NICHOLAS SCHOOL OF THE ENVIRONMENT

Duke Carbon Offsets Initiative: Energy Efficiency Carbon Offsets

A Project Evaluation

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Abstract

Duke University aims to achieve carbon neutrality by 2024 by a combination of efforts to reduce on campus energy consumption and off campus carbon offset generation. One of the offset options that DCOI is evaluating is energy efficiency retrofits in residential buildings leading to indirect emission reductions. The problem we have attempted to address in our project is how Duke University can identify potential carbon offset opportunities in terms of improving energy efficiency in homes and businesses and how these offsets can be verified and quantified.

In order to determine the feasibility of energy efficiency carbon offsets the team started with evaluating data from a similar residential retrofitting project implemented by the City of Durham's Sustainability Office. The pre and post retrofit energy consumption data from these houses was analyzed to determine the energy savings and resultant carbon emissions reduction. The average emission reduction obtained from this project was then used to determine the carbon price. This carbon price was used to conduct a comparative analysis with carbon prices found in the market, literature and regulations. The second step of the project involved studying energy efficiency retrofit projects that have been undertaken in other regions at various levels and sizes. The last question that this project aimed to answer was regarding the suitability of various financing mechanisms for the retrofitting project. In order to address this question a demand assessment survey was designed to determine the willingness of Duke employees to participate in such a program and pay for the retrofits. DCOI plans to conduct the survey in the foreseeable future.

The results of our analysis showed that average electricity savings of 113.13 KWh per month can be generated through retrofits including air and duct sealing and insulation enhancement. The average cost of retrofit was determined to be $1/sq feet of heated area. Using this investment cost and annual savings, the carbon price was determined to be 133.37 $/metric ton of CO_2 equivalent reduction. Sensitivity analysis conducted for this carbon price showed that the factors that had the largest impact on carbon price are the initial investment and annual energy savings. To further evaluate the results, we compared the City of Durham's returns on investment in terms of energy reduction, 0.97 kWh/$, and in terms of greenhouse gas reduction, 0.00046 metric ton of CO_2 equivalent/$, to returns on investment of 22 other residential energy efficiency programs around the U.S. The City of Durham program lies in the middle of the range of return on investment indicators. The calculated carbon price of 133.37 $/metric ton of CO_2 equivalent reduction, compared to 13.00 $/metric ton of CO_2 equivalent reduction median of 44 other carbon prices found in regulation, literature, and market is extremely high. The final set of recommendations provided to DCOI are based upon the results obtained from the City of Durham data analysis and the comparative programs and carbon price study along with the essential project requirements for meeting the Verified Carbon Standard carbon offset program criteria.

Table of Contents

List of Tables

List of Figures

Duke Carbon Offsets Initiative: Energy Efficiency Carbon Offsets, a Feasibility Study

1.0 Introduction

Duke University aims to achieve carbon neutrality by 2024. With this objective in mind, it is working towards reducing carbon emissions from on-campus sources and has so far succeeded in significantly reducing emissions by 53,000 metric tons of CO_2 equivalent ($mtCO_2e$) since 2007. Emission reduction activities undertaken so far include discontinuing the use of coal in campus steam plants, improving alternative transportation, energy conservation, and installation of solar photo-voltaic. However, on-campus carbon reductions will not be enough to achieve carbon neutrality in the set time frame, and Duke will eventually need to invest in off-campus carbon offset initiatives. In part, Duke aims to generate quantifiable greenhouse gas emission reductions by investing in energy efficiency projects in residential buildings in the region. The problem we will address in our project is how Duke University can identify potential carbon offset opportunities in terms of improving energy efficiency in homes and how these offsets can be verified and quantified [3].

1.1 Our Client – The Duke Carbon Offsets Initiative

The Duke Carbon Offsets Initiative (DCOI) was established under the Duke Sustainability Office in June 2009 to develop and implement carbon offset programs to enable Duke University to meet its carbon neutrality commitment. Close to 183,000 metric tons (about 50% of business as usual emissions) of carbon offsets per year will be required to achieve this by 2024. This amount, however, is expected to decrease as Duke Energy, the primary energy provider of Duke University, shifts away from coal based generation to more sustainable sources. The carbon intensity of Duke Energy is projected to decrease from 0.5 metric tons/MWh in 2010 to 0.3 metric tons/MWh by 2024. This decrease will in turn reduce the carbon emission rate of the electricity used on the university campus [4]. The DCOI aims to invest in projects at the local, regional and state level to generate creditable carbon credits while contributing effectively to the community in terms of environmental protection, energy savings, job creation and public health protection. It also aims to establish itself as a benchmark and a resource for other academic institutions who wish to create carbon offsets programs in future. The three general types of offset options that the DCOI is evaluating are[3]:

- Installation of waste management systems at North Carolina swine farms to capture methane
- Forest carbon offsets through forest conservation, reforestation and afforestation

- Community based energy efficiency projects

The first project that the DCOI invested in, Loyd Ray Farms in Yadkin County, became operational in May 2011. It is a swine farm waste to energy project where hog waste is collected and used to generate electricity that is utilized at the farm to support operations and also qualifies for renewable energy credits. It is generating 500 to 600 MWh of power per year and 235 to 282 offset credits. DCOI has yet to investigate in detail the potential of acquiring offsets from forest conservation, reforestation, and afforestation programs. Lastly, the purpose of our study is focused on the possibility of obtaining carbon offsets from residential energy efficiency programs in the local community.

1.2 Carbon Offsets

A carbon offset can be described as "*a contract between two parties under which one party voluntarily agrees to reduce its emissions (or increase carbon sequestration) in exchange for payment from the other party*"[5]. Carbon offsets can be generated and traded under a compliance program in capped markets as well as in voluntary markets in uncapped economies [5, 6]. A carbon offset program offers flexibility in terms of emissions reduction measures and allows entities to take the most cost effective path to achieving the greenhouse gas (GHG) requirements. It can also result in enhanced environmental and social benefits through utilization of less carbon intensive technologies, protection of vulnerable ecosystems, and community awareness [5]. In case of energy efficiency programs, an offset would work by reducing the consumption of electricity and natural gas in residential and/or commercial buildings which will lead to reduction in carbon (CO_2e) emission from power generation. This reduction in CO_2 emission will then be counted as a carbon offset. One offset stands for one ton of carbon dioxide equivalent emission reduction [5].

There are three broad categories of carbon offset projects [5]:

1. **Direct emissions reduction**: this category includes projects that cause reduction of carbon emissions at the project site itself such as methane capture, fuel switch from high carbon intensive to low carbon intensive, and increase in fuel efficiency of vehicles.
2. **Indirect emissions reduction**: this category covers projects that reduce emissions occurring away from the project site by lowering the demand for electricity and natural gas or by lowering the addition of fossil fuel generating capacity. Examples include energy efficiency retrofitting projects.

3. **Sequestration:** this involves the capturing and storing carbon dioxide from the atmosphere or emission source long term. Sequestration may further be categorized as
    a. Biological sequestration: storing carbon in biomass such as forests, grasslands, soil
    b. Carbon capture and sequestration: capturing GHGs at the emission source and storing them in sound geological formations to prevent re-emission into the atmosphere
    c. Avoided deforestation: under this measure, the release of carbon is prevented by conserving standing forest masses

In order to ensure that carbon offsets produce real reductions in emissions, certain criteria have been laid down by various independent bodies and are considered to be the basic requirements for any offset program. These are [5, 7]:

- **Additionality**: the emissions reductions generated by the project must be "*above and beyond what would have occurred without the project*" [5-7]. It can be done by showing that there are significant barriers for the implementation of the project such as financial inadequacy of the concerned entity, lack of technology, community acceptance concerns, etc. If the emission reduction would have taken place anyway without the project, they will not be counted as additional. There are number of tests, performance-based and project-based, available under different methodologies that can be used to verify additionality of a carbon offset program [5-7].
- **Leakage**: an offset program must ensure that avoided emissions in a given project do not lead to increased emissions outside the project boundary. Displacement of emissions from one activity to another constitutes leakage. This may occur, for example, if a replaced appliance is re-used in another location or activity outside the project governance. In order to avoid leakage of emissions, careful accounting of all project constituents and activities must be done [5-7].
- **Permanence**: the program must ensure that the emission reduction is permanent and will not be reversed to release the avoided emissions at a later time. This is particularly applicable to biological sequestration projects where the future harvest of forests or clearing of grasslands for cultivation may lead to release of carbon stored in them. An offset program can be protected against such reversal of carbon storage by careful monitoring and legal instruments[5-7].

There are a number of standards currently available that can be used to certify the quality of carbon offsets. Each standard has its own set of methods to verify the additionality, leakage and permanence of carbon offsets. The standard that we chose to use for our project is the Verified Carbon Standard which is discussed in detail in Section 3 of this report.

2.0 Purpose and Scope

The purpose of this report is to assess the potential of Duke University to generate quantifiable and verifiable carbon offsets from energy efficiency projects in Durham, North Carolina. This assessment includes the technical and economic evaluation of a similar program implemented by the City of Durham. The results from this program have been compared with the results from similar energy efficiency retrofit programs implemented in other locations to obtain a broader perspective. The break-even carbon price determined from the data analysis has also been compared to carbon prices found in the literature and the market price to determine the financial adequacy of the project. The final recommendations for DCOI have been supplemented by a demand assessment survey which will be conducted among the Duke employees to determine their willingness to participate and pay for such a program.

3.0 Carbon Offset Standards

For our study, we will focus on three major carbon offset standards used in the voluntary market, the Verified Carbon Standard, the Clean Development Mechanism, and the Gold Standard. The Verified Carbon Standard (VCS) is created with the goal to be a widely adopted standard with low hurdles and costs [8]. The Clean Development Mechanism (CDM) is developed under Kyoto protocol and "*aims to create economic efficiency while also delivering development with co-benefits to developing nations*" [8]. Since its implementation a substantial number of CDM and Joint Implementation projects have been undertaken that have led to considerable offset creation across the globe. However, measuring the co-benefits of these projects has been questionable and unverifiable. The Gold Standard (GS) "*aims to enhance quality of carbon offsets and increase their co-benefits by improving and expanding on the CDM process*"[8]. GS uses the CDM additionality tool for both large and small scale projects under its guidelines[8].

These three standards are used widely in the voluntary market but they have their own strengths and weakness with respect to application to U.S. residential energy efficiency offset programs. The team selected VCS as the offset standard that is the strongest and most applicable to a DCOI energy efficiency project. It is important to summarize how a carbon offset project cycle works before discussing the strengths and weaknesses of the three offset standards. An offset project cycle consists of the following:

1. Project design by project developer
2. Validation by primary auditor
3. Registration by standards board
4. Monitoring by project developer
5. Verification by primary/secondary auditor
6. Certification and issuance of credits by standards board

DCOI will be the project developer for the residential energy efficiency project and will design the project implementation and finance. The project specifications must be validated by a third party entity that acts as an auditor. Next, DCOI will register the project with the VCS board as an energy efficiency offsets project. Once the project is implemented, DCOI must monitor the project and reports its benefits including energy savings, monetary savings, and community co-benefits. A third party entity, which may be the same validation auditor or a different entity depending on the standard, will audit and verify the reported benefits. If the results are correct, then the VCS board will certify the project as a VCS project and issue offset credits to DCOI [8].

3.1 Advantages of Using VCS

The following table summarizes the main differences between the three standards. The price of offsets under each standard is different because of the project types that dominate each standard. CDM projects are large scale and international and a high price for offsets is reflected in the market.

Table 1. Carbon Offset Standard Differences[8]

Standard	Market Share	Additionality Tests (relative to VCS)	Third Party-Verification Required	Separation of Verification and Approval Process	Registry	Project Types	Price of Offsets ($/mtCO2e)
VCS	New; Likely to be large	N/A	Yes	No	Planned	All	6-20
CDM	Large	Same Requirements	Yes	Yes	Yes	All	18-39

GS	Small	More Requirements	Yes	Yes	Planned	EE, RE	13-26

The main advantages of using the VCS for a DCOI residential energy efficiency program is less administrative hurdles, lower administrative costs, more flexibility, and more applicability in comparison to the CDM and the GS. These are discussed further below [8, 9]:

- VCS does not require an additional approval process for evaluating offset standards. A single party is allowed to conduct both verification and validation of the project. Both advantages can potentially reduce administrative costs for the project [8, 9].
- The additionality tests for VCS are either project-specific or performance-based. The project-specific tests grant flexibility to additionality tests depending on the type of the offset project. DCOI can test an energy efficiency project's additionality against regulatory and investment barriers and common practice tests. If the project is designed for the sole purpose of complying with regulations and applicable policies, it cannot be counted as additional. The investment test would assume the project is considered additional if the returns without offset revenue are too low. DCOI will have to determine the minimum IRR for implementing an energy efficiency project. The project would also be considered additional if "*it succeeds in overcoming significant non-financial barriers that the business-as-usual alternative would not have had to face*." [8, 9] The lack of energy efficiency know-how and institutional barriers in Durham is sufficient for DCOI's program to pass this test. For the common practice test, the project will employ commonly used technologies for non-additionality [8, 9].
- Performance-based additionality tests address weaknesses of project-based tests. Performance-based tests establish a baseline threshold for technologies or processes that is more objective and quantifiable to determine additionality. Offset projects that rely on these tests are associated with easier administrative procedures and lower administrative costs. Additionally, a project using performance based additionality test can be scaled up more easily because the criteria will already have been established at the beginning of the project. Thus, DCOI will be able to expand the number of houses in which the project is implemented at a later stage and those houses will still be additional if they meet the performance standard [8, 9].
- Baseline requirements are VCS are very flexible and encompass VCS, CDM, and California Climate Action Registry methodologies. Under VCS, baselines can be measured using project-specific and/or best practice approaches. DCOI will find standard methodologies or original

customized baseline methodologies more flexible and suitable for its scope. The options of using more than one methodology mitigate the weakness of using one approach. The approval process of new methodologies is similar to that of GS, where the new methods have to be approved by a board [8, 9].

- VCS accepts any offset project except new hydrochlorofluorocarbons-22 facilities. Residential energy efficiency projects fit perfectly under VCS because the methodologies are scaled and targeted for projects of this size and goal [8, 9].
- VCS's start date is defined as "*the date on which the project reached financial closure*". For example, DCOI offset project is considered to start after they used their investment fund. This definition is more concrete and makes the savings calculations easier [8, 9] .
- Under VCS, CDM pre-registration credits are allowed and no further additionality proof is required. This can reduce project costs if DCOI want to move credits between projects [8, 9].
- VCS has to be in compliance with environmental laws. The project document must also address and incorporate the results of stakeholder consultations and an appropriate method for continued communication with them. These co-benefit requirements of VCS will ensure that DCOI's project bring community benefits in addition to monetary benefits. DCOI can reach out to a larger portion of the community regarding energy efficiency and other energy related issues [8, 9].
- VCS offsets trade at a range of 6 to 20 $/mtCO2e. The prices are comparative to those for CDM and GS. VCS prices depend on the project type, so an energy efficiency project will trade at a certain price [8]. Less price volatility will mitigate risk for DOCI during the project design phase
- VCS has outsourced a number of tasks such as project and methodology approvals. Outsourcing tasks to specialists can potentially increase the quality of work in those areas[8].
- VCS can potentially be applied to projects across a wide range of residential buildings and income groups. This gives DCOI the flexibility in terms of homes of Duke employees that are more likely to benefit from energy efficiency retrofits without being constrained by building requirements [8].
- According to the World Wildlife Fund report, VCS is "*broadly supported by the carbon offset industry and will likely become one of the more important standards in the market because VCS is able to balance the complexity and strictness of certain standards with the flexibility and easy implementation rules from other standards*" [8].

3.2 Drawbacks of the Clean Development Mechanism

The major drawbacks of CDM as compared to VCS are that it applicability and flexibility for U.S. energy efficiency projects and also has higher administrative hurdles and costs associated with its process. This is elaborated in points given below:

- The CDM targets large scale projects implemented by developed countries in developing countries to acquire carbon offsets while bringing development co-benefits [8]. Projects under the CDM are usually large scale power generation or forestation projects. From a policy and scale perspective, the CDM may not be a good fit for small U.S. projects, such as local community projects like residential energy efficiency retrofits [8].
- The additionality tests for the CDM are all project-specific. The problem with the project-based additionality testing is that they are subjective. These tests depend on a project's internal rate of return (IRR) which is determined by the developer [8]. An additionality demonstration is thus dependent on the project developer's desirable rate of return. It is very challenging to examine whether the provided IRR is too low or too high for a project.
- According to the World Wildlife Fund report, the number of project that has been rejected by CDM Executive Board has increased recently. Some developers have brought to attention that project assessment differ between different board decision makers [8].
- Third party entities that perform validation and verification for the CDM are hired by project developers, such as DCOI. The auditors offer to provide low cost services in shorter time frames. Therefore, considerations for project integrity have been discussed and questioned recently [8].

3.3 Drawbacks of the Gold Standard

The GS is similar to the CDM in its inflexibility and high administrative hurdles and costs. Although the GS can be applied to residential level energy efficiency projects, its weaknesses make it a poor choice compared to the VCS.

- The GS employ an additional approval process for evaluating voluntary offset standards, which imposes an additional administrative cost to the project [8, 10, 11].
- The additionality tests for the GS are all project-specific. The testing can be subjective, similar to that of the CDM. A GS projects has to pass voluntary and certified emission reduction additionality testing in addition to CDM [8, 11]. This will lead to an increase in the administrative costs for GS projects.

– The GS's stakeholder process and additionality testing for small scale projects like residential energy efficiency are not very well defined. In other areas, the GS documentation is very complex and sets demanding requirements. The validation and verification processes are very time and resource intensive [8].

The following table summarizes the requirements for additionality, baseline, and starting date and crediting period for the VCS, the CDM, and the GS.

Table 2. Requirements for the Carbon Offset Standards from SEI Report[8]

Requirements

Standard		**VCS**	**CDM**	**GS**
Additionality	Project-Specific or Performance Standards	Project-specific or Performance-based	Project-specific	Project-specific
	Determination of Additionality	Regulatory surplus, implementation barriers, investment barrier or technological barrier or institutional barrier, and common practice	Regulatory surplus, investment analysis, barrier analysis, common practice, impact of CDM registration	Same as CDM with additional certified and verified emission reductions
Baseline	Determination of Baseline	VCS, CDM and CCAR approved methodologies; performance standards of best practice approaches allowed	Project specific and performance standards	CDM approved methodologies or approval by GS Technical Advisory Committee
	Methodology Approval	New methodologies contained in VCS approved GHG programs do not require further approval process. All other new	New methodologies are reviewed and commented on by the CDM Methodology Panel with the final decision being made	CDM approved methodologies or approval by GS Technical Advisory Committee

		methodologies are accepted by the VCS after undergoing a review and approval process conducted by two VCS accredited independent verifiers	by the Executive Board	
Crediting Period	Crediting Periods Fixed/ Renewable	3x10 yrs	10 yrs / 3x7 yrs	10 yrs / 3x7 yrs
	CDM Pre-registration Credits	Allowed without further additionality verification	Not allowed	Allowed with applicable conditions

4.0 Data Analysis and Results

4.1 The City of Durham Project

With Duke University's aim to generate carbon offsets from energy efficiency retrofits in residential buildings, we investigated similar projects that were or are being implemented in and around Durham to obtain a perspective of their scope and costs and benefits. Neighborhood Energy Retrofit Program (NERP) and Home Energy Savings Program (HESP) are two such programs that were started by the City of Durham's Office of Sustainability to reduce residential energy consumption by energy efficiency retrofits and education of homeowners about energy conservation [12, 13]. In this report, we focus on the evaluation of energy consumption data from the retrofitted houses and determining the resultant energy savings and emission reductions.

The City of Durham's office recruited houses through an application process and screening criteria based on preliminary energy audit and home inspection. Close to 700 homes in 14 neighborhoods were recruited under the two programs [14, 15]. The programs included energy efficiency retrofits as well as do-it- yourself energy upgrade workshops and door-to-door canvassing [12, 13]. The retrofits performed under the project are listed below [12]

- Air sealing of ductwork, attic and ground floors
- Installation of programmable thermostats
- Attic insulation enhancement

- Installation of Water saving shower heads and faucet aerators
- Installation Carbon monoxide detectors

The funding for NERP and HESP was obtained through two separate grants: US Department of Energy's Energy Efficiency and Conservation Block Grant program and the Environmental Protection Agency's Climate Showcase Communities Grant Program [12, 16].

The programs were set to target neighborhoods and communities instead of just teaching individuals about energy efficiency and sustainability. Another benefit of implementing the program at a large scale was greater economies of scale that could be achieved in terms of labor as well as material requirements [16].

4.1.1 Project Implementation

The City of Durham's office hired outside contractors to undertake the retrofit work through a bidding process [15]. A contractor assessed each site by walking through and checking the condition of the house, insulation, and shower heads. The contractor was able to gauge the retrofits that were required with the help of the initial inspection and estimate the final reimbursement. Combustion testing was performed at some houses before and after the retrofits. The contractors also provided carbon monoxide detectors to certain houses that had inadequate venting for their gas/combustion appliances. In addition, the contractors also performed blower door tests to assess the air tightness of houses. The appliances that were replaced with more efficient alternative, such as shower heads and faucet aerators, were destroyed or disposed of in a safe manner. After work at a house is completed, a city inspector will approve the site [16].

The cost of retrofits was shared by the City of Durham and the house owner. The level of cost sharing varied form one phase to other. The following table summarizes the cost estimates for each phase of the project.

Table 3: Costs of Retrofit [16]

Phase	Total Cost Per Home	Cost Shared By Owner	Cost Shared by City
1	$2000	$200	$1800
2	$1500	$300	$1200
3	$2000	$400	$1600

The City of Durham is planning another phase of the project under which they will undertake further retrofits including cross-base insulation and water heater replacement. Also, the electricity usage data 1 year prior to the retrofit and 2 years after the retrofit will be collected from the homeowners. Contractors also have to follow more stringent regulations with equipment disposals [16].

4.1.2 Data

Data collected as part of the retrofit programs was obtained from the City of Durham with the help of David Cooley at the Duke Carbon Offset Initiative. The raw data was provided to us with initial and final R-values, a thermal resistance measure of buildings, technical data of the house (number of rooms, age, etc.), electricity and natural gas billing dates, electricity and natural gas consumption, and date of the retrofit. Electricity and natural gas data was obtained by the City of Durham through homeowner cooperation and indirectly through the electricity and natural gas providers (Duke Energy and PSNC). Out of the 700 retrofitted homes, the City of Durham was able to provide energy data for 45.

4.1.3 Method

The carbon offset standard the team chose to use is the Verified Carbon Standard (VCS). It is a better fit to measure energy savings and emission reductions from small-scale building retrofit projects than some of the other standards available. The main purpose of this analysis is to examine how much potential emission reductions can be achieved, so we will follow the general procedures for determining energy reductions given under the Emission Reductions And Monitoring Parameters section in the VCS methodology [9].

The City of Durham project falls under Category A of the VCS methodology which includes efficiency enhancement of the building envelope and central heating/cooling and appliance replacement [9]. The data available to us is most suitable for the adjusted consumption approach of emission reductions calculation. This approach uses pre and post retrofit energy consumption that is corrected for changes in energy demand over time and for seasonal variations through the use of heating and cooling degree days [9]. The grid emission factor is obtained from the US Environmental Protection Agency and the natural gas emission factor is obtained from the US Energy Information Agency [17, 18] [19, 20].

Emission reductions were calculated as follows:

$$ER_{yElec} = \sum_{i=1}^{I} (Elec_{b,i} * CDDCF_y - Elec_{p,y,i}) * Elec_{CO2} \quad (1)$$

$$ER_{yGas} = \sum_{i=1}^{I} (NG_{b,j} * HDDCF_y - NG_{p,y,i}) * NG_{CO2} \quad (2)$$

Where:

ER_y = Emission reduction in year y in metric tons CO_2e/yr

$Elec_{b,i}$ = Electricity consumed in period prior to project implementation for dwelling i in kWh

$Elec_{p,y,i}$ = Electricity consumed by the project in period y for dwelling i in kWh

$CDDCF_y$ = Cooling degree days correction factor for period y

$HDDCF_y$ = Heating degree days correction factor for period y

$NG_{b,j}$ = Natural gas consumed in period prior to project implementation for dwelling i in therms

$NG_{p,y,i}$ = Natural gas consumed by the project in period y for dwelling i in therms

$Elec_{CO2}$ = Grid emission factor in tCO_2e/kWh

NG_{CO2} = Natural gas emission factor in $tCO_2e/therms$

I/i = Number of dwellings

y = A number of months during the project's crediting period

The Heating Degree Day correction factor shall be calculated as follows:

$$HDDCF_y = \frac{HDD_y}{HDD_b} \qquad (3)$$

HDD_y = Heating degree days for period y after the retrofit

HDD_b = Heating degree days for the same period before the retrofit

The Cooling Degree Day correction factor shall be calculated as follows:

$$CDDCF_y = \frac{CDD_y}{CDD_b} \qquad (4)$$

CDD_y = Cooling degree days for period y after the retrofit

CDD_b = Cooling degree days for the same period before the retrofit

The calculation for emission reductions under VCS includes an electricity correction factor, which is used to update the baseline electricity consumption if there are decreases in electricity demand over time [9]. The team did a review of recent electricity consumption in North Carolina through the US Energy Information Administration's database and found that consumption has increased in the residential sector. Thus, the electricity correction factor is omitted in our calculations [17, 21].

The values of heating and cooling degree days for the given months were obtained from the state Climate office of North Carolina. The following two stations located in Durham were used as sources [22]:

- North Durham Water Reclamation Facility (DURH Econet) - Latitude: 36.02896, Longitude: -78.85851

- Durham (COOP, 312515) - Latitude: 36.0425, Longitude: -78.9625

In addition, VCS procedures accounts for leakage from continued operation of appliances and leakage from improper disposal of refrigerators or air conditioners [9]. The City of Durham project administrators confirmed with us that the replacement equipment is disposed of and there will be no leakage problems.

4.1.4 Results

The VCS methodology is adopted to calculate the emission reductions for electricity and natural gas consumption. The cooling degree days correction factor and the heating degree days correction factor for each house are specific on a house-to-house basis and are calculated for the same months prior to the retrofit and after the retrofit (equations 3 and 4). The same calculations are performed for emissions reductions (equations 1 and 2). The dataset does not have complete data for a year prior and a year after the retrofit is completed. Also, the period of months before and after the retrofit is not the same for all the houses. For example, one house may have 11 months of energy data before and after the retrofit and another house may only have 3 months of energy data before and after the retrofit. As long as the house had electricity and/or natural gas consumption data for more than one month before and after the retrofit, emission reductions were calculated. In order to remove the difference in the number of months for which the reduction was calculated, the average reduction per month was calculated for each house first and then for all the houses.

Another issue with the methodology using the given data set is that some houses use electricity and some others use natural gas. Most of the energy in a house is used for space cooling and heating. We assume that the cooling load is provided by electricity while the heating load is provided by natural gas. None of the houses have sufficient data for using both electricity and natural gas.

Statistical Analysis

The raw data analysis shows that the sample distribution is not normal, thus a logarithmic transformation was used to transform the data into a normal distribution. The preliminary statistical analysis was performed using log transformed data to determine the statistical significance of the difference in electricity use before and after the retrofit and the confidence interval for the difference. The table below gives the results of the statistical analysis of the dataset provided to us by the City of Durham.

Table 4: Statistical Analysis Result

Descriptive Statistics	Raw Data	Transformed Data (See description below)
Number of Observations	45	25
Average Monthly Energy Consumption Before (KWh)	949.32	969.72
Average Monthly Energy Consumption After (KWh)	809.40	856.48
Transformation	Log	Log
Paired t-test P Value	0.1097	0.0022
95% Confidence Interval (ratio)	-	[1.09 – 1.50]
Average Monthly Saving (KWh/house)	139.92	113.13
95% Confidence Interval	[-80.68 – 360.52]	[26.25 – 200.22]

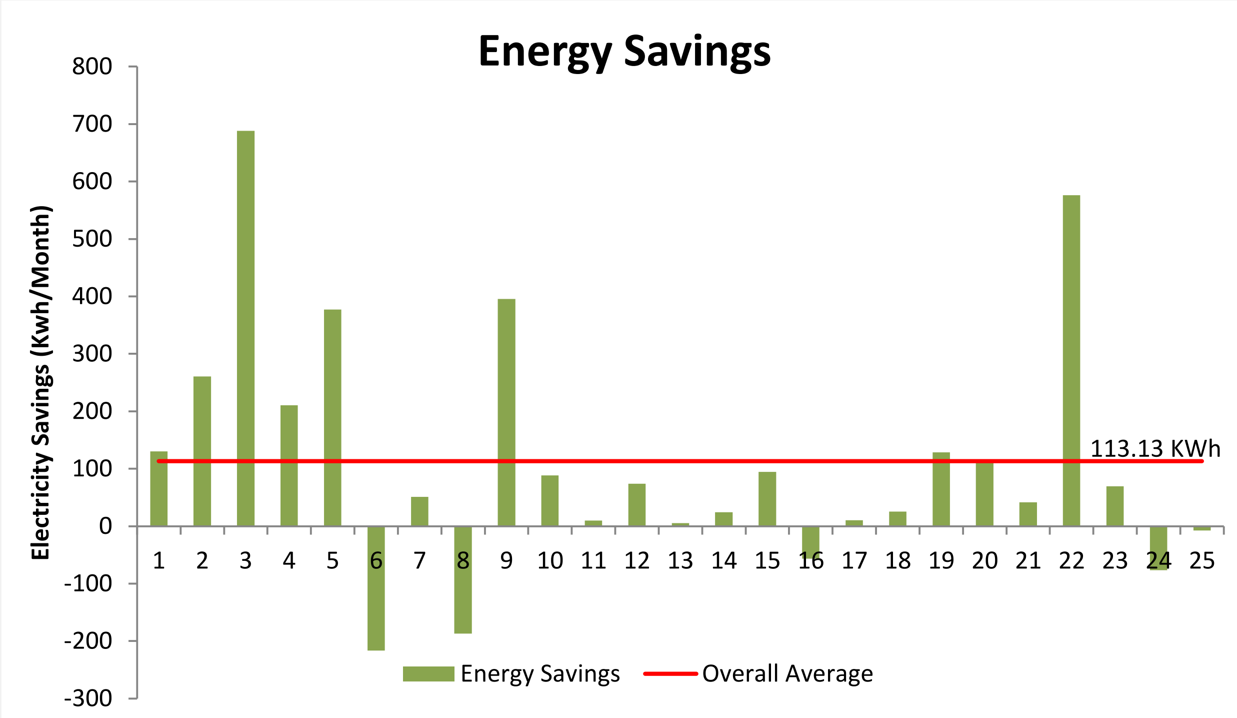
As shown in the table above, the raw data analysis yielded a p value above 0.05 indicating that the difference between the average monthly energy consumption of a house before and after the retrofit was not statistically significant. The team then cleaned the data and removed the houses which had less than six months of energy data available. This enabled us to analyze a smaller but more robust set of data and we again ran the statistical tests. The results of cleaned data gave a p value of less than 0.05 indicating a significant difference between per and post energy consumption. The average monthly energy savings per house was determined to be 113.13 KWh with a 95% confidence interval of 26.25 – 200.22 KWh.

Table 5: Average monthly energy savings and emission reductions

Energy Data	Number of households	Consumption reduction per house	Emission reduction per house (mt/month)	Bill savings per house ($/month)
Electricity	25	113.13 KWh/month	0.053	10.51
Natural Gas	7	10 therms/month	0.05	9.91

Table 5 summarizes the reductions and savings achieved by the City of Durham energy programs. The details for each house are in the appendix of this report. There is a total of 25 houses that use electricity and a total of 7 houses that use natural gas. The energy consumption difference of each house can be seen in the chart below with the average saving shown by the red line.

Figure 1: Energy Saving Per Month



Out of those 25 houses, 20 houses had positive reduction in energy consumption while 5 houses showed increase in consumption after retrofit. Given the average monthly consumption before retrofit of 970 KWh, the houses show an average of 11.60% reduction. Using the 2013 residential rates of Duke Energy and PSNC, a house saved approximately $10.51 per month on its electricity bill and approximately $10 on its natural gas bill [23, 24].

Considering a saving of $10.51/month on utility bill and an investment of $400 (The highest cost portion shared by the house owner in City of Durham project) by the house owner, the payback period comes out to be 3.17 years. The home owners are able to recover their financial costs in slightly more than 3 years. There are also un-valued economic costs that include environmental and house-value externalities that are not calculated in this analysis. Emissions reductions will bring positive benefits to air quality and health. Retrofitting the house will increase the value of the property [25].

Carbon Price Analysis

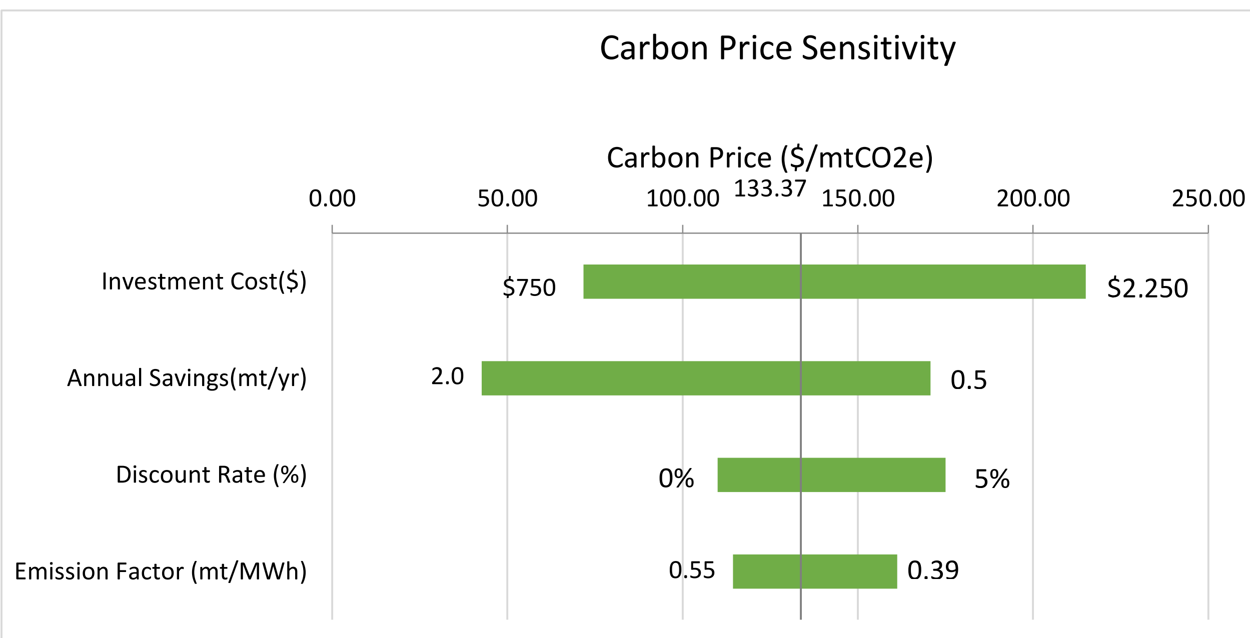
Another important aspect of the analysis is to determine the necessary carbon price needed to invest in a home energy savings project. Our analysis enables us to calculate a carbon price per house and for all the houses using the initial investment cost and the amount of carbon emissions reduced. Using the data and results available to us, we also conducted a sensitivity analysis for the carbon price which resulted in the tornado chart given below. Table 6 here illustrates the costs, carbon emission reductions, and carbon prices for the City of Durham project.

Table 6: Investment Cost and Carbon Prices

Parameter	Value
Average electricity saving per year (KWh/per house)	1357.56
Average total cost of retrofit	$1395.75
Average emission reduction per year (mt/house)	0.64
Discount rate	2%
Project life	20 years
Estimated carbon price ($/metric ton)	$133.37

We have used a discount rate of 2% here based upon literature review done on carbon pricing. The table above shows what the carbon price will be if the retrofit cost $1396 and generated an annual return of approximately 1kWh per dollar invested. Since, the cost of retrofit and energy saving can vary greatly from one house to another we conducted a sensitivity analysis for carbon price with respect to the cost of retrofit, emission reduction, discount rate and emission factor. The results are shown in the chart below.

Figure 2: Carbon Price Sensitivity



As shown in this chart, investment cost and emission reduction have the highest impact on carbon price while emission factor and discount rate tend to vary it within a smaller range. The annual savings depend highly on the energy savings resulting from the retrofit. The City of Durham project had average annual saving of 0.64 metric tons which resulted in a carbon price of $133.37 per ton. The City of Durham data showed the maximum annual emission reduction of more than 3 metric tons. To be conservative the team chose to conduct the sensitivity analysis for a maximum reduction of 2 metric tons per year. If the savings can be increased to 2 metric tons per year the carbon price decreases significantly to below $50 per ton.

4.1.5 Conclusion

Using the VCS methodology, we find that the City of Durham energy projects result in energy consumption and emissions reductions as well as monetary savings. The average energy saving per house was determined to be 113.13 KWh per month. The average natural gas consumption decreased by 10 therms per month for each of the 7 houses after the retrofits. The energy savings from electricity translated to emission reduction of 0.053 metric tons per month per house and bill saving of $10.51 per month. Average emission reduction of 0.64 mtCO_2e per year and average investment cost of $1396 yielded a carbon price of $133.37 per metric ton. However, this project also had several community and social benefits that could not be incorporated into financial evaluation.

The results demonstrate that the energy programs taken by the City of Durham are effective in reducing energy use and bring monetary savings for the participants in its scale. Emission reductions achieved through such a program and calculated from VCS methodology can be registered for carbon credits. The credits can be used to achieve DCOI's goal of achieving carbon neutrality.

5.0 Comparative Programs

There are a large number of residential programs currently in the market that specialize in obtaining energy reductions through home weatherization and retrofitting. The efficiency programs can vary in scale from neighborhood-sized to state-wide. Many of the programs are funded federally through mechanisms such as the American Recovery and Reinvestment Act (ARRA). The U.S Department of Housing and Urban Development website states that its national program has been granted $600 million under ARRA in order to make communities more energy efficient [26].

We have now determined the effectiveness of City of Durham's program in achieving energy savings and the related costs. The next important step for the study is to compare the results from our data analysis to results from other energy efficiency programs across the country. We have collected and summarized some of the neighborhood and city sized programs to compare their results with that of Durham's. The main indicators used for comparison are energy savings per dollar invested (kWh/$) and GHG emissions reductions per dollar invested (mtCO2e/$). The conversion between the reduced energy consumption and reduced GHG emissions is made using state specific emission factors. The amount of GHG emissions dependent on power generation is specific to the resource mix of each state and is taken into account in the study. The emission factors are obtained from eGRID2012 [27].For a few of the programs, direct energy savings is not available. However, we are able to calculate the energy savings using available monetary savings from bills and state-specific residential retail electricity rates [28].

The following are summaries of several community and city based energy efficiency programs:

The Chapel Hill Worthwhile Investments Save Energy (WISE) homes and building program is a community level energy retrofit program federally funded by the ARRA. Under the program, home owners can receive $150 towards a comprehensive energy assessment. The program managers state that qualifying homes that can achieve an estimated 10-15% energy savings or more can receive another $1500 for home energy efficiency improvement. They have five pilot projects with average projected energy savings of 32.8% [29]. The detail information on these pilot projects is given in the table below:

Table 7. Summary Costs and Savings from Chapel Hill EE Program

House type	Total Cost	**Estimated Saving/Yr**	**Estimated Reduction in Energy Use**	**Project payback time with WISE subsidy**
1927 2-Story Home	$7,043	$465/8,388kWh	47%	8 years
1952 1-Story Home	$10,740	$585/26,400kWh	41%	10 years
1967 2-Story Home	$5,175	$400/3,500kWh	15%	7 years
1982 1-Story Home	$4,800	$500/5,200kWh	20%	5 years
1998 2-Story Home	$9,960	$550/13,600kWh	41%	12 years
Average	$7543.6	$500/11,418kWh	32.8%	8.4 years

The State of Rhode Island has an energy efficiency program conducted by the Narragansett Electric Company. We focused our analysis specifically on in-home services of the residential program. The utility provides comprehensive energy audits, energy education, and installations of low cost energy efficiency measures at no direct cost for program participants. The company's website states that the program will subsidize up to 75% of the cost for any needed insulation and provide rebates of $100 – $450 to replace inefficient refrigerators. It will also provide subsidies for the installation of other major retrofits and make an up-front payment for any unsecured loans for the interested participants. For the year 2005, program implementation expenses amounted to a total of $2902.20 and the program achieved an annual energy saving of 4130 MWh with 4291 participants [30].

Clean Energy Works Oregon Program (CEWO) is another non-profit program providing energy efficiency retrofits to residents of Oregon with the help of diverse financing mechanisms, technical expertise and partnerships with local utilities and agencies. The program publishes a summary of impacts measured from October 2012 through June 2012 on their website. According to the program summary, 2,200 homes were retrofitted between October 2012 and June 2012 which also led to the creation of 300 jobs and $26 million in economic development. CEWO also estimates that on average a retrofitted house saves $280 annually on its energy bills. The average cost for retrofitting per house is $2000 [31].

In addition to the programs discussed in this section, the U.S. Department of Energy runs a Better Buildings Neighborhood Program under its Better Buildings Initiative. The agency partners with various local and state governments to implement home energy savings or retrofit programs. The number of residential building upgrades has increased to more than 35,000 since 2010. Through this program the DOE aims to reduce the energy consumption by 15% to 30% with a saving of approximately $65 million on the energy bills per year [26]. Some of the programs started in different states through this initiative are discussed below:

a. Alabama is developing a long-term program in collaboration with local communities and energy departments in other states to implement and energy saving measures in cities like Birmingham and Huntsville. The program will involve providing financial assistance for energy efficiency retrofit, community education and outreach [32].
b. Colorado is implementing programs in Boulder and Eagle County through the Energy Smart initiative [33, 34].
c. The Connecticut Energy Fund is a grant established by the state of Connecticut to carry on energy efficiency programs [35]. One particular study investigated the impact of the 2007 Weatherization and Assistance Partnership Program (WRAP) on its 92 participants. The report states that the company provided weatherization measures for customers with gross income at

or below 60% of the state median income. The program cost $230,000 and achieved 20,360,458 MWh of overall savings [36].

d. The state of Maine runs the Efficiency Maine Home Energy Savings Program that works with residents to reduce their energy consumption by retrofitting and weatherization. Information provided by the program states that an average Maine home upgrade will cost $8,800. The program provides loan options for participants to pay off upgrade costs on a 15-year installment plan. Energy saving is stated to start immediately in year one with the estimated saving in first year to be $705 and savings in subsequent years to be $1,292. Home owners are expected to save an average of 40% a year on their energy bills [37].
e. Omaha and Lincoln, the two largest cities in Nebraska, have implemented energy efficiency programs and made them more accessible to residents. The reenergize program has set the goal to achieve improve energy efficiency by 25% in buildings [38].
f. The government of Philadelphia and certain non-profit organizations have become partners to push for efficiency programs to reduce energy use in the city. EnergyWorks, a comprehensive energy solutions program, has been created to lead the initiative for residential and commercial/industry buildings [39].
g. As of March 31, 2012, contractors in Phoenix, Arizona had completed 7 single-family home retrofits for a 3-year energy efficiency program in collaboration with the city government, universities, and the state’s largest electricity provider. The 7 homes are estimated to have a total savings of 19,133 kWh/yr [40].
h. The city of Seattle put forward a proposal to encourage efficiency upgrades for residential homes in June 2012. Community Power Works has been carrying out the goals in the proposal and making achievements in energy and GHG reductions [41].
i. The Southeast Energy Efficiency Alliance (SEEA), developed in 2007, is a consortium of 13 cities across eight states and one territory. Each city in the SEEA has developed and approached energy efficiency in a unique and different way to match their specific requirements and reach their goals [42]. We used information from the programs in Carrboro, Charleston, Charlottesville, Decatur, Hampton Roads, Huntsville, Jacksonville, Nashville, and New Orleans for the comparative study.
j. Even though University Park, Maryland has only 2,138 citizens, the town has decided to create the Small Town Energy program (STEP-UP) to increase awareness and accessibility to energy

savings programs. The Floyd family gave a testimony on the cost and savings of retrofitting their 1,424 square feet home [43].

The following table summarizes all the input parameters including savings, cost, and number of participants and ROI outputs for each of the program described above.

Table 8. Summary of Parameters used for Comparative Study

Program	Annual Energy Savings	Annual Monetary Savings	Project Cost	Participants	ROI-energy reduction	ROI-GHG reduction
	kWh/house	$/house	$/house	# of house	kWh/$	mtCO2/$
Durham, NC	1358	126	1396	25	0.97	0.00046
Chapel Hill, NC	11418	1163	7544	5	1.51	0.00071
Carrboro, NC	3219	328	4101	28	0.78	0.00037
Charleston, SC	5481	637	6647	106	0.82	0.00031
Charlottesville, VA	5455	545	8052	861	0.68	0.00031
Decatur, GA	8449	866	9534	54	0.89	0.00052
Hampton Roads, VA	13864	1385	12274	62	1.13	0.00051
Huntsville, AL	3662	397	6288	522	0.58	0.00027
Jacksonville, FL	5908	670	8643	206	0.68	0.00037
Nashville, TN	4427	444	5772	430	0.77	0.00037
New Orleans, LA	7272	637	9916	72	0.73	0.00038
Birmingham, AL	5800	629	750	131	7.73	0.00365
Boulder, CO	1700	188	1203	5072	1.41	0.00111
Eagle County, CO	2890	320	2593	1439	1.11	0.00088
Rhode Island	44891	6644	2902	4291	15.47	0.00628
Connecticut	20360	3471	2500	92	8.14	0.00213
Maine	18627	2721	1063	875	17.52	0.00398
Portland, OR	2902	280	2000	100	1.45	0.00024
Omaha, NE	20445	1783	3500	101	5.84	0.00423
Philadelphia, PA	6189	764	3849	1082	1.61	0.00083
Phoenix, AZ	2733	280	2202	7	1.24	0.00061
Seattle, WA	3129	266	3769	359	0.83	0.00011
University Park, MD	4504	563	4320	92	1.04	0.00058

Summary Statistics

The following table provides the summary statistics of the different parameters used to make comparisons between the City of Durham program and all the other energy efficiency programs mentioned in this section of the study.

Table 9. Summary of Descriptive Statistics for Parameters and ROIS

Summary Statistics	Energy Savings (kWh)	Monetary Savings ($)	Project Cost ($)	Participants (number of households)	Energy Reduction ROI (kWh/$)	GHG Reduction ROI (mtCO2e/$)
Mean	8899.30	1091.68	4818.11	696.17	3.17	0.00127
Standard Error	2031.91	305.05	676.41	275.65	0.99	0.00034
Median	5480.57	628.72	3849.00	106.00	1.11	0.00052
Standard Deviation	9744.72	1462.97	3243.93	1321.96	4.74	0.00164
Sample Variance	94,959,472.71	2,140,276.61	10,523,060.14	1,747,580.60	22.51	0.00000
Kurtosis	8.05	9.51	-0.43	7.03	4.41	3.11245
Skewness	2.60	2.92	0.71	2.74	2.26	1.96092
Range	43,533.30	6,517.66	11,524.00	5,067.00	16.94	0.00618
Minimum	1,358.00	126.25	750.00	5.00	0.58	0.00011
Maximum	44,891.30	6,643.91	12,274.00	5,072.00	17.52	0.00628
Sum	204,683.90	25,108.62	110,816.59	16,012.00	72.96	0.02921
Count	23.00	23.00	23.00	23.00	23.00	23.00000

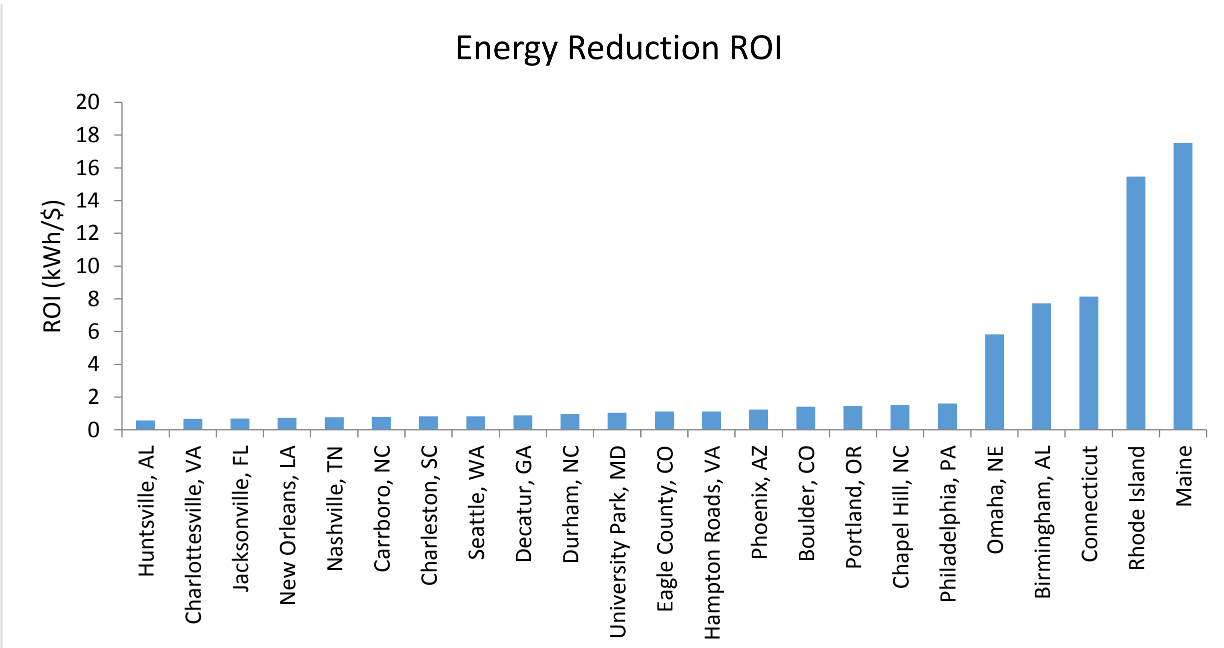
A total of 23 programs are sampled for this specific comparative study. Energy savings, project cost, and number of participants are the input parameters used to calculate the annual energy reduction and annual GHG reduction return on investment per participant values. The monetary savings parameter is calculated from the energy savings value using specific state electricity rates and is included solely as an extra indicator.

Median values are used to report the results instead of mean values because the sample parameters are all skewed. Thus, reporting the mean may not give the true representation of the sample. A positive skew indicates a tail of large values on the probability distribution and a negative skew indicates a tail of small values on the probability distribution.

Analysis

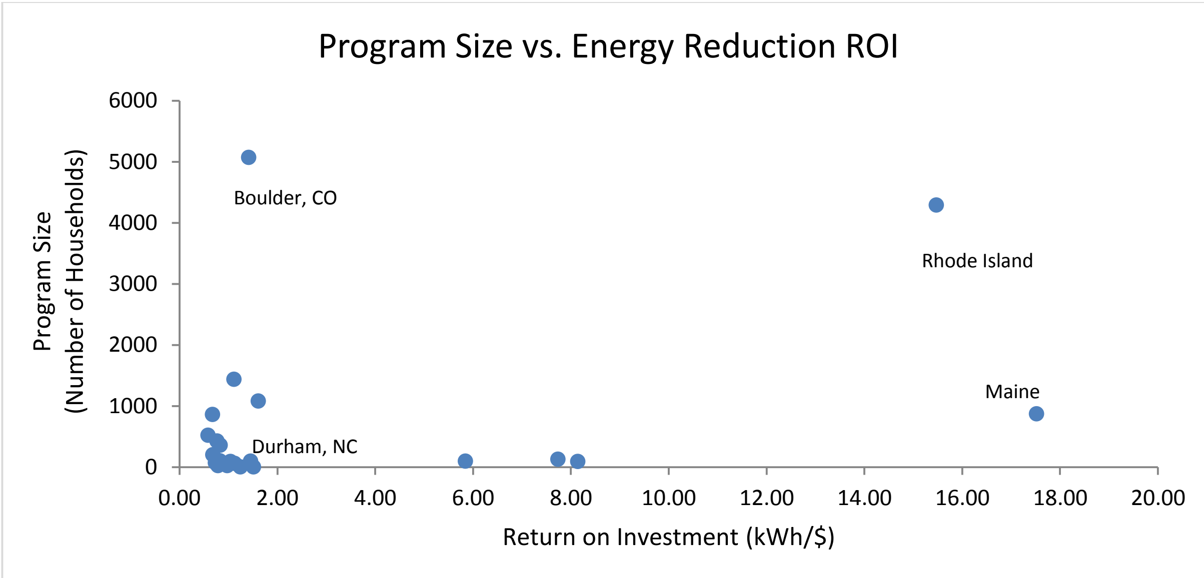
The energy reduction ROI graph illustrates kWh of energy reduction for every dollar invested into an energy efficiency program. The graph shows that the City of Durham has a comparable energy reduction ROI compared to the other 22 programs. The difference between the ROIs of Durham and the best

Figure 3: Ranked Energy Reduction ROI



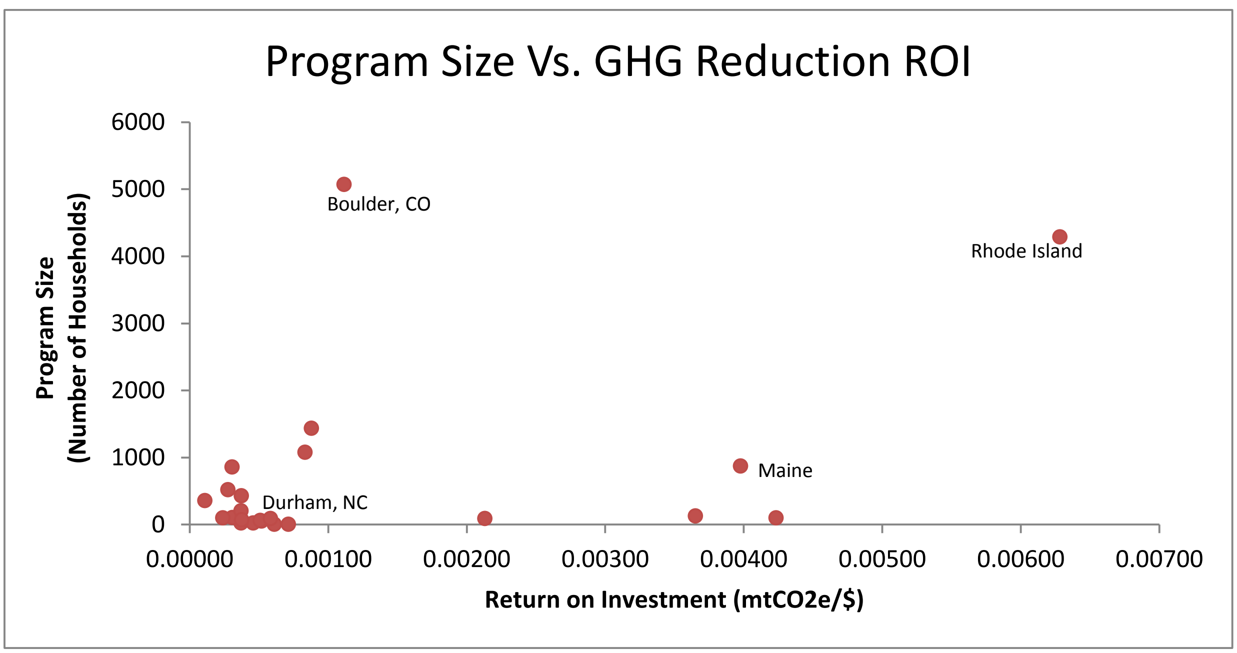
program is 17.00 kWh/$. The Huntsville, AL program has lowest ROI value and the Maine state program has the highest ROI value. Most of the programs with high ROIs are in the Northeast of the U.S., in areas with colder climates than Durham. A colder climate may help the programs target different aspects of energy efficiency. In Durham, the goal of the energy efficiency retrofit is to lower the overall residential energy requirement. In states like Maine and Rhode Island, the programs are targeting space heating, which accounts for the largest part of residential energy use. Targeting space heating may lead to specialization in that area and improve efficiency of implementing projects compared to targeting overall energy use. Colder climates in the Northeast of the U.S. generally has a higher space heating load during winter compared to the other regions of the U.S. Insulation retrofits completed in the Northeast by energy efficiency programs have a large impact on improving heat leakage. Thus, heating demand is lowered and overall energy used for space heating is reduced after energy efficiency retrofits. Insulation retrofits completed in other regions of the U.S. may not lead to similar substantial energy reductions. It will be useful for DCOI to investigate the details of the programs with high returns and incorporate their protocols into the DCOI model.

Figure 4: Scatterplot of Programs Size vs. Energy Reduction ROI



The scatterplot illustrates correlation between number of participants and the energy reduction ROI. Most of the programs are under 1000 participants and can achieve energy reduction ROIs in the range of 0.58 to 17.51 kWh/$. The programs with more than 1000 participants achieve ROIs within that range. The Durham program, with 25 participants, has a ROI of 1.32 kWh/$.

Figure 4: Scatterplot of Program Size vs. GHG Reduction ROI

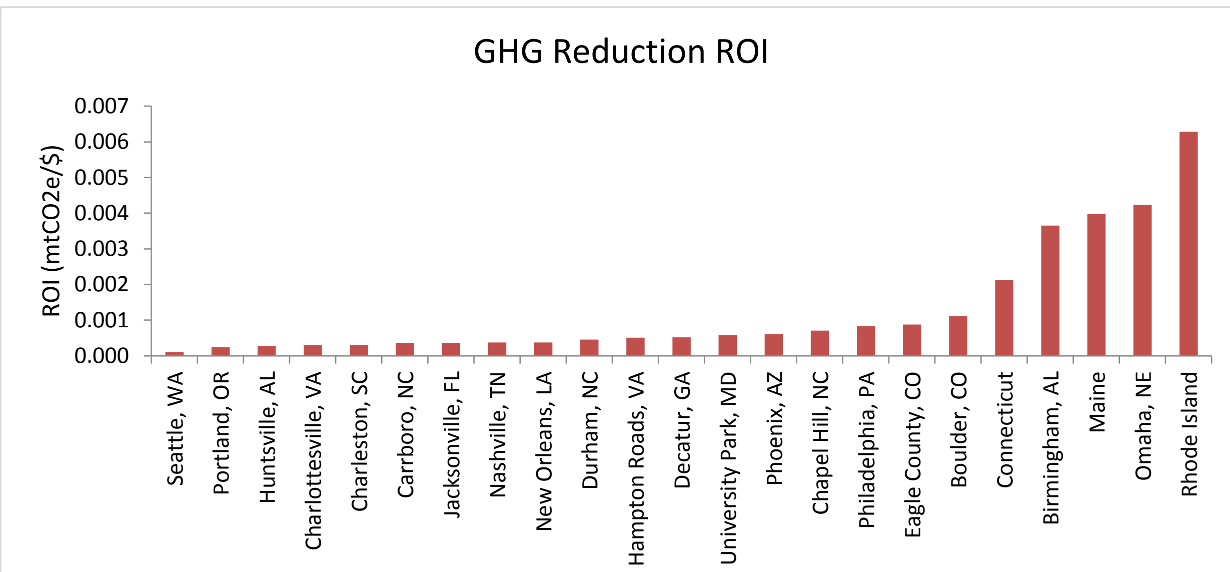


The scatterplot illustrates any correlations between number of participants and the GHG reduction ROI. Most of the programs are under 1000 participants and can achieve GHG reduction ROIs in the range of

0.0007 to 0.004 mtCO2e/$. The programs with more than 1000 participants can achieve ROIs in the range of 0.001 to 0.006 mtCO2e/$. The Durham program, with 25 participants, has a ROI of 0.0006 mtCO2e/$. Again, the discrepancy between the energy reduction ROI and the GHG reduction ROI is caused by the state specific emission factor. The scatterplots illustrates that program size does not influence the returns of the programs. In theory, large programs may benefit from economies of scale to reduce administrative costs and improve efficiencies. Large programs can also benefit from learning by doing through implementation of projects, which may also reduce cost or improve efficiency.

DCOI should investigate into scalability, target specification, market potential, and participant incentives to increase their return on investments.

Figure 5: Ranked GHG Reduction ROI



The GHG reduction ROI graph illustrates how many metric tons of CO2e emissions is reduced for every dollar invested into an energy efficiency program. The graph shows that the City of Durham has a comparable GHG reduction ROI compared to the other 22 programs. The difference between the ROIs of Durham and the best program is 0.00583 mtCO2e/$. Seattle, WA's program so have lowest ROI value. The GHG reduction ROI ranking is not identical to the energy reduction ROI ranking. There is a conversion factor that is causing the two rankings to be different. The energy reduction ROI is multiplied to a state specific emission factor to calculate the GHG reduction ROI. Since the emission factor for each state is dependent upon the state power generation mix, the two ROIs are thus disconnected from one another. For example, Maine has the highest energy reduction ROI of 17.52 kWh/$ but only has a GHG reduction ROI of 0.003975 mtCO2e/$. Rhode Island has an energy reduction ROI of 15.47 kWh/$ but has the highest GHG reduction ROI of 0.00628 mtCO2e/$. Maine's power generation mix has lower emissions compared to that of Rhode Island's, so a large energy savings will lead to a smaller amount of emissions. Thus, Maine's GHG emissions ROI is lower than that of Rhode Island's. States with resource mixes that has higher emissions will benefit more from their investments compared to cleaner states.

6.0 Carbon Pricing

Carbon offset pricing is one of the most important aspects of a DCOI energy efficiency project. We have calculated the break-even carbon offset price of 133.37 $/mtCO2e for City of Durham's program. We can compare this derived carbon offset price to general carbon prices found in regulations, in markets, and in literature. The prices can be compared because they all try to capture the price of carbon to justify the benefits and costs of the markets.

6.1 Carbon Prices Used in Regulation

In 2010, an interagency panel in the U.S. government published a report to assess reasonable social costs of carbon. The purpose of the report was "*to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs*" [44]. The cost estimates are derived from mean cost outputs from three commonly used integrated assessment models. These cost estimates have been evaluated for three levels of discount rates: 2.5%, 3% and 5% [44]. The table below summarizes the yearly average cost estimates for different discount rates.

Table 10. Social Cost of CO_2 (dollars per mtCO2e) [44]

Discount Rate	**5%**	**3%**	**2.50%**
Year	Avg	Avg	Avg
2010	4.7	21.4	35.1
2015	5.7	23.8	38.4
2020	6.8	26.3	41.7
2025	8.2	29.6	45.9
2030	9.7	32.8	50

2035	11.2	36	54.2
2040	12.7	39.2	58.4
2045	14.2	42.1	61.7
2050	15.7	44.9	65

The carbon prices used by Federal agencies are highly variable [44]. The following illustrates some of the carbon price estimates used in federal regulation [44]

- The Department of Transportation (DOT) used a carbon price of $2 per mtCO2e in the establishment of 2011 Corporate Average Fuel Economy (CAFE) standard.
- In a 2008 regulation, the DOT proposed a carbon price of $7 per mtCO2e emissions.
- The Department of Energy used carbon prices between $0 and $20 per mtCO2e in a regulation finalized in October of 2008.
- The U.S. Environmental Protection Agency (EPA) estimated mean values of $40 and $68 per mtCO2e based on 3% and 2% discount rates respectively in its 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases.
- A study by the EPA estimates that the American Clean Energy and Security Act will set carbon prices to $20 per mtCO2e emissions in 2020 and increase prices to $75 per mtCO2e emissions in 2050 [44].
- On March 12, 2013, Representative Waxman, Senator Whitehouse, Representative Blumenauer, and Senator Schatz released a draft of their legislation to price carbon. The discussion draft set a range of carbon prices, $15, $25, and $35 per mtCO2e emissions, for debate and feedback purposes [45].

6.2 Carbon Prices in Trading (Offset and Emission) Markets

- The European Union carbon prices over the past two years have been averaging $20 per mtCO2e emissions [46].
- The nonprofit Investor Responsibility Research Center prices carbon at $28.24 per mtCO2e emissions for 2012. The analysis was conducted through an environmental firm's GHG emissions database [46].
- The World Bank published the State and Trends of the Carbon Market report in 2010 that included carbon prices for allowance, spot, and project-based markets. A wide range of carbon

prices exist in all the markets. The following table summarizes the markets analyzed by the World Bank [47].

Table 11: Summary Table for World Bank Carbon Price Report [47]

2011	Program Abbreviations	Program Names	Value ($)	Volume (MtCO2e)	Carbon Price ($/mtCO2e)
Allowance Markets	EUA	European Union Allowance	147848	7853	18.83
	AAU	Assigned Amount Unit	318	47	6.77
	RMU	Removal Unit	12	4	3
	NZU	New Zealand Unit	351	27	13
	RGGI	Regional Greenhouse $_2$Gas Initiative	249	120	2.08
	CCA	California Carbon Allowance	63	4	15.75
	Others		40	26	1.54
Spot and Secondary Offsets	sCER	Secondary Certified Emission Reduction	22333	1734	12.88
	sERU	Secondary Emission Reduction Unit	780	76	10.26
	Others		137	12	11.42
Project-based Transactions	pCER pre-2013	Primary Certified Emission Reduction	990	91	10.88
	pCER post-2012	Primary Certified Emission Reduction	1990	173	11.5
	pERU	Primary Emission Reduction Unit	339	28	12.11
Voluntary Markets	Of which VCS	Verified Carbon Standard	191	43	4.44
	Of which GS	Gold Standard	86	8	10.75
	Of which CAR	Climate Action Reserve	5	9	7.22
	Of which ACR	American Carbon Registry	24	4	6

- The following are definitions for the units of tradable credits in the market

- Assigned Amount Unit (AAU) is "*a tradable carbon credit representing one mtCO2e emission that is issued between ANNEX I countries (EU, US, Canada, Australia, etc.) under Article 17 of the Kyoto Protocol*"[48].
- Removal Unit (RMU) is "*a tradable carbon credit representing an allowance to emit one mtCO2e GHG absorbed by a removal or carbon sink that is generated and issued by Annex I countries under Article 3.3 of the Kyoto Protocol*"[48].
- Certified Emission Reduction (CER) are "*emission units representing one mtCO2e emissions issued by the Clean Development Mechanism for emission reductions achieved by CDM projects and verified under the rules of the Kyoto Protocol*"[48].
- Emission Reduction Unit (ERU) are "*emission units representing one mtCO2e emissions issued by the Joint Implementation mechanism for emission reductions achieved by JI projects and verified under the rules of the Kyoto Protocol*"[48].

6.3 Theoretical Carbon Prices in Literature

This section discusses the literature review done on carbon pricing. The main points extracted from the review are listed below.

- The Brookings Institute, a nonprofit public policy organization, published a paper on pricing carbon in the U.S. in June 2010. The authors evaluated macro-economic and power sector specific carbon prices using the computable general equilibrium economic modeling approach. The output carbon price is $13 per mtCO2e emissions in 2012 and rises to $25 per mtCO2e emissions in 2030 [49].
- Adam Newcomer and colleagues published a paper that examined the impacts of carbon price on electric power production related emissions. They estimate that 3-10% emission reductions can be achieved by imposing a carbon price of $35 per mtCO2e [50].
- A group of analysts at Resources for the Future released a discussion paper that examines the potential of impacts of carbon pricing on domestic industries. Using a price of $10 per mtCO2e emissions with four modeling approaches, they find that a set of industries will experience adverse impacts in the short term with rebounding in the long term [51].
- In Grainger and Kolstad's paper, they use a $15 per mtCO2e carbon price to investigate the burden on the tax on players in the economy. A carbon emissions policy will have adverse distribution effects at household levels according to the paper [52].

- Hasset and his colleagues published a paper on analyzing the incidence of a U.S. carbon tax with a carbon price of $15 per mtCO2e emissions. They find that "carbon taxes are more regressive when annual income is used as a measure of economic welfare" [53].
- Burtraw and his group investigated the effect of allowance allocation in carbon emission trading markets. They used $25, $38 and $40 per mtCO2e emissions under different approaches and reached a conclusion that an auction does the best at protecting households and preserving asset values for producers [54].
- David Pearce examined the social cost of carbon by compiling marginal costs in literature and calculating a carbon cost using the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) model. He concludes that the UK government's assessment of the cost has been overestimated because of misinterpretation of model outputs used to balance cost and benefits [55]. He concludes that a correct price should be set at a range of $3.6 to $22.5 per mtCO2e emissions. The following is a summary table of the studies he cite in his paper:

Table 12. Summary Carbon Prices from Pearce Paper [55]

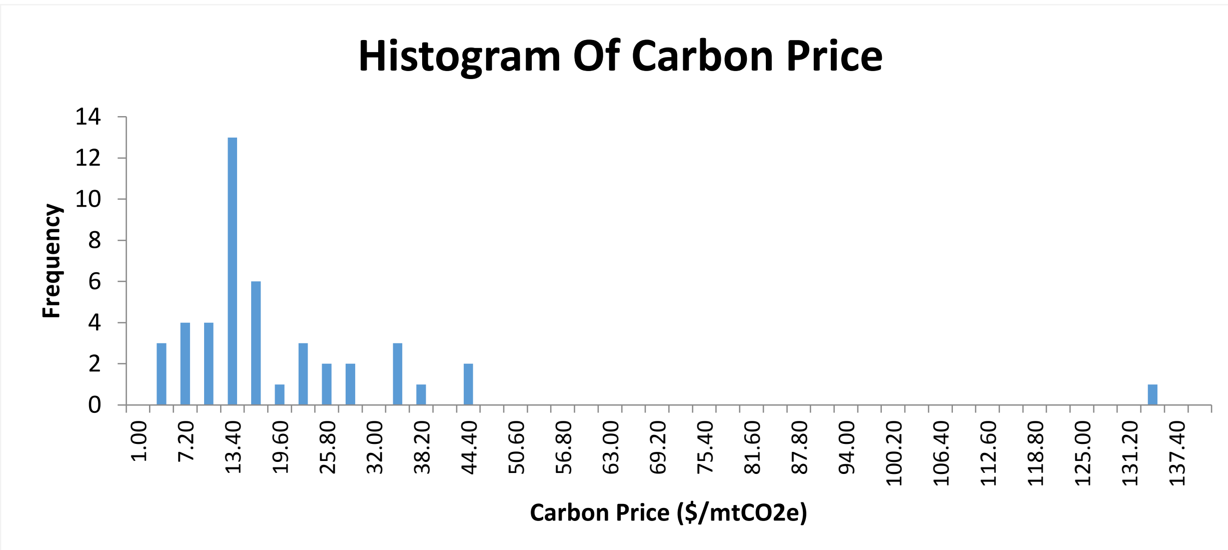
Study Author	Price ($/mtCO2e)
Tol and Downing	19.70
EU	20.00
Tol	20.20
Interagency	24.93
Waxman	25.00
Plambeck and Hope	26.90
IRRC	28.24
Fankhauser	34.20
Burtraw et al.	34.33
Newcomer et al.	35.00
Eyre et al.	36.00
EPA	42.67

- In a study by Richard S.J. Tol, 103 mitigation cost estimates are examined and characterized by the authors. The mean of the estimates for cost studies is $93 with a standard deviation of $203 per mtCO2e emissions. The mean marginal cost for peer-reviewed literature is $50 per mtCO2e emissions. Because of the probability distributions, the median cost estimate of $14 per mtCO2e emissions may be the best estimate [56].

6.4 Analysis

The carbon price obtained from the City of Durham was analyzed with respect to the carbon prices obtained from literature review, market and federal regulations. A histogram of the 45 carbon prices is shown below. This histogram indicates a non-normal right skewed distribution of prices. The calculated city of Durham carbon price is an outlier of the rest of the distribution. Most of the carbon prices are in the range of $1.54 to $114.34 per mtCO2e.

Figure 6: Carbon Price Sample Probability Distribution



The summary statistics of the 45 different carbon costs show that the median carbon price is $13.05/mtCO2e. The median is reported instead of the mean because of the skewedness of the distribution of the sample.

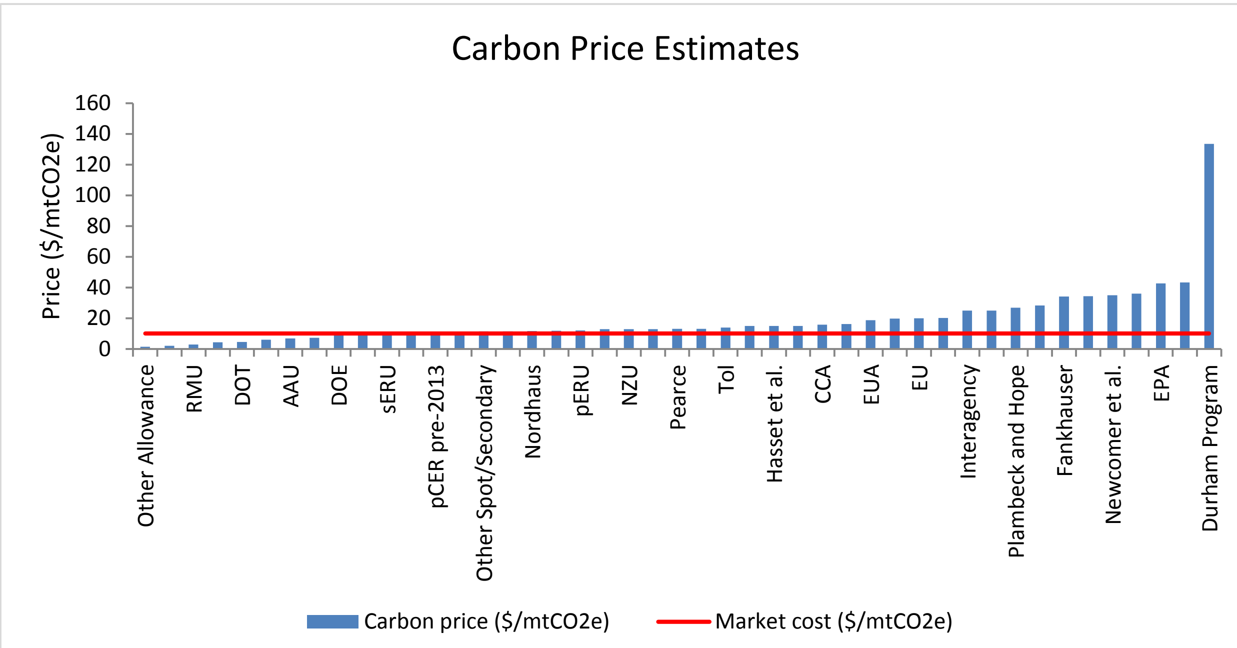
Table 13. Summary Descriptive Statistics of Carbon Prices

Descriptive Statistics	
Mean	19.02
Standard Error	3.03
Median	13.05
Mode	15.00
Standard Deviation	20.30
Sample Variance	412.27
Kurtosis	23.14
Skewness	4.27
Range	131.76
Minimum	1.54
Maximum	133.30
Sum	855.74

Count	45.00

The bar graph of different carbon cost highlights how low the carbon price has to be for the Durham program to be relevant compared to other carbon costs in the markets or estimated for government agencies, economists, and policy analysts. The carbon price calculated from dollars per GHG reduction for the Durham project is $133.37 per mtCO2e of reduced emissions. That is also the break even cost for the project.

Figure 7: Ranked Carbon Price Chart



If DCOI is to pursue an energy efficiency project following the City of Durham's protocols, they can expect a high investment cost for carbon offsets. An alternative to investing in an energy efficiency project is to acquire offsets directly from the voluntary market. Previous evaluation conducted by DCOI show that DCOI can purchase offsets for approximately $10 per mtCO2e emissions[57] . Compared to the energy efficiency project offsets, buying offsets from the market will be much cheaper. However, the disadvantage of buying market offsets is losing the social co-benefits from investing in a community energy efficiency project such as job creation, community improvement, energy saving, and better environment. DCOI may be able to regain those benefits by reinvesting their savings from buying market offsets into other community-based projects. DCOI can also investigate whether different funding mechanisms will be able to increase the cost-effectiveness of an energy efficiency project. If they can persuade homeowners to take a larger burden of the initial upfront cost of a retrofit project, the cost effectiveness of the project, from DCOI's perspective, will be greater. DCOI can either use a loan program or a subsidy program to analyze the portion of the upfront investment that they are responsible for.

7.0 DCOI Residential Energy Efficiency Retrofit Survey Design

7.1 Scope

With DCOI's aim to generate quantifiable carbon offset from energy efficiency retrofits locally, coupled with results from the City of Durham project we analyzed, we have developed a demand assessment survey to determine Duke University employees' willingness to participate in and pay for a home energy efficiency retrofit project. The survey will be administered to the members of Duke faculty and staff community. This section of the Duke community was chosen to maximize the response rate keeping in mind their relative permanency of residence in and around the city. The response rate and reliability of response among Duke faculty and staff members are expected to be higher, based upon a previous survey conducted by DCOI, which can generate a more tailored and reliable analysis for DCOI to start with.

7.2 Mode of Administration

There are several ways of administering surveys to different demographic sections and each of them has its merits and drawbacks. There are always trade-offs among different modes of survey administration. One must consider at least the following when choosing a mode: "*survey administration costs, time constraints, sample coverage, sample non-response bias, and context issues*" [58]. According to Champ et al (2003), web based mode of survey implementation gives better control over survey administration and also provides the ability to use visual aids [58].

Among the four major modes of administration, our project employs the web-based/email mode to minimize the cost and time of conducting the survey. The advantage of administering an email-based survey is that all the faculty members have access to Internet on and off campus and have an active Duke Email account. Thus, the survey can be sent out easily to the list-servers of each department in the University. Also, the results will be easier to collect and organize.

7.3 Sample Size

A large sample size can help improve the statistical level of confidence. Since this survey is being conducted on a pre-defined subset of the population, it is considered that subset constitutes the complete sampling frame. Though existing, the cost associated with a large sample size could be negligible in our survey. Therefore, we try to include as many as possible subjects in our survey. The subscribers of campus listservs are potential subjects of the survey. Four schools and one administrative office granted us the permission to use their listservs to email out the survey. As shown below, the total number of subscribers on their listservs is 2,594.

Table 14: Number of potential subjects of the survey

Schools & Offices	Number of subscribers on the listserv
Nicholas School of Environment	377
Law School	150
Pratt School of Engineering	420
Trinity College of Art & Science	1,642
Duke Sustainability Office	5
Total	**2,594**

7.4 Questionnaire Development

We developed the survey with the following sequence and content [59, 60]:

Table 15: Survey Questionnaire Development

Categories	Content
Demographic	– Name – Email address – Postcode – Decision right – Household income
Attitude and knowledge on energy efficiency and carbon offset	– Energy efficiency knowledge – Priority of retrofit – Energy retrofits already done or being considered
Demand Assessment	– Willingness to pay under different options
Follow-up questions	– Further comments on the program and participation

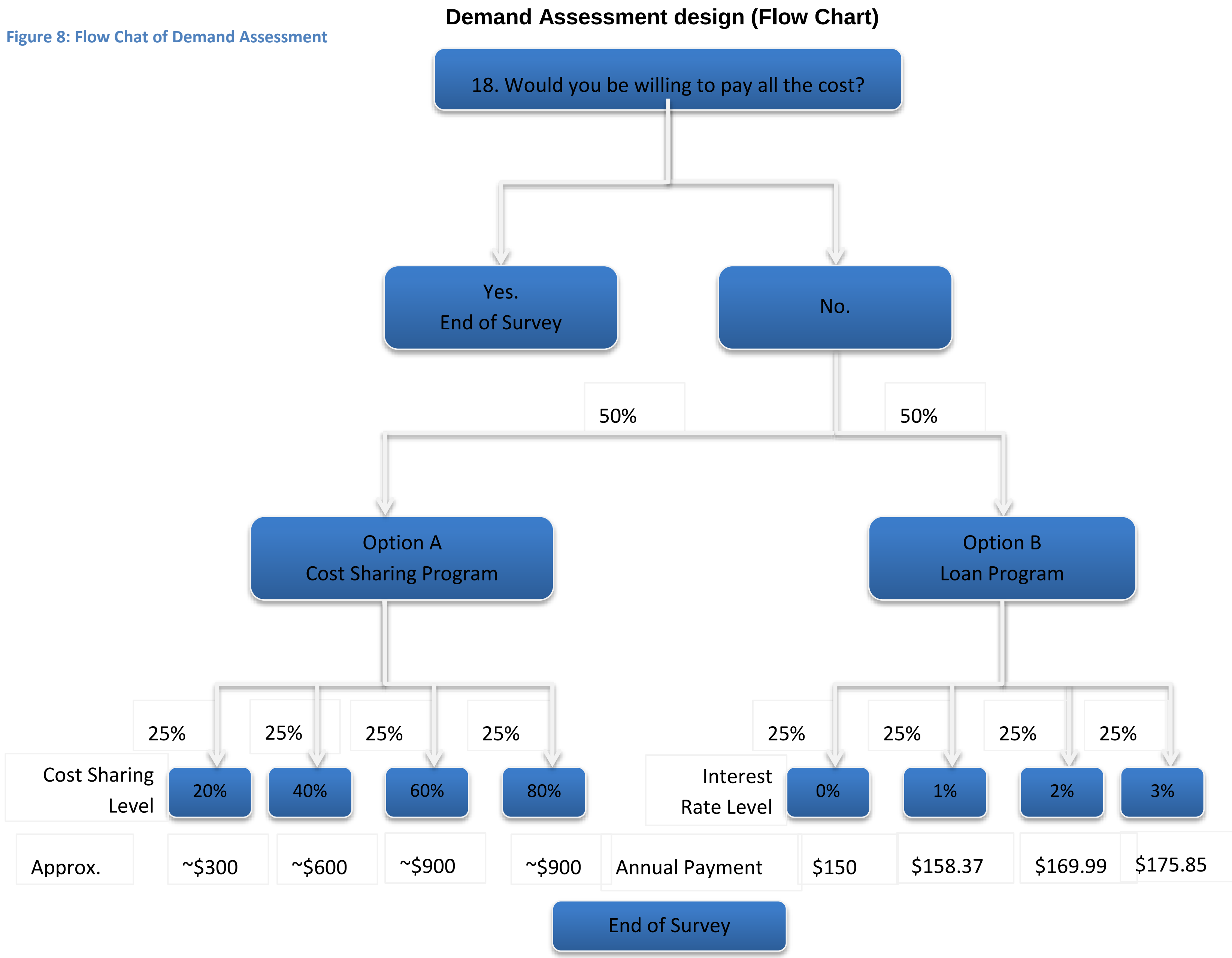
7.5 Demand Assessment

The first step of the demand assessment process will be clarifying the context of the survey questions. The respondents need to understand exactly what they would be purchasing and what the benefits that they will get in return are. In our project, they are purchasing the energy efficiency retrofit at a cost subsidized by DCOI, which can bring energy bill savings to them and generate carbon offsets for DCOI. Since a number of respondents will not be familiar with energy efficiency and, more particularly carbon offsets, there are a number of paragraphs and charts in the survey that will help them get an understanding of these concepts and enable them to make more informed choices for questions that follow.

After the respondents are familiar with all the information, they will be asked if they are willing to pay the full amount of retrofit cost if DCOI provides all the services and arranges the retrofits for them. As shown in the flow chart of demand assessment design below, if the respondent replies yes, then the survey will come to the end. However, if the respondent replies no, then the respondents will be randomly shown the cost sharing program (Option A) or low-interest loan program (Option B). This method is also called Split Surveying in survey terminology. Under each option, the respondent will be further shown a random cost sharing level (for Option A) or a random interest rate level (for Option B) and asked whether they will be willing to participate in the program for that given option of cost or interest rate level. Web-based surveying tools such as SurveyMonkey enable us to implement the random assignment described above [61].

Additionally, the way we elicit the WTP from respondent is also important. Instead of using a payment card that includes several cost sharing or interest level directly, we choose to use a hybrid of dichotomous-choice and payment card method. Under either cost sharing program or loan program, respondent can indicate whether or not they are willing to pay for one random cost sharing level or one random interest rate level. By doing this, we can avoid that respondent would not race to the bottom and choose the cheapest level. The complete survey is given in the Appendix II of this report. The flowchart given on the next page shows clearly how the survey will be administered and structured.

Figure 8: Flow Chat of Demand Assessment



8.0 Recommendations & Conclusion

8.1 Project Design

Currently, there are a variety of residential housing energy efficiency retrofit projects completed or underway in the United States. Forecasting energy savings and implementing the retrofits have their own difficulties. However, from our experience in analyzing and presenting the results from the City of Durham retrofit project with VCS methodology, we can conclude that project design is an essential aspect of any retrofit project.

Essential Elements

Large database management system

Our objective for evaluating the data from the City of Durham project was to determine how much savings in terms of energy consumption and energy bills can be expected from such a program. If those savings are substantial enough, then it may be worth the Duke Carbon Offset Initiative's time and effort to pursue a similarly scaled project.

Our experiences' on working with this project evaluation has revealed a very crucial deficiency in the project, the lack of pre and post retrofit energy consumption data. The data collected from the houses and home-owners included pre-and post-retrofit energy consumption, billing information, house size, house age, what retrofits were made, billing dates, and retrofit dates. The main issue is that the information does not cover a complete time series one year before and after the retrofit dates. In addition, the billing information has large missing sections. In order for these projects to show relevant and easy-to-present results, we recommend DCOI setting up a large database management system to record pre-retrofit and post-retrofit energy and billing information. Billing and energy use information should be collected from the home-owners or utilities at least 2 to 3 years before the retrofits. The collected information can be stored in a database and used to set up the baseline energy consumption scenario. To measure the energy and billing saving as a result of the retrofit, the billing and energy use information after the retrofit can be extracted from post-retrofit part of the database.

It is also important to include the costs of each retrofit or costs for retrofitting a particular house for the data analysis. The costs enable calculations for net present values, pay back periods, and break even carbon prices. The amount of energy savings and total costs can be used to solve for the cost per ton of carbon. This value should be used to compare to market carbon prices to evaluate the worth of the project.

To summarize, a large database management system should be set up to collect long term data for the pre-retrofit and post-retrofit time horizons. Housing technical data and demographics should be included for normalizing energy consumption calculations. It is essential to collect energy and billing information for at least 2 to 3 year for the pre-retrofit and the post-retrofit time horizons.

Normalization of data

Another aspect of data collection and analysis that must be taken care of is the removal of weather trends from the data. In particular, the heating and cooling degree days for each month of the project duration and for at least 2 years before the start of the project are required to normalize the data across different years. Since the project results depend heavily on the weather data, it is important to ensure that the weather data is as complete as possible. Data completeness here stands for the number of days the weather data was recorded in a month. It is recommended to use data with close to 100% records to ensure accuracy of energy and emissions calculations. The team used data from the North Carolina State Climate Office since it was the only agency reporting data completeness statistics along with the degree days summary. When a retrofit project is designed, the project management team should also collect information on house characteristics such as age and size to enable comparison of energy consumption reduction among different houses and perform statistical analysis.

Other Monitoring Approaches

Some of the projects intend to obtain third party certification for its carbon offsets, so it must have comprehensive and accurate data on energy consumption both before and after retrofit. Since we have used the Adjusted Consumption Approach of VCS methodology to determine the impact of the City of Durham project, it would be appropriate to model the savings with other approaches to verify the preliminary result. Other approaches include pre and post retrofit audit approach, control group approach, deemed saving approach and mobile home approach, all of which have been discussed in the literature review part of the report.

DCOI has conducted a technical survey last year and determined almost all of the technical requirements in VCS requirement table. We recommend DCOI focusing on the rest of the requirements in the future projects and particularly regarding the sections discussed above. Aside from this, we have also incorporated the barrier analysis of the additionality determination part into our willingness to pay survey. We recommend DCOI conducting the survey in the foreseeable future and analyze the result.

Furthermore, we also recommend DCOI to probe into other local residential energy efficiency projects, such as the ones in Carrboro mentioned in comparative program part in this report. Comparing our project to other local projects would help double check the reliability of our result. Besides, DCOI's other carbon offsets projects on methane and forest management are also excellent references, from which we can learn lots of experiences with carbon offsets.

8.2 Conclusion

The purpose of this report is to examine the potential of acquiring carbon offsets from residential energy efficiency programs in the local community for the Duke Carbon Offset Initiative. The organization, created in 2009, seek to invest in an energy efficiency program in the Duke community to acquire offsets in order for Duke University to achieve carbon neutrality in 2024.

We have conducted the following reviews and analysis in this report:

- Literature review of the Climate Action Plan and DCOI
- Literature review of carbon offset standards
- Selection of VCS as standard for DCOI
- Organization and manipulation of City of Durham's program dataset
- Calculation of energy and monetary savings from Durham's program
- Calculation of GHG emissions and offsets from Durham's program
- Comparison of carbon price from literature review and City of Durham program
- Comparison of Durham's programs results to other programs
- Literature review of survey design
- Design survey to elicit interest in participating in a DOCI energy efficiency program

Our recommendations for DCOI and other institutions for continuing this investigation and/or implementing a residential energy efficiency project in the local community are the following:

- Have defined protocols for acquiring pre and post retrofit energy data from participants in order to establish baseline and to calculate savings
- Create a database management system to store energy, billing, demographic, and physical information for post retrofit evaluations

- Compile accurate temperature data, emission factors, and other parameters included in the savings calculation methodology that may be specific to geographical location, climate variations, and electricity resource mix
- Model savings with a variety of methodologies to ensure that calculations are accurate
- Conduct the survey and analyze the result
- Investigate other local residential energy efficiency programs

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Appendix I

Electricity	CDDCF	HDDCF	# of Months	kWh before	kWh after	Elec. Red./Mo	Elec. E. Red.	Energy bill Savings/Month ($)
CV028	0.88	1.68	3.00	1,414.01	2,003.92	-253.70	-0.12	-23.57
CV038	0.95	0.77	9.00	8,549.83	6,920.05	130.34	0.06	12.11
ED052	0.95	1.68	5.00	5,162.25	8,388.64	-701.21	-0.33	-65.14
HESP031	0.87	0.83	4.00	6,786.19	6,223.45	-78.29	-0.04	-7.27
HESP036	0.88	0.75	5.00	7,037.25	4,887.05	255.17	0.12	23.70
HESP041	1.02	0.76	6.00	4,724.42	3,244.78	260.85	0.12	24.23
HESPG502	1.02	0.76	6.00	12,793.68	8,895.99	688.20	0.32	63.93
HESPG647E	5.71	0.81	2.00	2,068.89	2,352.11	4,732.82	2.22	439.66
LH010	0.95	0.98	8.00	15,129.24	12,635.82	210.29	0.10	19.54
LH013	0.95	0.79	12.00	17,735.05	12,316.20	377.26	0.18	35.05
LH015	0.95	1.07	12.00	11,636.61	13,650.62	-216.77	-0.10	-20.14
LH033	0.93	0.79	12.00	9,802.96	8,549.93	50.79	0.02	4.72
LH038	0.93	1.54	6.00	8,081.13	8,644.31	-186.87	-0.09	-17.36
NP003	0.83	0.74	3.00	845.10	461.30	78.75	0.04	7.32
NP012	0.95	0.79	11.00	13,809.20	8,754.34	395.47	0.19	36.74
NP015	0.86	0.79	7.00	3,118.70	2,046.34	88.65	0.04	8.23
NP022	0.97	0.79	10.00	8,101.38	7,749.36	9.75	0.00	0.91
NP044	1.02	0.76	6.00	3,972.98	3,600.88	74.00	0.03	6.87
NP053	0.86	0.79	7.00	4,894.96	4,149.19	5.23	0.00	0.49
PW043	1.02	0.76	6.00	1,604.91	1,489.83	24.02	0.01	2.23
PW060	1.02	0.76	6.00	3,778.08	3,279.37	94.51	0.04	8.78
PW077	0.86	0.79	7.00	3,259.49	3,181.96	-56.39	-0.03	-5.24
PW079	0.88	0.75	5.00	3,189.27	3,543.10	-150.02	-0.07	-13.94
SV003	0.94	1.26	7.00	7,604.00	7,080.11	10.50	0.00	0.98
SV018	0.94	1.26	7.00	8,640.02	7,951.04	25.32	0.01	2.35
SV502	0.93	1.54	6.00	6,648.10	5,418.73	128.38	0.06	11.93

TL002	0.97	1.68	5.00	2,589.96	3,335.22	-166.90	-0.08	-15.50
TL005	0.97	0.79	10.00	6,052.03	4,748.97	111.29	0.05	10.34
TL019	0.95	1.68	5.00	4,448.95	4,707.02	-99.82	-0.05	-9.27
TL024	0.97	1.68	4.00	1,594.78	1,201.02	84.70	0.04	7.87
TL025	0.97	1.68	4.00	2,278.24	2,348.74	-37.25	-0.02	-3.46
TL044	0.93	1.54	6.00	5,977.55	5,314.07	41.79	0.02	3.88
TL053	0.80	1.68	2.00	435.00	382.05	-17.24	-0.01	-1.60
TL058	0.80	1.68	2.00	981.87	811.06	-13.26	-0.01	-1.23
TL061	0.87	0.80	5.00	5,270.37	3,829.73	147.92	0.07	13.74
TL515	0.80	1.68	2.00	1,090.98	858.86	6.43	0.00	0.60
TP002	0.97	0.79	10.00	22,226.83	15,769.33	575.92	0.27	53.50
TP007	0.87	0.83	5.00	2,304.98	2,233.59	-45.22	-0.02	-4.20
WH004	0.80	1.68	2.00	933.11	1,097.24	-175.83	-0.08	-16.33
WH015	0.95	0.79	12.00	14,968.91	13,337.90	72.27	0.03	6.71
WH016	0.84	0.79	8.00	5,665.20	5,365.38	-76.52	-0.04	-7.11
WH017	0.83	1.00	3.00	2,948.01	3,060.96	-203.90	-0.10	-18.94
WH030	0.95	1.68	5.00	8,773.08	7,638.00	131.96	0.06	12.26
WH047	0.97	0.79	10.00	6,609.80	6,475.62	-7.35	0.00	-0.68
WH056	0.83	1.00	3.00	839.92	786.96	-29.71	-0.01	-2.76
Average						139.92	0.07	13.00
Total						6,296.34	2.96	584.90
Electricity emission factor					**0.000470 tons/kWh**			

Appendix II

The complete survey is given below:

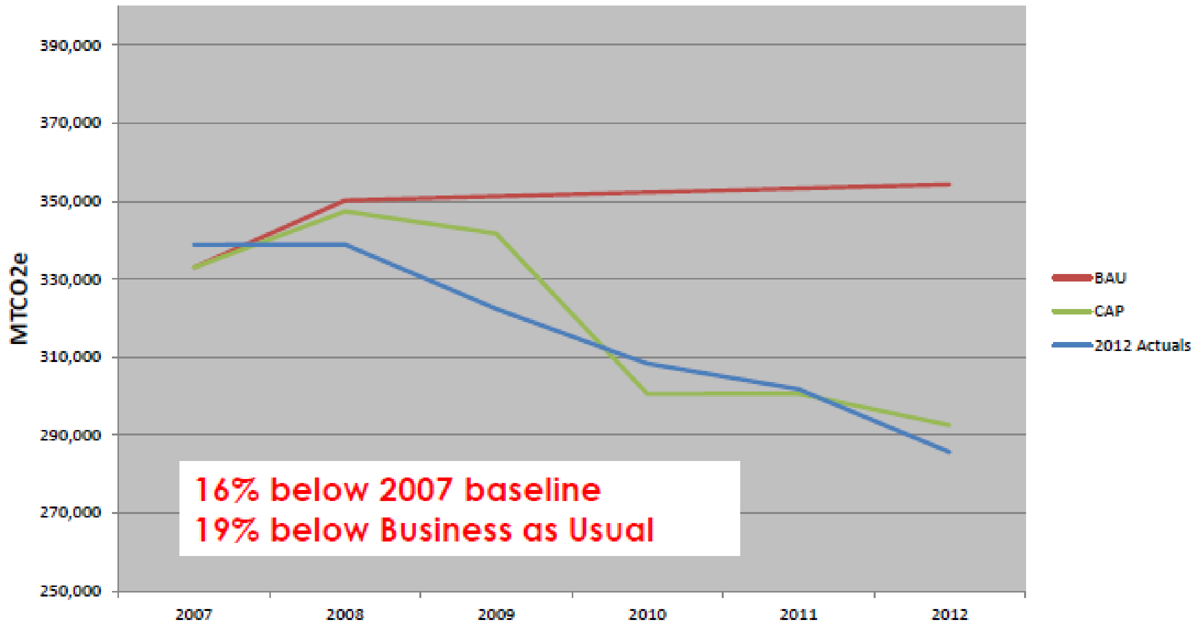
Duke Carbon Offsets Initiative Home Energy Efficiency Retrofit Survey

** Once you have answered a question, you cannot go back to it later in the process. Please consider each question carefully before answering. **

Basic definitions:

It has been known for some time now that increase in carbon dioxide and other greenhouse gas (GHG) emissions will lead to increase in the average global temperature. An increase in the global temperature, also known as global warming, will have far reaching and irreversible impacts on the ecological systems on the earth and influence the biodiversity, agriculture, human health, and even our energy supply [62, 63]. One of the major sources of carbon dioxide is the consumption of energy in various forms such as electricity and vehicle fuel. A number of organizations, institutes and states have already started taking actions to curb their GHG emissions. Some of the American Universities that have made a commitment to reduce their impact on the global climate include Duke University, Yale University, University of North Carolina at Chapel Hill, and University of California at Berkeley[64].

Duke University committed to environmental sustainability in March 2005 with the signing and release of its environmental policy. The Duke Campus Sustainability Committee was formed in 2007 which developed the Climate Action Plan (CAP) aimed at achieving carbon neutrality by 2024 [4]. Being carbon neutral means having zero net greenhouse gas emissions. According to the base line constructed in 2007, the University had carbon emissions of 338,828 metric tons of carbon dioxide equivalent. The University aims to become carbon neutral through a combination of efforts to reduce emissions on campus and develop carbon offset projects off-campus. The chart below depicts the milestones reached by the CAP since 2007 [65]. The green line is the projection of 2012 reductions and the blue line is the actual 2012 reductions.



The Duke Carbon Offsets Initiative (DCOI) in integral part of the Duke Sustainability office and is working with them to meet the carbon neutrality goal by 2024. As a part of one of its project, DCOI is planning to develop a program to undertake energy efficiency retrofits in the homes of Duke employees. Depending upon the homeowner's interest and expected costs, the retrofits may include the following: air and duct sealing, appliance replacement, insulation enhancement. This survey is being conducted to determine the level of interest of the Duke employees for participation in such a program. Please complete this survey only if you own your home in Durham/Triangle region.

Your responses would help DCOI decide how to implement this project

PLEASE ANSWER THE FOLLOWING QUESTIONS:

Reminder: once you have answered a question you cannot go back to it

1. Do you currently own or rent the house you are living in? (Own/Rent).

   If you are renting your house, please do not complete this survey

2. Please select the type of your housing unit from the options given below:

   a. Single-family Unit

   b. Apartment/Flat

   c. Condominium

d. Townhouse

3. Please enter your first and last names

____

4. Please enter your email address

____

5. Please enter your postcode

____

6. Are you in the position to make decision on behalf of your family?

Yes

No

7. Please indicate your approximate household income range ($/year) (before taxes) earned last year.

- Under $40,000
- $40,000-$59,999
- $60,000-$79,999
- $80,000-$99,999
- $100,000-$119,999
- $120,000-$139,999
- $140,000-$159,999
- $160,000 or more
- Don't know

8. How many stories does your house have?

____

9. In what year was your house built?

____

Don't Know

10. How many square feet is your house including basement?

____

Don't know

Energy Efficiency:

Energy efficiency refers to "*reduction in the amount of energy required to do the same amount of work*". Energy efficiency credits (EECs), restricted to power use, are defined as equal to 1 MWh of electricity savings from energy efficiency measures, also known as "white tags", "white credits", "white certificates", or "energy saving certificates"[5, 66]. Homeowners can save considerable amounts of energy by improving or replacing features of their houses. The investment made in energy efficiency improvements pays off in the subsequent years in the form of lower energy bills with the same or enhanced level of comfort [67]. You can read more about energy efficiency in buildings here: http://www.epa.gov/greenhomes/ReduceEnergy.htm

Based on this information please answer the questions below:

11. What do you think about energy efficiency?
    - It is a way to save money
    - It is desirable but costly
    - I do not care about it
    - Other, please specify

12. Please rank the following reasons from 1 to 4 (1 being highest and 4 being lowest significance) to undertake energy efficiency retrofits in order of significance
    - Safety - upgrading to better and safer appliances
    - Reducing energy bills
    - Replacement of old inefficient equipment

    Other, please specify

13. Have you had any energy efficiency retrofits done at your home before since January 01, 2010?

If yes, please answer question 13 to 15.

If no, please go to question 16

14. Which of the following retrofits were undertaken (you can select more than one)
    - Air sealing
    - Duct sealing
    - Shower heads replacement
    - Insulation enhancement
    - Appliance replacement
    - Other, please specify
15. How much did the retrofits cost you?

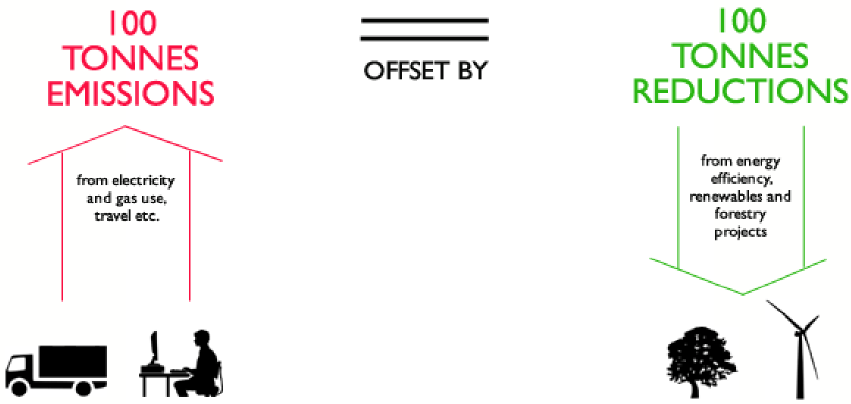
    _____

    Don't know
16. Are you considering undertaking any energy efficiency upgrades in your home?
    - Yes
    - No
17. Are there any factors that are preventing you from undertaking those yourself?
    - Yes. Please select from the following
        - Cost
        - labor availability
        - Time constraints
        - Other, please specify
    - No

Please review the information given below and answer the following questions

A similar retrofitting project was conducted by the City of Durham in close to 700 residential buildings in the city. The data of electricity and natural gas use of a subset of these houses was shared with DCOI.

What is Carbon Offset? [1, 2]



Carbon offsetting is a cost-effetive way of reducing carbon emissions.

According to data collected and analyzed by the City of Durham, an average saving of 113.23 KWh per month can be expected after the retrofitting is done. This translates to a saving of approximately $10.52 on your electricity bill every month (considering 2012 electricity rates of Duke Energy). This translates to a saving of approximately $123 per year.

How energy efficiency translates to carbon offset: In case of energy efficiency programs, an offset would work by reducing the consumption of electricity and natural gas in residential and/or commercial buildings which will lead to reduction in carbon (CO2e) emission from power generation. This reduction in CO_2 emission will then be counted as a carbon offset. One offset stands for one metric ton of carbon dioxide equivalent emission reduction [10]. Considering the energy mix of North Carolina as given by the Energy Information Administration, each KWh of electricity produced releases 470 kg of CO2 equivalents. Thus, reducing your energy consumption by 1 KWh in one month will lead to an emission reduction of 470 kg of CO2e [11, 12]. Over a year, a 12 KWh of energy saving will generate 3.24 metric tons of emission reduction or 3.24 carbon offsets.

Depending upon the financing structure of the project and DCOI's budget, one or more of the following retrofits will be undertaken in the participant's (Duke employee) home.

- air sealing
- duct sealing
- insulation enhancement

18. Demand assessment:

According to City of Durham project, the cost of retrofitting a typical house (1500 sq. feet) is $1500 ($1 per square floor area). This cost includes programmable thermostat, insulation, duct sealing, air sealing and showerhead replacement.

Would you be willing to participate in this program if Duke helps you arrange the retrofit but you have to pay all the cost?

- Yes
- No

(If yes, the survey comes to the end. If no, go to either Option A (50% probability) or Option B (50% probability))

Option A: Cost Sharing

Under this option a part of the total cost will be paid by DCOI while the house owner will be responsible for the rest.

Would you be willing to participate in this program if you had to pay these proportions of the total cost. Please Circle A or B for each given cost level. (A random cost sharing level appearing on the payment card will be chosen to ask the respondent)

	YES	NO
20% (~$300)	A	B
40% (~$600)	A	B
60% (~$900)	A	B
80% (~$1200)	A	B

Option B loan program:

Under this option, a household can apply for a low-interest loan from DCOI to finance the retrofit.

Based on this information, would you be willing to participate in this program with the following interest rates on loan? The term of the loan is 10 years, with an approximate fixed monthly payment of (A random selection from the interest rate levels given below appearing on the payment card will be chosen to ask the respondent)

Interest Rate	Annual Payment	YES	NO
0%	$150	A	B
1.0%	$158.37	A	B
2.0%	$166.99	A	B

3.0%	$175.85	A	B

<u>Finally, we would like to know your opinion about this survey:</u>

19. How likely are you to participate in the follow up survey?

1 being “not at all likely” and 5 being “very likely”

- 1
- 2
- 3
- 4
- 5

Please leave your comments here.