
2	More concern about general efficiency than Cluster-1 and Cluster-4
3	Most concerned group of managers/owners about general efficiency (highest mean)
4	More concerned about general efficiency than Cluster-1 but less concerned than Cluster-2 and Cluster-3

Now, to verify the descriptive statistics I look at the statistics derived from univariate ANOVA[16]. With ANOVA I compared the measure of central tendency across the clusters and found that three clusters (Cluster-2, Cluster-3, and Cluster-4) were not much different from each other compared to Cluster-1[17]. The overall mean (not within the groups) is zero and overall variance is 1 because the component scores were standardized (See ***Table 10***). In other words, the measure of component scores was standardized with zero mean and unit variance.

Table 12. Tests of Between-Subjects Effects for PC-1 (General Efficiency Concern)

Dependent Variable: FAC1_2_C						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	87.066[a]	3	29.022	52.75	0.000	0.458
Intercept	21.129	1	21.129	38.403	0.000	0.170
Cluster_Member_jmp	87.066	3	29.022	52.75	0.000	0.458

[16] Notice that the Box-plot uses 'median' but ANOVA uses 'mean' for the measure of central tendency
[17] I got the negative 'mean' because the component scores were standardized and has negative scores even though the original responses and the component loadings did not have any negative number

Error	102.883	187	0.550			
Total	189.949	191				
Corrected Total	189.949	190				
a. R Squared = .458 (Adjusted R Squared = .450)						

Tests of Between-Subjects Effects (Table 12) shows statistics for the overall model. The degrees of freedom for the corrected model is 3 because there are four clusters. F-statistics for the corrected model is significant (F=52.75). Adjusted R-squared is also moderate (0.450) which is an indicator that the overall model is significant. It reveals that 45.8% of the variability in 'general efficiency concerns' (PC-1) is accounted for by the four clusters.

Table 13. Parameter Estimates for PC-1 (General Efficiency Concern)

Dependent Variable: FAC1_2_C							
					95% Confidence Interval		
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound	Partial Eta Squared
Intercept	0.636	0.175	3.638	0.000	0.291	0.981	0.066
[Cluster_Member_jmp=1]	-1.233	0.189	-6.525	0.000	-1.606	-0.860	0.185
[Cluster_Member_jmp=2]	0.152	0.216	0.702	0.483	-0.275	0.578	0.003
[Cluster_Member_jmp=3]	0.165	0.219	0.757	0.450	-0.266	0.597	0.003
[Cluster_Member_jmp=4]	0[a]	.	.	.	.	.	.
a. This parameter is set to zero because it is redundant.							

Parameter Estimates (Table 13) reveals what the effects are for each cluster membership. Cluster-4 is the baseline (Beta is zero), thus I compared this cluster with the other three clusters (Cluster-1, Cluster-2, and Cluster-3). I can say that compared to Cluster-4: Cluster-3 is not significantly different (sig.=0.450), Cluster-2 is also not significantly different (sig.=0.483), but Cluster-1 is significantly different (sig.= more than 0.0001). The highly significant effect in this model is membership in Cluster-1 among the four clusters with respect to PC-1.

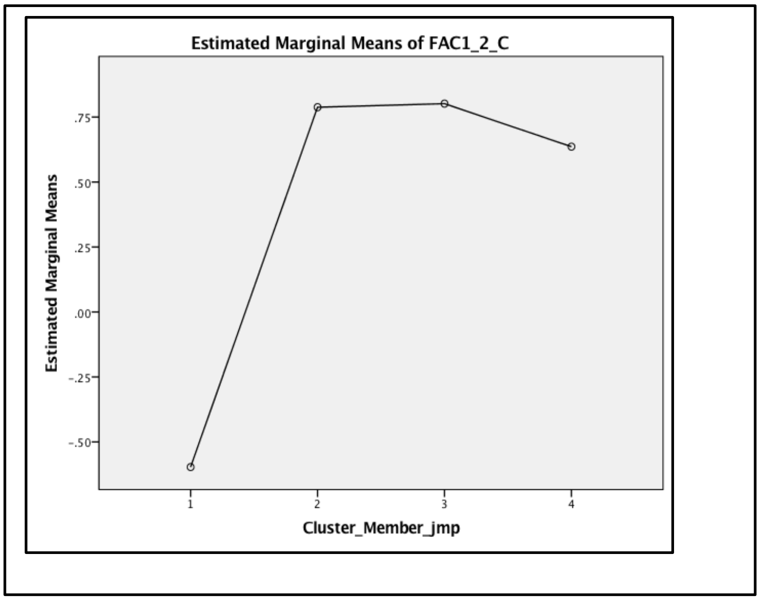
Table 14. Pairwise Comparison for PC-1 (General Efficiency Concern)

Dependent Variable: FAC1_2_C						
(I) Cluster_Member	(J) Cluster_Member	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-1.385*	0.146	0.000	-1.774	-0.995
	3	-1.398*	0.149	0.000	-1.797	-1.000
	4	-1.233*	0.189	0.000	-1.737	-0.729
2	1	1.385*	0.146	0.000	0.995	1.774
	3	-0.014	0.183	1.000	-0.501	0.474
	4	0.152	0.216	1.000	-0.425	0.728
3	1	1.398*	0.149	0.000	1.000	1.797
	2	0.014	0.183	1.000	-0.474	0.501
	4	0.165	0.219	1.000	-0.417	0.748
4	1	1.233*	0.189	0.000	0.729	1.737
	2	-0.152	0.216	1.000	-0.728	0.425
	3	-0.165	0.219	1.000	-0.748	0.417

Based on estimated marginal means. *. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.

Pairwise Comparison (Table 14) also supports the results that I got from the Parameter Estimates (Table 13). From this table I can conclude that Cluster-1 is significantly different from Cluster-2, Cluster-3 and Cluster-4 (Sig.=0.000) with respect to their means. Cluster-2 is significantly different from Cluster-1 (Sig.=0.000) but Cluster-2 is *not* significantly different from Cluster-3 and Cluster-4 (Sig.=1.000). Cluster-3 is significantly different from Cluster-1 but Cluster-3 is *not* significantly different from Cluster-2 and Cluster-4 (Sig.=1.000). Cluster-4 is significantly different from Cluster-1 but Cluster-4 is *not* significantly different from Cluster-2 and Cluster-4 (Sig.=1.000) with respect to their means.

Figure 5. Profile Plots for PC-1 (General Efficiency Concern)



I can also see the similar results in the Profile Plot[18]. I can conclude that Cluser-2, Cluster-3, and Cluster-4 are not different from each other and Cluster-1 is significantly different from Cluser-2, Cluster-3, and Cluster-4. Cluster-1 is the non-energy efficiency and non-conserving group because as it registers a negative mean.

11.2.2 Four Clusters for Principal Component – 2 (PC-2: Insulation Upgrade)

The interpretation for PC-2 is 'insulation upgrade'. I have all the positive component loadings for the variables that relate to insulation upgrade except two variables. 'Increased the operating efficiency of the ventilation system' and 'Implemented an automated energy management system' have negative component loadings, -0.309 and -0.366 respectively; but they also have high component loadings for PC-1, 0.737 and 0.610 respectively (Table 7). PC-2 primarily represents insulation upgrade since I am dealing with the energy efficiency of buildings.[19]

[18] Profile plot shows the marginal means of the cluster memberships (dependent variables). Check four dots (group means) in the graph. They represent marginal means for the corresponding clusters.
[19] PC-2 tells us, with respect to overall measures, I have first set of actions for buildings that deal with general efficiency concerns (PC-1) and once I account for the general efficiency concerns then there is a second set of actions for buildings (taken by managers/owners) that deal with insulation. PC-2 is a particular sort of aspect for general efficiency (PC-1)

The Boxplot for the four-cluster solution of PC-2 shows no outliers. Cluster-2 has the lowest value, below negative one, which means that the members in Cluster-2 are less concerned about insulation upgrade. The error bars for Cluster-3 and Cluster-4 are overlapping which says that they are not vastly different from each other. I can also look at the means (***Table 15***) and find that Cluster-2 is the discriminating cluster since it has the lowest score (only mean that is negative) for PC-2. It also reveals that the members of Cluster-2 are reluctant on insulation upgrades for their buildings.

Figure 6. Box-plot for PC-2 (Insulation upgrade)

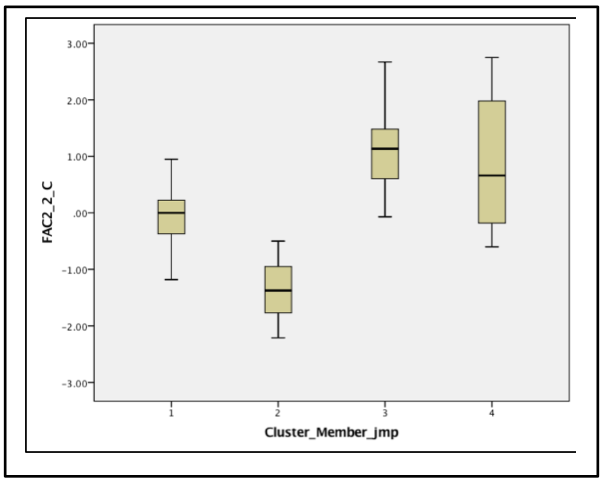


Table 15. Cluster Means for PC-2 (Insulation upgrade)

Dependent Variable: FAC2_2_C			
Cluster_Member	Mean	Std. Deviation	N
1	-0.053	0.452	107
2	-1.383	0.486	34
3	1.133	0.635	32
4	0.914	1.252	18
Total	0.000	1.000	191

Table 16. Characteristics of Four Clusters for PC-2

Cluster #	Cluster Characteristics
1	Indifference for insulation upgrade (mean is close to zero)
2	Not concerned about insulation upgrade (mean is negative)
3	Most concerned group of managers/owners about insulation upgrade (highest mean)
4	More concerned about insulation upgrade than Cluster-1 and Cluster-2 but less concern than Cluster-3

With ANOVA I compared the measure of central tendency across the clusters and found that two clusters (Cluster-3 and Cluster-4) are not much different from each other compared to Cluster-2.

Table 17. Tests of Between-Subjects Effects for PC-2 (Insulation upgrade)

Dependent Variable: FAC2_2_C						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	121.396[a]	3	40.465	110.275	0.000	0.639
Intercept	2.972	1	2.972	8.100	0.005	0.042
Cluster_Member_jmp	121.396	3	40.465	110.275	0.000	0.639
Error	68.62	187	0.367			
Total	190.016	191				
Corrected Total	190.016	190				
a. R Squared = .639 (Adjusted R Squared = .633)						

Tests of Between-Subjects Effects (Table 17) shows statistics for the overall model. The degrees of freedom for the corrected model is 3 because there are four clusters. F-statistics for the corrected model is significant (F=110.275). Adjusted R-squared is also high (0.633) which is an indicator that the overall model is significant. It reveals that 63.3% of the variability in 'insulation upgrade' (PC-2) measure is accounted for by the four clusters.

Table 18. Parameter Estimates for PC-2 (Insulation upgrade)

Dependent Variable: FAC2_2_C							
					95% Confidence Interval		
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound	Partial Eta Squared
Intercept	0.914	0.143	6.401	0.000	0.632	1.196	0.180
[Cluster_Member_jmp=1]	-0.966	0.154	-6.262	0.000	-1.271	-0.662	0.173

[Cluster_Member_jmp=2]	-2.297	0.177	-13.008	0.000	-2.645	-1.948	0.475
[Cluster_Member_jmp=3]	0.219	0.178	1.225	0.222	-0.133	0.571	0.008
[Cluster_Member_jmp=4]	0[a]	.	.	.	.	.	.
a. This parameter is set to zero because it is redundant.							

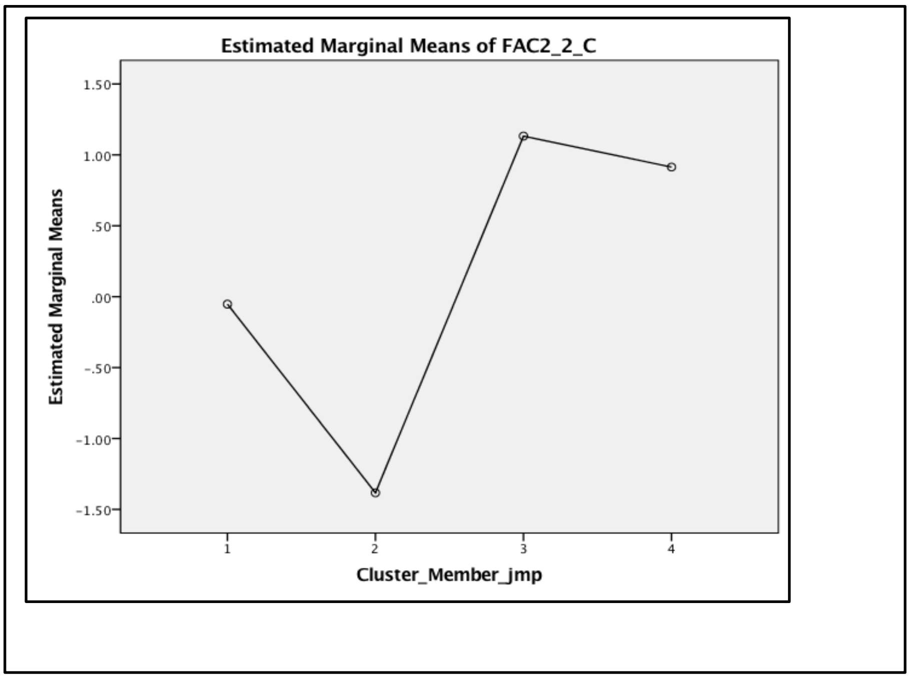
The parameter Estimates (Table 18) reveals what the effects are for each cluster membership. Cluster-4 is the baseline (Beta is zero), thus I compared this cluster with the other three clusters. I can say that compared to Cluster-4: Custer-3 is not significantly different (sig.=0.222), but Cluster-2 and Cluster-1 are significantly different (sig.= more than 0.0001). The regression coefficients have an impact to make the means of first two groups (Cluster-1 and Cluster-2) to be negative (***Table 15***). The biggest distinction is between Cluster-2 and Cluster-3. The highly significant effect in this model is membership in Cluster-2 and this cluster is making the variability among the four clusters with respect to PC-2.

Table 19. Pairwise Comparison for PC-2 (Insulation upgrade)

Dependent Variable: FAC2_2_C						
					95% Confidence Interval for Difference[b]	
(I) Cluster_Member_jmp	(J) Cluster_Member_jmp	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	1.330*	0.119	0.000	1.012	1.648
	3	-1.185*	0.122	0.000	-1.510	-0.860
	4	-.966*	0.154	0.000	-1.378	-0.555
2	1	-1.330*	0.119	0.000	-1.648	-1.012
	3	-2.515*	0.149	0.000	-2.913	-2.118
	4	-2.297*	0.177	0.000	-2.768	-1.826
3	1	1.185*	0.122	0.000	0.860	1.510
	2	2.515*	0.149	0.000	2.118	2.913
	4	0.219	0.178	1.000	-0.257	0.695
4	1	.966*	0.154	0.000	0.555	1.378
	2	2.297*	0.177	0.000	1.826	2.768
	3	-0.219	0.178	1.000	-0.695	0.257
Based on estimated marginal means. *. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.						

Pairwise Comparison (Table 19) also supports the results that I got from the Parameter Estimates (Table 18). Cluster-1 is statistically different from Cluster-2, Cluster-3, and Cluster-4 (Sig.=0.000) with respect to their means. Cluster-2 is statistically different from Cluster-1, Cluster-3, and Cluster-4 (Sig.=0.000). Cluster-3 is statistically different from Cluster-1and Cluster-2, but Cluster-3 is not statistically different from Cluster-4 (Sig.=1.000). Cluster-4 is statistically different from Cluster-1and Cluster-2, but Cluster-4 is not statistically different from Cluster-3 (Sig.=1.000) with respect to their means.

Figure 7. Profile Plots for PC-2 (Insulation upgrade)



I can also see the similar result in the Profile Plot. I can conclude that Cluster-3 and Cluster-4 are not different from each other and Cluster-2 is significantly different from Cluser-1, Cluster-3, and Cluster-4. I can say that Cluster-2 is the non-insulation and non-conserving group. This tells us, with respect to insulation, Cluster-3 and Cluster-4 are not very different, but Cluster-1, Cluster-2, and Cluster-3 are different from each other. Cluster-2 in PC-2 is the least concerned group of managers/owners at insulation. Cluster-1, which was a big differentiating cluster in PC-1 now has a mean close to zero (-0.053), and this mean is almost same as the overall mean (0.00). Cluster-3 and Cluster-4 are not different from each other in terms of their means but their means are positive and close to one (1.133 and 0.914, respectively)[20]. Cluster-2 is the main differentiating factor in this model because the mean is -1.383 and it is making all the differences in overall models. I can say that the members in the Cluster-3 and Cluster-4 are doing the insulation (their means are positive, 1.133 and 0.914 respectively), Cluster-2 are not doing the insulation (mean is negative, -1.383), and Cluster-1 is somewhat indifferent in terms of doing insulation because its mean is close to zero (-0.053). I have shown the differentiating characteristics of Cluster-1 for PC-1 (Cluster-1 were not concerned in terms of the general efficiency measure), and now it shows that the members of Cluster-1 are also indifferent in terms of doing insulation. Notice that the means for Cluster-1 and Cluster-2 are negative, so they are not insulating groups. Cluster-3 and Cluster-4 are insulating groups because the mean is positive. I can conclude that managers/owners of the buildings that belong to Cluster-1 and Cluster-2 are not doing the insulation and managers /owners of the buildings that belong to Cluster-3 and Cluster-4 are doing the insulation.

11.2.3 Four Clusters for Principal Component – 3 (PC-3: Resource Conservation)

The interpretation of the PC-3 is 'resource conservation'. This component has only two variables that had high-enough component loadings[21] (greater than 0.3) – 'installed a green roof' and 'added water conservation technologies'. The Boxplot for the four-cluster solution of PC-3 shows that case number 9, 21, 57 and some other rows have some outliers in comparison to all members in Cluster-1. Also, Cluster-1, Cluster-2, and Cluster-3 have negative values which means that the members in these clusters are less concerned about resource conservation. The error bars for Cluster-1, Cluster-2, and Cluster-3 are overlapping which is an indicator that they are not vastly different from each other. I can also look at the means (Table 20) and say that Cluster-4 is the discriminating cluster since only this one has the positive mean (2.087) for PC-3. It indicates that the members of Cluster-4 are enthusiastic about energy conservation.

[20] The means are standardized and the scores that are greater than +/-1 are unusual because they are outside of one standard deviation

[21] All components have loadings on all variables but only the variables with loadings that are greater than or equal to 0.3 in absolute terms are considered significant for the analysis

Generally speaking, the members of Cluster-4 are very concerned about resource conservation for their buildings.

Figure 8. Box-plot for PC-3 (Resource Conservation)

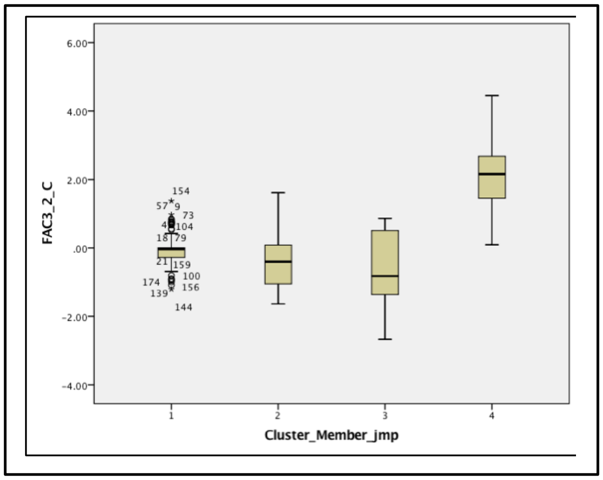


Table 20. Cluster Means for PC-3 (Resource Conservation)

Dependent Variable: FAC3_2_C			
Cluster_Member	Mean	Std. Deviation	N
1	-0.070	0.448	107
2	-0.315	0.818	34
3	-0.606	1.011	32
4	2.087	1.112	18
Total	0.000	1.000	191

The mean for Cluster-1 is close to zero (-0.070). The mean for Cluster-2 and Cluster-3 are negative (-0.315 and -0.606 respectively), but the mean for Cluster-4 is positive and so I can say that Cluster-4 is the differentiating factor for the model. Green roofers have positive component loading which indicates that they tend to favour installing green room for heat conservation but in the same time it indicates that they are not doing water conservation.

Table 21. Characteristics of Four Clusters for PC-3

Cluster #	Cluster Characteristics
1	Indifference for resource conservation (mean is close to zero)
2	Not concerned about resource conservation (mean is negative)
3	Not concerned about resource conservation (mean is negative)
4	Cluster-4: Most concerned group of managers/owners about resource conservation (highest mean with positive score)

Now, to verify the descriptive statistics I look at the statistics derived from univariate ANOVA. In terms of ANOVA, I compared the measure of central tendency across the clusters to find that two clusters (Cluster-1 and Cluster-2) were not much different from each other compared to Cluster-4. The overall mean (not within the groups) was zero and overall variance was 1 because the component scores were standardized (Table 20).

Table 22. Tests of Between-Subjects Effects for PC-2 (Resource Conservation)

Dependent Variable: FAC3_2_C						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	94.030[a]	3	31.343	61.037	0	0.495
Intercept	9.555	1	9.555	18.607	0	0.090
Cluster_Member_jmp	94.03	3	31.343	61.037	0	0.495
Error	96.028	187	0.514			
Total	190.058	191				
Corrected Total	190.057	190				
a. R Squared = .495 (Adjusted R Squared = .487)						

Tests of Between-Subjects Effects (Table 22) shows statistics for the overall model. The degrees of freedom for the corrected model is 3 because there are four clusters. F-statistic for the corrected model is significant (F=61.037). Adjusted R-squared is also high (0.487) which is an indicator that the overall model is significant. It reveals that 48.7% of the variability in 'resource conservation' (PC-3) measure is accounted for by the four clusters.

Table 23. Parameter Estimates for PC-3 (Resource Conservation)

Dependent Variable: FAC3_2_C							
					95% Confidence Interval		
Parameter	B	Std. Error	t	Sig.	Lower Bound	Upper Bound	Partial Eta Squared
Intercept	2.087	0.169	12.354	0.000	1.753	2.420	0.449
[Cluster_Member_jmp=1]	-2.157	0.183	-11.814	0.000	-2.517	-1.797	0.427
[Cluster_Member_jmp=2]	-2.402	0.209	-11.499	0.000	-2.814	-1.990	0.414
[Cluster_Member_jmp=3]	-2.693	0.211	-12.753	0.000	-3.109	-2.276	0.465
[Cluster_Member_jmp=4]	0[a]	.	.	.	.	.	.
a. This parameter is set to zero because it is redundant.							

The parameter Estimates (Table 23) reveals what the effects are for each cluster membership. Cluster-4 is the baseline (Beta is zero), so I compared this cluster with the other three clusters. I can say that compared to Cluster-4: Cluster-1, Cluster-2 and Cluster-3 are significantly different (sig.= more than 0.0001). Cluster-4 is the baseline and it is quite different from other clusters because every cluster with respect to Cluster-4 has negative parameter estimates. The highly significant effect in this model is membership in Cluster-4 among the four clusters with respect to PC-3.

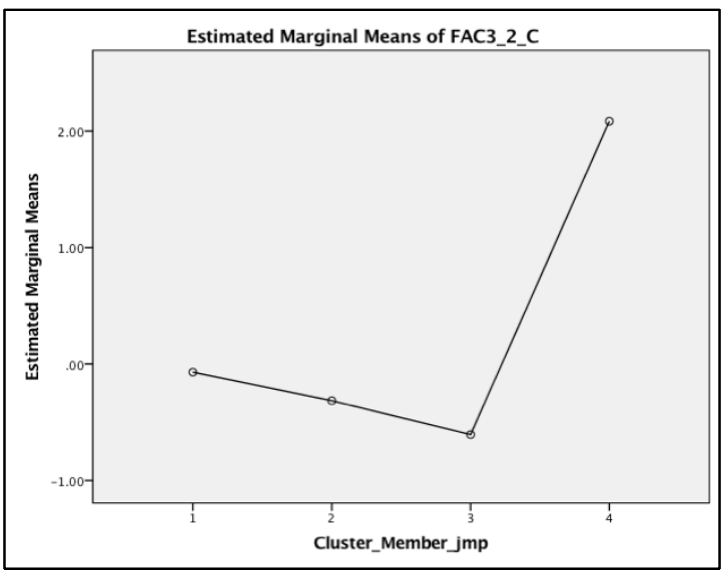
Table 24. Pairwise Comparison for PC-3 (Resource Conservation)

Dependent Variable: FAC3_2_C						
					95% Confidence Interval for Difference[b]	
(I) Cluster_Member_jmp	(J) Cluster_Member_jmp	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound
1	2	0.245	0.141	0.503	-0.131	0.621
	3	.536*	0.144	0.002	0.151	0.921
	4	-2.157*	0.183	0.000	-2.644	-1.670
2	1	-0.245	0.141	0.503	-0.621	0.131
	3	0.291	0.176	0.608	-0.180	0.761
	4	-2.402*	0.209	0.000	-2.959	-1.845
3	1	-.536*	0.144	0.002	-0.921	-0.151
	2	-0.291	0.176	0.608	-0.761	0.180
	4	-2.693*	0.211	0.000	-3.256	-2.130
4	1	2.157*	0.183	0.000	1.670	2.644

	2	2.402*	0.209	0.000	1.845	2.959
	3	2.693*	0.211	0.000	2.130	3.256
Based on estimated marginal means. *. The mean difference is significant at the .05 level. b. Adjustment for multiple comparisons: Bonferroni.						

Pairwise Comparisons (Table 24) also supports the results that I got from the Parameter Estimates (Table 23). Cluster-1 is statistically different from Cluster-3 (Sig.=0.002) and Cluster-4 (Sig.=0.000) with respect to their estimated means, but Cluster-1 is *not* statistically different from Cluster-2 (Sig.=0.503). Cluster-2 is statistically different from Cluster-4 (Sig.=0.000), but Cluster-2 is not statistically different from Cluster-1 (Sig.=0.503) and Cluster-3 (Sig.=0.608). Cluster-3 is statistically different from Cluster-1 (Sig.=0.002) and Cluster-4 (Sig.=0.000), but Cluster-3 is not statistically different from Cluster-2 (Sig.=0.608). Cluster-4 is statistically different from Cluster-1, Cluster-2, and Cluster-3 (Sig.=0.000) with respect to their means.

Figure 9. Profile Plots for PC-3 (Resource Conservation)



I can also see the similar result in the Profile Plot. I can conclude that Cluster-1 and Cluster-2 are not different from each other and Cluster-4 is significantly different from Cluser-1, Cluster-2, and Cluster-3. Notice that the mean for Cluster-4 is above 2 (2.087) and the mean is standardized, so I can conclude that members of Cluster-4 are very concerned about resource conservation.

11.3 Characteristics of the Regression Models

11.3.1 General Efficiency Concerns vs Full-time Employees and Building Area

The model summary shows that Adjusted R^2 is only 0.057, which means that only 5.7% of the variation in general efficiency concerns is explained by the number of full-time employees and total building area (Table 25). Here in the model Q21_Log_Impute is the log of the number of full-time equivalent employees, Q32_Log_Impute is the log of the total building area, and New is the interaction variable that was created by multiplying the log of *number of full-time equivalent employees* and log of *total building area*.[22]

Table 25. Model Summary for General Efficiency Concerns (PC-1) vs Full-time Employees and Building Area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.269[a]	.072	.057	.97078	.072	4.852	3	187	.003

a. Predictors: (Constant), new, Q32_Log_Impute, Q21_Log_Impute

b. Dependent Variable: FAC1_2_C. It is the Principal Component-1 or General Efficiency Concern

Regression coefficients (Table 26) show that the predictor variables are not statistically significant because sig=.376 for log of full-time employee, sig=.457 for log of total building area and sig=.208 for the New variable. The regression result shows that the managers/owners of the commercial buildings are less likely to be concerned about the energy efficiency of their buildings when the building size goes up *or* when the number of employees goes up but they are more likely to be concerned when the size of the buildings *and* the number of employees both go up together.

[22] Independent variables were logged (10-base) to make them normally distributed for parametric statistics such as regression analysis

Table 26. Coefficients for General Efficiency Concerns (PC-1) vs Full-time Employees and Building Area

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.558	1.546		.361	.719
	Q21_Log_Impute	-.230	.259	-.564	-.887	.376
	Q32_Log_Impute	-.099	.132	-.122	-.745	.457
	new	.028	.022	.854	1.265	.208
a. Dependent Variable: FAC1_2_C. It is the Principal Component-1 or General Efficiency Concern						

11.3.2 Insulation Upgrade vs Full-time Employees and Building Area

The model summary shows that Adjusted R^2 is only 0.062 which means that only 6.2% of the variation in concern for insulation upgrade is explained by the number of full-time employees and total building area (Table 27). Here in the model Q21_Log_Impute is the log of number of full-time equivalent employees, Q32_Log_Impute is the log of total building area, and New is the multiplication of log of number of full-time equivalent employees and log of total building area.

Table 27. Model Summary for Insulation upgrade (PC-2) vs Full-time Employees and Building Area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.278[a]	.077	.062	.96830	.077	5.221	3	187	.002
a. Predictors: (Constant), new, Q32_Log_Impute, Q21_Log_Impute									
b. Dependent Variable: FAC2_2_C. It is the Principal Component-2 or Insulation upgrade									

Regression coefficients (Table 28) show that the predictor variables are not statistically significant because sig=.180 for log of full-time employee and sig=.209 for the New variable. Log of total building area is significant because sig=.009 for this independent variable. The regression result shows that the managers/owners of the commercial buildings are less likely to insulate their buildings if the building size goes up *or* if the number of employees goes up but they are more likely to insulate their buildings if the size of the buildings *and* the number of employees both go up together.

Table 28. Coefficients for Insulation upgrade (PC-2) vs Full-time Employees and Building Area

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.252	1.542		2.758	.006
	Q21_Log_Impute	-.348	.258	-.853	-1.345	.180
	Q32_Log_Impute	-.350	.132	-.434	-2.650	.009
	new	.028	.022	.849	1.261	.209
a. Dependent Variable: FAC2_2_C. It is the Principal Component-2 or Insulation upgrade						

11.3.3 Resource Conservation vs Full-time Employees and Building Area

The model summary shows that Adjusted R^2 is only 0.007 which means that only 0.7% of the variation in concern for resource conservation is explained by the number of full-time employees and total building area (Table 29). Here in the model Q21_Log_Impute is the log of number of full-time equivalent employees, Q32_Log_Impute is the log of total building area, and New is the multiplication of log of number of full-time equivalent employees and log of total building area.

Table 29. Model Summary for Resource Conservation (PC-3) vs Full-time Employees and Building Area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.150[a]	.022	.007	.99674	.022	1.434	3	187	.234
a. Predictors: (Constant), new, Q32_Log_Impute, Q21_Log_Impute									
b. Dependent Variable: FAC3_2_C. It is the Principal Component-3 or Resource Conservation									

Regression coefficients (Table 30) show that the predictor variables are not statistically significant because sig=.143 for log of full-time employee, sig=.142 for log of total building area and sig=.106 for the New variable. The regression result shows that the managers/owners of the commercial buildings are less likely to be concerned about resource conservations (i.e., water, heat) when the building size goes up *or* when the number of employees goes up but they are more likely to be concerned when the size of the buildings *and* the number of employees both go up together.

Table 30. Coefficients for Resource Conservation (PC-3) vs Full-time Employees and Building Area

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.101	1.587		1.324	.187
	Q21_Log_Impute	-.391	.266	-.960	-1.470	.143
	Q32_Log_Impute	-.200	.136	-.248	-1.473	.142
	new	.037	.022	1.125	1.624	.106

a. Dependent Variable: FAC3_2_C. It is the Principal Component-3 or Resource Conservation

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