ANALYSIS OF FINANCIAL INVESTMENT REQUIRED TO CERTIFY ADAPTIVE REUSE PROJECTS USING LEED v4.1 RESIDENTIAL: MULTIFAMILY

by

Travis Plystak

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Approved: _____

Dr. Mohsin Siddiqui, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: _____

Dr. Jack Puleo, Ph.D.
Chair of the Department of Civil and Environmental Engineering

Approved: _____

Dr. Levi Thompson, Ph.D.
Dean of the College of Engineering

Approved:

_____

Louis F. Rossi, Ph.D.
Vice Provost for Graduate and Professional Education and
Dean of the Graduate College

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ABSTRACT

As Wilmington continues to grow as a city in the Mid-Atlantic region and continues to set out goals for sustainable growth, it has made efforts to produce built infrastructure that has little impact on the environment while maintain its historical character. This research sets out to determine the investment costs required for adaptive reuse projects pertaining to multifamily construction using the LEED v4.1 Residential: Multifamily certification system. In addition, this study will look at the cost associated with each category in the scoring system and relate its financial impact to total invested cost.

A sample of six representative residential projects were selected for this study. A model was created for each project to estimate the cost of upgrading the project to different LEED tiers. The model was optimized to select the path to certifying the projects at each tier at the lowest possible financial investment. All the projects' costs to upgrade are based on estimates and quotations.

The research shows LEED certification at the Certified and Silver tiers require negligible increases in financial investment while projects seeking Gold and Platinum certifications require an average increased investment as a percentage of total project cost of 0.65% and 6.77%, respectively.

Chapter 1

INTRODUCTION

Construction in Wilmington

Wilmington, Delaware is a city with a rich history dating back to its founding in 1638. It has grown into the largest metropolitan area in Delaware with its population of 70,898. The city is a key highway and rail connector between the major cities in the Mid-Atlantic / Northeast regions with I-95 passing directly through the city as well as its train station which services both AMTRAK and SEPTA.

Most of Wilmington's housing inventory consists of single-family homes at 64% while only 35% of dwellings were multifamily units. Of the occupied units, almost 75% are 50 years or older with the greatest portion being built before 1939 (*Wilmington 2028*, 2019). This paints a picture for the general age of buildings in the city.

Being a city that wants to capitalize on the migration of young professionals and businesses, there have been a growing number of multifamily apartment buildings constructed in the area. Many of these buildings have taken advantage of existing structures and repurposed them to mixed-use or strictly residential living.

This type of construction somewhat counteracts the fact that new construction increases the amount of carbon emissions. In 2018, the building sector accounted for 36% of energy use and 39% of total carbon emissions, 11% of which was produced as a result of building material manufacturing (IEA, 2019).

Green Building Definition

Due to the disruptive and sometimes harmful nature of new construction within the building life cycle, there are concerns regarding the sourcing of non-renewable resources and the damage which a new building may cause to the local environment, thus impacting the lives of future generations. This fact designates a need to identify methods and regulations for construction that would reduce resource consumption and efficiency of buildings.

This brings up the concepts of Green Buildings and sustainability. The World Green Building Council (WGBC) defines a green building as, “a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment. Green buildings preserve precious natural resources and improve our quality of life.” The concept of the green building was developed from the need to solve a plethora of issues including but not limited to, building efficiency, environmental impact, and economic and social justice.

Furthering this definition, the United States Green Building Council (USGBC) defines a green building as, “as the planning, design, construction, and operations of buildings with several central, foremost considerations: energy use, water use, indoor environmental quality, material section and the building's effects on its site.”

Research Objective

The main objective of this study is to estimate the additional investment required to certify adaptive reuse projects in the city of Wilmington with all applicable tiers of LEED v4.1 for Multifamily buildings. This research focuses specifically on the adaptive reuse of former commercial use buildings for use as multifamily dwellings. This paper aims to close the information gap on the financial feasibility of building these types of buildings to LEED standards.

Research Questions

The research aims to answer two main questions:

- What is the financial investment required to certify a project with the different tiers of LEED?
- Which categories of LEED have the biggest impact for this specific type of construction?
- Which categories would require the largest investment?

Research Hypothesis

The research intends to investigate the following hypothesis:

- The LEED rating system does not have a significant impact on total project cost for adaptive reuse multifamily residential projects.

Chapter 2

LITERATURE REVIEW

Green Buildings Status in Wilmington, DE

Although Wilmington cannot be considered a leader in Green Building construction, it does have its fair share of LEED certified and registered buildings. According to the Green Building Information Gateway, Wilmington currently, the city has 22 LEED-certified projects and 21 LEED-registered projects. There are 7 LEED Gold, 9 LEED Silver, and 6 LEED Certified projects. This figure accounts for approximately 17% of the 128 total LEED projects in the state.

Wilmington's Vision for Sustainable Growth and Construction

The city of Wilmington, Delaware has outlined its commitment to reducing its greenhouse gas emissions. According to the Wilmington 2028 Comprehensive Development Plan, the city is well ahead of its plan reducing its emissions by 20% below 2008 levels. Additionally, Wilmington provides funding for energy audits for residential and mixed-use projects in LEED certification through the Downtown Development District Program. With the population expected to grow by approximately 3,000 by 2030, it is necessary to continue to add housing wherever possible, which could replace the multitude of off-street parking locations over time.

Green Building Construction Cost

The main adversary to developers attempting to obtain green building certifications is additional cost to green alternatives to traditional construction methods. As Green Building rating systems mature, professionals increasingly continue to implement them, and additional research is conducted, the cost premium for green building will decrease. Two studies researching the cost impact of LEED certification for new construction residential projects (Dabash, 2019) and education retrofit projects (Elkhapery, 2021) show that increased investments as a percentage of total project cost is negligible for LEED Certified through LEED Gold tiers while certifying projects at LEED Platinum would require significant investment.

The future is promising for Green Buildings. Demand for sustainable construction is predicted to grow 14.3% during the 2020-2027 period (Market Research Future, 2020). More specifically, there is remarkable growth occurring in multifamily buildings. According to Dodge Data & Analytics, almost half (47%) of builders surveyed are planning on focusing 60% of their construction on green projects.

Benefits of Green Buildings

Some of the major aspects of green buildings are improved indoor environmental quality and less usage of electricity and water when compared to traditional buildings. According to USGBC, LEED-certified homes use 20 to 30% less

energy than traditional buildings. Additionally, because Americans spend about 90% of their time indoors (EPA, 1989), it is imperative that buildings provide spaces for positive health outcomes. Some primary examples of how Green Buildings can benefit those that either own or live/work within them are as follows:

- Improved health outcomes when compared to buildings that have poor indoor air quality
- Increased productivity
- Less money used to produce electricity or water
- Green Buildings provide increased rental revenue while also sustaining high occupancy (Wiley et al., 2008)

Adaptive Reuse

Definition

This research focuses on a specific type of construction known as adaptive reuse. Some commonly used definitions of this type are known to be:

- A process that retains as much as possible of the original building while upgrading the performance to suit modern standards and changing user requirements (Latham, 2000).
- Rehabilitation or renovation of existing buildings or structures for any uses other than the present uses (Dolnick and Davidson, 1999).

To challenge the claim that the most sustainable buildings are ones that are the most modern in design, adaptive reuse aims to tackle sustainability using buildings that already exist. According to Carl Elefante, the greenest buildings are the ones that already exist have previously been considered the "holy grail" of the Green Building movement (Melaver and Mueller, 2009, 168).

Leadership in Energy & Environmental Design (LEED)

LEED (Leadership in Energy and Environmental Design) is the most commonly used Green Building certification system in the United States. It operates through and is updated by the USGBC (United States Green Council). The USGBC defines LEED as "a holistic system that doesn't simply focus on one element of a building such as energy, water or health, rather it looks at the big picture factoring in all of the critical elements that work together to create the best building possible.

Categories

LEED is a point system where builders attempting to certify a building must acquire points (Max. 110) to meet one of four tiers:

- Certified (40-49 points)
- Silver (50-59 points)
- Gold (60-79 points)
- Platinum (80+ points)

Points are divided into nine total categories:

- Integrative Process
- Location & Transportation
- Sustainable Sites
- Water Efficiency
- Energy & Atmosphere
- Materials & Resources
- Indoor Environmental Quality
- Innovation
- Regional Priority

Implementation in Wilmington, DE

Although Wilmington, DE is not home to any world-renowned LEED-certified buildings, it does have its fair share of projects that are either registered or have achieved some sort of certification. To date, Wilmington has 21 LEED Registered projects, 6 LEED Certified projects, 9 LEED Silver projects, and 7 LEED Gold projects.

Case Studies

Case Study 1: The Economics of Adaptive Reuse of Old Buildings (Stas, 2007)

The study found that adaptive reuse construction has numerous benefits including reducing the production of hazardous materials, preserving the building's embodied energy (total energy used to construct), reducing crime, and having various economic benefits to not only the owner but also the local area. While the study found there are several barriers in the way of adaptive reuse projects such as zoning laws, contamination, and potentially structural issues, these types of projects may still be more profitable than new construction buildings. Their research studied three possibilities for their selected sample projects: adaptive reuse, demolishing and building a new building on the same site, or simply constructing a new building elsewhere. After reviewing the return on investment for each scenario, it was determined that the adaptive reuse scenarios had the lowest construction costs and generally the highest return on investment compared to the alternatives.

Case Study 2: Financial Feasibility Study of LEED Certified Buildings for Developers and Investors (Henriksen, 2019)

This research found that the LEED certification worked best for developers who were looking for a return on their investment in the long-term as opposed to investors who desired quick returns. Namely, small developers as well as large-scale developers whose objectives were to take advantage of the added premium on rental income associated with LEED properties were more incentivized to go for LEED certification while mid-sized developers who sought quick returns were less likely to seek certification.

Case Study 3: Comparing Green Building Rating Schemes in North America, Europe, and Asia (Varma, 2019)

Researchers examined ten Green Building rating systems used across North America, Europe, and Asia to determine best practices for construction. Some proficiencies identified within LEED rating system include pre-requisite categories to ensure minimum performance and Regional Priority credits which address issues related to the local context. However, compared to other Green Building rating systems, LEED was identified to be lacking in the triple-bottom-line aspects of sustainable development. These aspects are known to be the social, economic, and environmental impacts. Most of the rating systems studied showed unequal preference for the environmental impacts of a project with much less attention paid to the others.

Case Study 4: Comparative Whole-Building Life Cycle Assessment of Renovation and New Construction (Hasik, et al., 2019)

This research studied the life cycle impact of material use on new construction versus renovation for a certain project. The researchers compared the full life cycle impacts of renovation/reuse and maintenance of an existing building in Philadelphia, PA to the life cycle impacts of demolishing and replacing it. The data showed 53-75% reductions across six environmental impact categories when renovation was compared to new construction (Hasik et al., 2019). Reuse of structural and building envelope components provided most of the reductions since most of the renovation involved the interior finishes. The largest environmental impacts within the renovation scenario were found in the Finishes and Openings and Glazing categories of Construction

Specification Institute (CSI) Master Format Division while in the new construction scenario the largest environmental impacts involved Concrete and Metal work (Hasik, et al., 2019).

Chapter 3

METHODOLOGY

The methodology chapter outlines and elaborates the steps taken to conduct the research in this study, including the literature review, project selection criteria, assumptions, data collection, data analysis, and conclusion.

To determine the increase in investment required for LEED certification, the research sought to determine the average added cost as a percentage of total project costs for each LEED certification level across five sample projects.

Data Collection & Assumptions

Data was obtained from a property development company who has worked on a various number of residential projects in the area, including but not limited to the 5 projects used for this research. The data collected included full sets of as-built drawings from the developer, specifications for most projects, and combined electricity/water usage bills. An assumption was made where if a project was missing its specifications, that the research would follow the commonly used materials and/or requirements of another project built around the same time. Additionally, although all the mentioned projects also include a new commercial use, this research will only focus on the residential portion of the new construction. Finally, all these projects are located within a ½ mile radius of each other, which creates the possibility of the data points sharing similar outcomes.

Data Analysis

The data analysis in this research is conducted in accordance with the LEED v4.1 Residential: Multifamily scorecard. For the LEED analysis, an Excel Model is used to analyze the maximum number of points to be obtained and certification tiers achieved. The LEED v4.1 Residential Multifamily scorecard is divided into categories and a maximum number of obtainable points (Max. 110 pts) as follows:

- Integrative Process (1pts)
- Location & Transportation (15pts)
- Sustainable Sites (9pts)
- Water Efficiency (12pts)
- Energy & Atmosphere (34pts)
- Materials & Resources (13pts)
- Indoor Environmental Quality (16pts)
- Innovation (6pts)
- Regional Priority (4pts)

The analysis is performed in two stages. The first stage of the analysis is to study the status of the existing buildings. Project data is collected from contract documents and includes project specifications, drawings, and electricity/water usage bills. Because the projects are already completed, they were first analyzed based on how many points are obtained from point original construction completion. They were then analyzed to determine what upgrades were necessary to obtain a maximum amount of points. Since LEED is a point-based rating system with multiple pathways

to achieve the different tiers the Excel Model is created to find the pathway to each tier while minimizing costs.

The LEED model looks at the Prerequisites and Credits in LEED v4.1 Residential: Multifamily. The model collects the required information from the projects to estimate the costs required to attain points. Then the credits are organized into a table where they have their associated maximum point values and associated costs. From there the costs and points are optimized for each LEED certification tier to find the lowest financial path for each tier. The model was not limited to only achieving the exact (or minimum) points required for each certification tier. This flexibility is necessary as there exists the possibility of attaining more points required than the minimum at a lower cost. For example, it may be cheaper to obtain 61 points as opposed to 60 points). Similarly, there is the possibility for projects to obtain more than the minimum amount of points for no added cost. Finally, after the total points were tallied and estimates added, the percent increase in investment was calculated and averaged for each tier of certification among the 5 projects.

LEED v4.1 for Residential: Multifamily											
Project Number: P2		Maximum		Certified		Silver		Gold		Platinum	
Credit Categories		Points	Cost	Points	Cost	Points	Cost	Points	Cost	Points	Cost
		110		40		50		60		80	
	Totals	88	$386,866.28	41	$0.00	51	$849.00	60	$21,280.46	80	$115,285.20
Integrative Process		1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Integrative Process	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Location and Transportation		15	$8,140.00	12	$0.00	12	$0.00	14	$8,140.00	14	$8,140.00
Credit	LEED for Neighborhood Development Location	15	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Sensitive Land Protection	2	$0.00	2	$0.00	2	$0.00	2	$0.00	2	$0.00
Credit	High-Priority Site	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Surrounding Density and Diverse Uses	5	$0.00	5	$0.00	5	$0.00	5	$0.00	5	$0.00
Credit	Access to Quality Transit	3	$0.00	2	$0.00	2	$0.00	2	$0.00	2	$0.00
Credit	Bicycle Facilities	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Reduced Parking Footprint	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Electric Vehicles	2	$8,140.00	0	$0.00	0	$0.00	2	$8,140.00	2	$8,140.00
Sustainable Sites		9	$26,499.97	2	$0.00	2	$0.00	3	$4,927.00	3	$4,927.00
Prereq	Construction Activity Pollution Prevention	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Site Assessment	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Protect or Restore Habitat	1	$4,927.00	0	$0.00	0	$0.00	1	$4,927.00	1	$4,927.00
Credit	Open Space	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Rainwater Management	3	$21,572.97	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Heat Island Reduction	2	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Light Pollution Reduction	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Water Efficiency		12	$1,700.00	5	$0.00	6	$0.00	7	$1,700.00	7	$1,700.00
Prereq	Water Use Reduction	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Building-Level Water Metering	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Water Use Reduction	10	$0.00	5	$0.00	5	$0.00	5	$0.00	5	$0.00
Credit	Water Metering	2	$1,700.00	0	$0.00	1	$0.00	2	$1,700.00	2	$1,700.00
Energy and Atmosphere		34	$346,476.35	3	$0.00	3	$0.00	7	$2,463.50	27	$96,468.24
Prereq	Fundamental Systems Testing and Verification	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Minimum Energy Performance	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Energy Metering	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Fundamental Refrigerant Management	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Enhanced Commissioning	6	$17,165.01	0	$0.00	0	$0.00	3	$0.00	6	$17,165.01
Credit	Optimize Energy Performance	18	$258,447.84	0	$0.00	0	$0.00	0	$0.00	14	$59,739.73
Credit	Whole Building Energy Monitoring and Reporting	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Grid Harmonization	2	$2,463.50	0	$0.00	0	$0.00	1	$2,463.50	1	$2,463.50
Credit	Renewable Energy	5	$68,400.00	0	$0.00	0	$0.00	0	$0.00	3	$17,100.00
Credit	Enhanced Refrigerant Management	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Domestic Hot Water Pipe Insulation	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Materials and Resources		13	$3,200.00	7	$0.00	7	$0.00	8	$3,200.00	8	$3,200.00
Prereq	Storage and Collection of Recyclables	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Construction and Demolition Waste Mangement Planning	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Building Life-Cycle Impact Reduction	5	$0.00	3	$0.00	3	$0.00	3	$0.00	3	$0.00
Credit	Environmentally Preferable Products	6	$0.00	4	$0.00	4	$0.00	4	$0.00	4	$0.00
Credit	Construction and Demolition Waste Management	2	$3,200.00	0	$0.00	0	$0.00	1	$3,200.00	1	$3,200.00
Indoor Environmental Quality		16	$849.96	11	$0.00	14	$849.00	14	$849.96	14	$849.96
Prereq	Minimum Indoor Air Quality Performance	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Combustion Venting	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Garage Pollutant Protection	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Radon-Resistant Construction	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Interior Moisture Management	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Environmental Tobacco Smoke Control	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Prereq	Compartmentalization	Req.	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Enhanced Compartmentalization	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	No Environmental Tobacco Smoke	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Enhanced Indoor Air Quality Strategies	4	$849.96	0	$0.00	3	$849.00	3	$849.96	3	$849.96
Credit	Low-Emitting Materials	4	$0.00	4	$0.00	4	$0.00	4	$0.00	4	$0.00
Credit	Indoor Air Quality Assessment	2	$0.00	2	$0.00	2	$0.00	2	$0.00	2	$0.00
Credit	Thermal Comfort	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Daylight and Quality Views	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Credit	Acoustic Performance	2	$0.00	2	$0.00	2	$0.00	2	$0.00	2	$0.00
Innovation		6	$0.00	6	$0.00	6	$0.00	6	$0.00	6	$0.00
Credit	Innovation	5	$0.00	5	$0.00	5	$0.00	5	$0.00	5	$0.00
Credit	LEED Accredited Professional	1	$0.00	1	$0.00	1	$0.00	1	$0.00	1	$0.00
Regional Priority		4	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Regional Priority	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Regional Priority	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Regional Priority	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Credit	Regional Priority	1	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00
Project Cost				Required		Required		Required		Required	
$2,950,894.26				0.00%		0.03%		0.72%		3.91%	

Table 3.1: LEED Project Analysis Example

This research used JMP software statistical analysis to determine the significance of the difference between the categories. The ANOVA test was utilized to determine the significance of the categories holistically while the Student T test was used to study the differences specifically.

Chapter 4

DATA COLLECTION, ANALYSIS & RESULTS

This study aims to determine the average increase in project cost for each LEED certification tier for adaptive reuse construction of multifamily buildings. The research uses the LEED Green Building evaluation process as it is the most popular in the United States. This assessment includes the cost of upgrading the previously performed projects to each of the LEED tiers, given their original project costs and data. Finally, the assessment will provide insight on the projects and discuss which LEED scoring categories were easier or harder to obtain based on the upgrade cost analysis.

LEED Model

A model is created to estimate the cost of upgrading the sample projects to each LEED tier. The model identifies characteristics of the projects by comparing the projects' plans and specifications to the requirements of each scoring category. The model takes input data and calculates the total number of achievable points per category. Afterward, points are tallied to a maximum and then optimized to find the minimum cost to achieve each tier. Once the minimum cost is found for each tier, the model calculates the increased investment cost percentages compared to each project's original cost. Finally, the increased cost percentages are averaged and presented.

LEED Total Project Analysis

The procedure applied to the sample project was also applied to the remaining 4 projects considered in the study. Table 4.1 presents a summary of the projects. Adjusted for 2022 US Dollars ($), the selected projects vary in cost with a range of $2,950,894.26 for P2 to $11,582,915.63 for P4. The construction cost per square foot for these projects is $119.78 and $24.89, respectively.

Project No.	Building Type	Project Cost ($)	Project Size (SF)	Construction Cost/SF ($)
P1	Low-rise Building	$5,880,837.08	47,636	$123.45
P2	Low-rise Building	$2,950,894.26	24,635	$119.78
P3	Low-rise Building	$4,863,648.97	67,817	$71.72
P4	High-rise Building	$11,582,915.63	465,366	$24.89
P5	Low-Rise Building	$4,007,915.94	19,980	$200.60
P6	Low-Rise Building	$6,073,705.75	69,739	$87.09

Table 4.1: Project Details

The increased costs to certify the projects are presented in Table 4.2. To ensure that there is no bias between the different project costs, an ANOVA test was utilized to compare between the different building types. Figure A-1 shows that there is no significant difference between the project types, with a p-value of 0.1545. Thus, we should not expect a bias because of the differing construction costs for the projects. To ease the comparison between projects the cost for the four certification tiers is calculated as a percentage of the project cost. The results are presented in Table 4.3.

Project No.	Project Cost ($)	LEED Certified	LEED Silver	LEED Gold	LEED Platinum
P1	$5,880,837.08	$0.00	$0.00	$20,349.01	$266,402.55
P2	$2,950,894.26	$0.00	$849.00	$21,280.46	$115,285.20
P3	$4,863,648.97	$0.00	$0.00	$27,063.58	$330,418.67
P4	$11,582,915.63	$0.00	$0.00	$178,582.71	$1,778,222.10
P5	$4,007,915.94	$0.00	$0.00	$10,800.83	$164,048.03
P6	$6,073,705.75	$0.00	$0.00	$28,162.90	$359,905.06

Table 4.2: Cost Increase per LEED Certification

Project No.	Project Cost ($)	LEED Certified	LEED Silver	LEED Gold	LEED Platinum
P1	$5,880,837.08	0.00%	0.00%	0.35%	4.53%
P2	$2,950,894.26	0.00%	0.03%	0.72%	3.91%
P3	$4,863,648.97	0.00%	0.00%	0.56%	6.79%
P4	$11,582,915.63	0.00%	0.00%	1.54%	15.35%
P5	$4,007,915.94	0.00%	0.00%	0.27%	4.09%
P6	$6,073,705.75	0.00%	0.00%	0.46%	5.93%

Table 4.3: Cost Increase as a Percentage of Total Project Cost

Reviewing the results presented in Table 4.3, there are no variations at the Certified and Silver tiers while there is slight variation at the Gold tier and a noticeable variations at the Platinum tier. LEED v4.1 certification at the Certified and Silver tiers average at negligible additional cost to the projects, while costs for Gold and Platinum tiers require an increase of investment at averages of 0.65% and 6.77%, respectively. At the Gold and Platinum tiers, the average percentage increase is mainly driven by the largest project in the sample group, nearly doubling the next lowest project. When removing the High-Rise Building from the data, the Gold and Platinum averages become 0.47% and 5.05%, respectively.

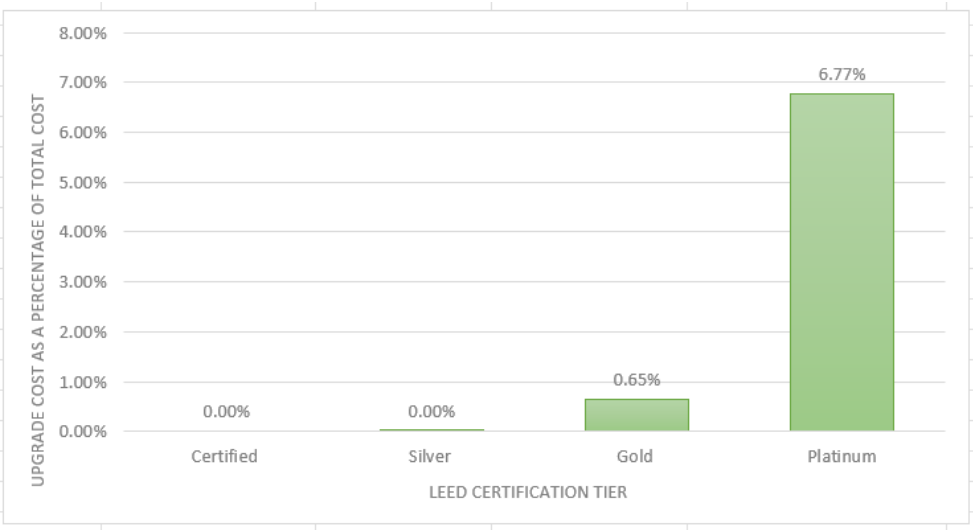

Figure 4.1: LEED Certification Cost as a Percentage of Total Cost

Figure 4.1 shows the variation is between the tiers. Certified and Silver tiers have less variation among them than Gold and Platinum tiers.

Discussion

This section's goal is to answer the questions posed at the beginning of the research which are, "What is the financial investment required to certify a project with the different tiers of LEED?", "Which LEED categories have the biggest influence for this specific type of construction?", and "Which categories require the largest investment?" In this study, the comparison between upgrading the projects to the applicable tiers of LEED v4.1 Residential: Multifamily is discussed. The credits and

regulations with regional benefits in the Green Building rating system are identified. Finally, the hypothesis is discussed.

Total Investment

Figure 4.2 depicts the cost estimate performed on all project upgrades to achieve different LEED certification tiers.

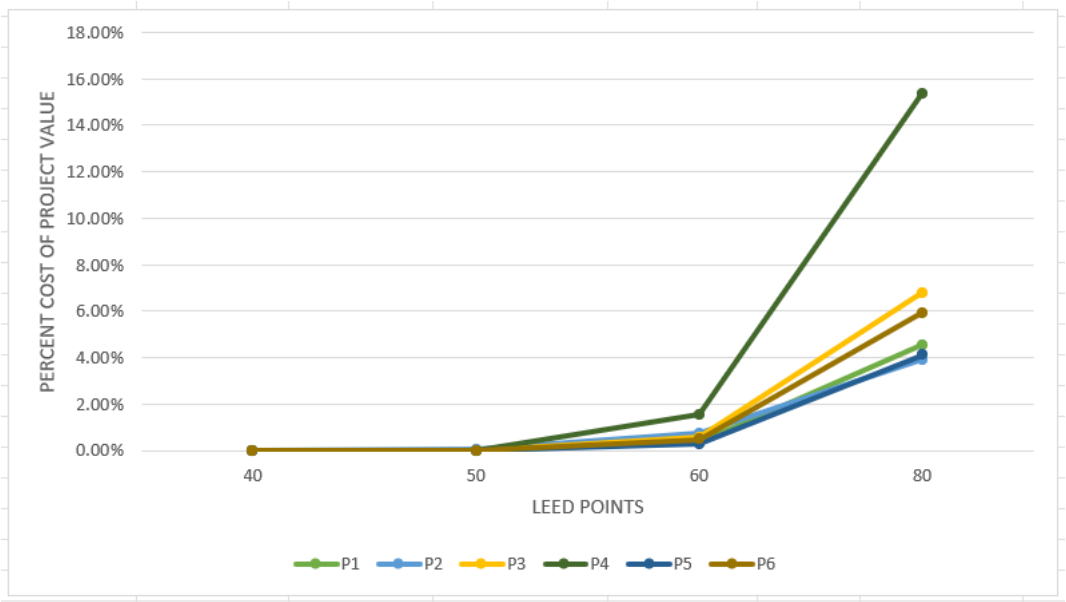

Figure 4.2: LEED Certification at All Tiers

Category Influence & Investment Required Per Category

The LEED scoring categories are broken up into nine categories. Only five of these categories carry at least 10% of the total points available. The categories and

their associated percentage makeup of the maximum available points are shown below:

- Integrative Process (0.9%)
- Location & Transportation (13.6%)
- Sustainable Sites (8.2%)
- Water Efficiency (10.9%)
- Energy & Atmosphere (30.9%)
- Materials & Resources (11.8%)
- Indoor Environmental Quality (14.5%)
- Innovation (5.5%)
- Regional Priority (3.6%)

As we can see from this breakdown, approximately 60% of all available points come from just three categories (Location & Transportation, Energy & Atmosphere, and Indoor Environmental Quality). This research also aims to determine the financial impact of each category and the ease at which they are obtainable in relation to this specific type of construction.

Chapter 5

SUMMARY & CONCLUDING REMARKS

A methodology was developed to compare the average cost and percentage increase of investment to upgrade 5 projects to LEED Certified, Silver, and Gold levels using LEED v4.1 for Multifamily Construction. The minimum cost to meet the different tiers was estimated.

LEED (Leadership in Energy and Environmental Design) is the most common Green Building certification system used in the United States. This study showed that projects can obtain LEED Certified and Silver tiers at negligible cost, while projects aiming to obtain Gold and Platinum tiers would require minimal to significant investments.

This research set out to answer three questions, as presented in Chapter 1. The first question pertains to the increased investment cost required to certify adaptive reuse projects at each of the LEED tiers. The data was investigated to conclude that projects acquiring Certified, Silver, Gold, and Platinum tiers required, on average, an additional investment of 0%, 0.01%, 0.65%, and 6.77%, respectively.

The second and third questions ask which category has the largest impact on total points and which category requires the largest investment. The data suggests that Location and Transportation and Indoor Environmental Quality have the largest impact on adaptive reuse projects hoping to maximize points while minimizing costs.

The main benefit of the specific nature of these projects is their urban location and existing infrastructure when considering the Location & Transportation and Indoor Environmental Quality credits. Many points are achieved at little-to-no cost when compared to the total project cost. Comparatively, significant investments in Energy and Atmosphere are required when aiming for LEED Gold and Platinum tiers.

Research Contribution

This research contributes to the available knowledge by:

- Providing an estimate for the cost of different tiers for LEED v4.1 MF for Wilmington, DE.
- This research found that projects can obtain LEED Certified and Silver tiers at negligible costs while Gold and Platinum were dependent on energy consumption.
- This research found that due to this specific type of construction and the locations of the projects, points in Location and Transportation and Indoor Environmental Quality were almost guaranteed at little-to-no additional cost.

Research Limitations

Some limitations while conducting this research:

- Lack of modeling for the Optimize Energy Performance credit. This research used a published study to estimate and assess the cost and points for this credit.
- Lack of month-by-month data for energy consumption.
    - This research estimated energy consumption using histograms provided by the project owner.
- Since the entirety of the projects' data was provided by one source, it is important to note that there may be an implicit bias. Nevertheless, the given data was evaluated fairly.

Future Research

In the future, this research would like to continue to add projects to the list of those studied. Additionally, since most of these projects were of similar size, it would be useful to determine if there are large variations in upgrade costs as project size increases. Finally, future research may also benefit from studying projects with varying distances from public transportation.

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Appendix A

STATISTICAL ANALYSIS

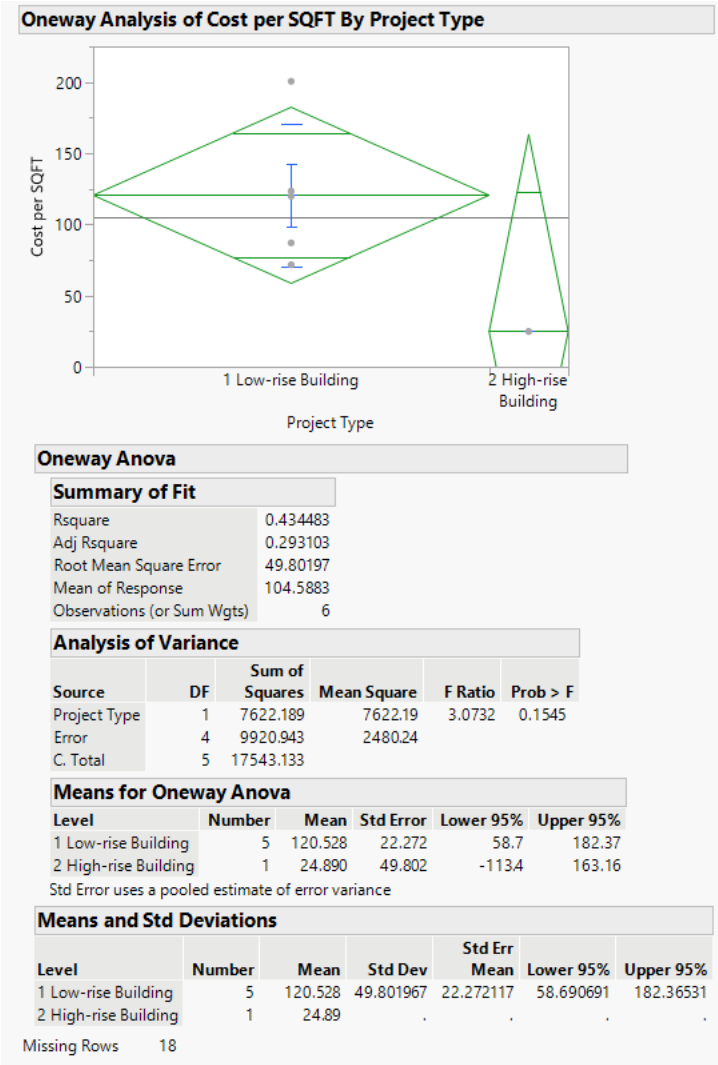


Figure A-1: ANOVA Test for Project Type vs Cost per SQFT

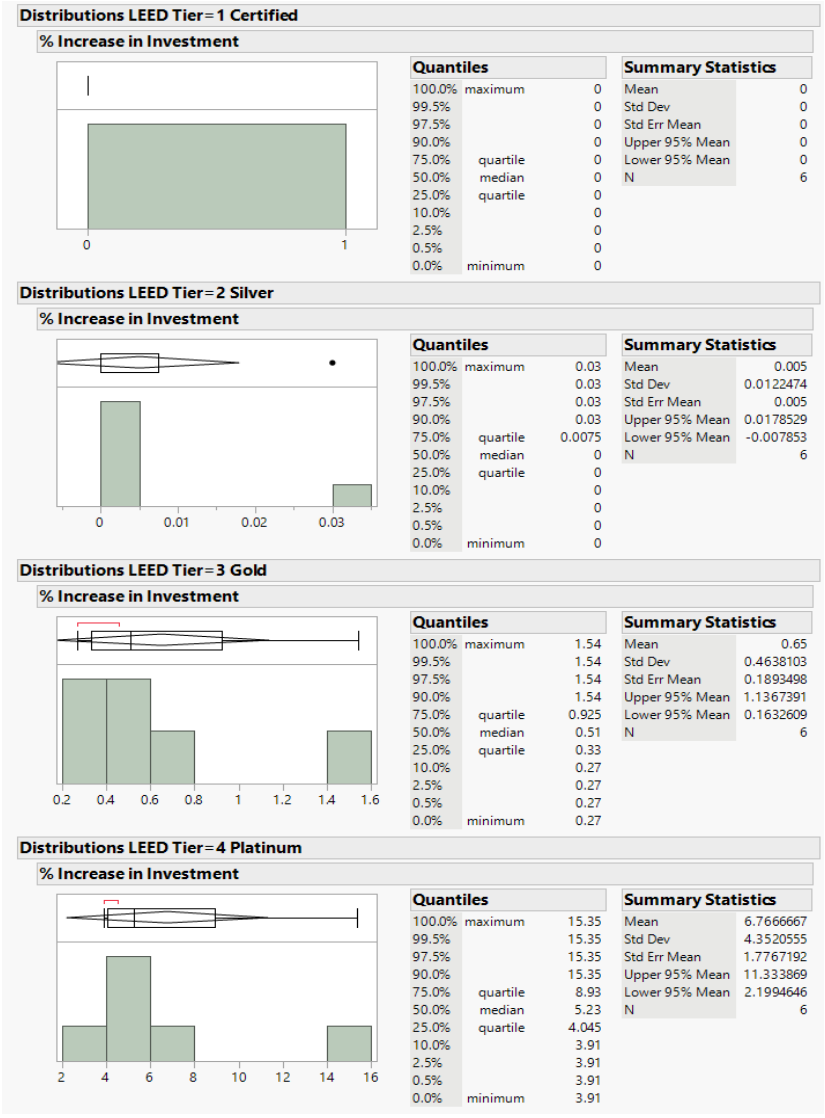


Figure A-2: Distribution of Cost Increase per LEED Tier

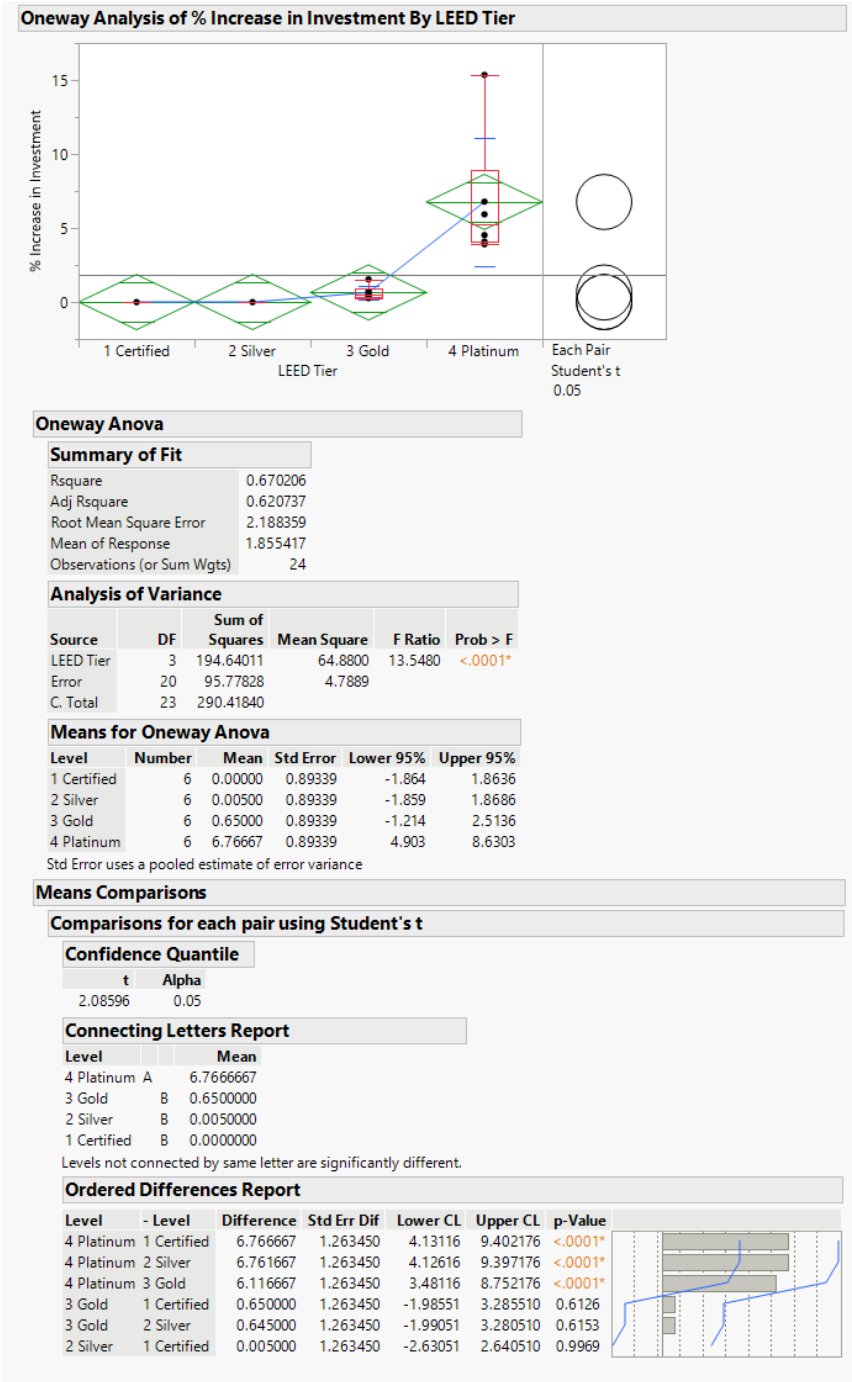
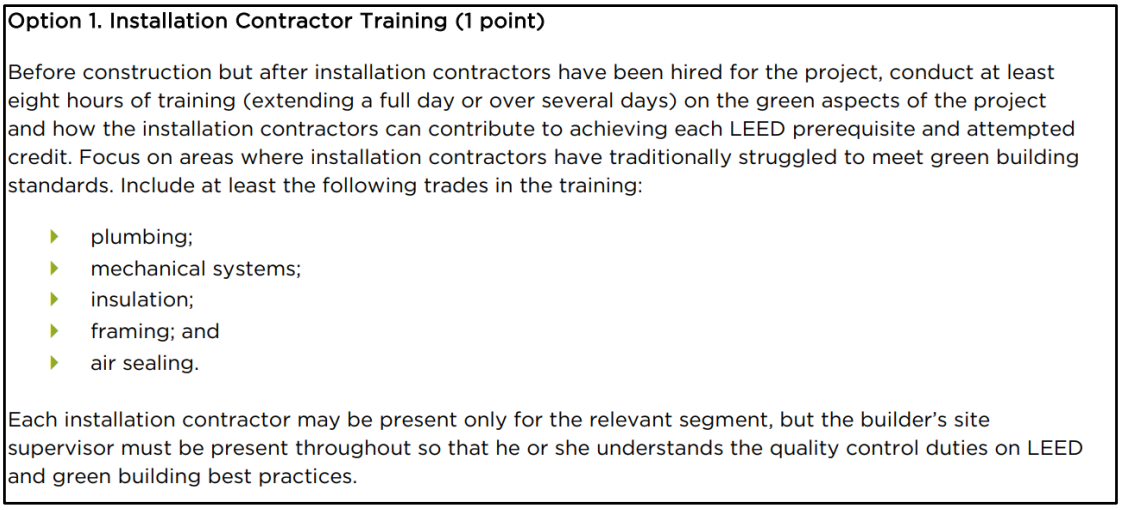


Figure A-3: ANOVA Test of Increased Investment per LEED Tier

Appendix B

PROJECT SUMMARY DATA

Integrative Process



Option 1. Installation Contractor Training (1 point)

Before construction but after installation contractors have been hired for the project, conduct at least eight hours of training (extending a full day or over several days) on the green aspects of the project and how the installation contractors can contribute to achieving each LEED prerequisite and attempted credit. Focus on areas where installation contractors have traditionally struggled to meet green building standards. Include at least the following trades in the training:

- plumbing;
- mechanical systems;
- insulation;
- framing; and
- air sealing.

Each installation contractor may be present only for the relevant segment, but the builder's site supervisor must be present throughout so that he or she understands the quality control duties on LEED and green building best practices.

Figure B-1: Screenshot of Integrative Process

This credit can be accomplished at no additional cost to the project. Project owner and managers can organize a project-wide meeting to train and inform each project team on the specific green aspects of the project.

Location & Transportation

Sensitive Land Protection

Sensitive Land Protection				Points	Cost
				2	$ -
Option 1: Previously Developed Land					
Is the project located on land that has previously been developed?			Yes		
or	**Can choose either**				
Option 2: Avoidance of Sensitive Land					
Is the project located in any of the following areas? (Yes/No)					
Prime Farmland					
Floodplains					
Habitat land of threatened species					
Water bodies					
Wetlands					

Option 1. Previously Developed Land (2 points)

Locate the development footprint on land that has been *previously developed*.

OR

Option 2. Avoidance of Sensitive Land (1 point)

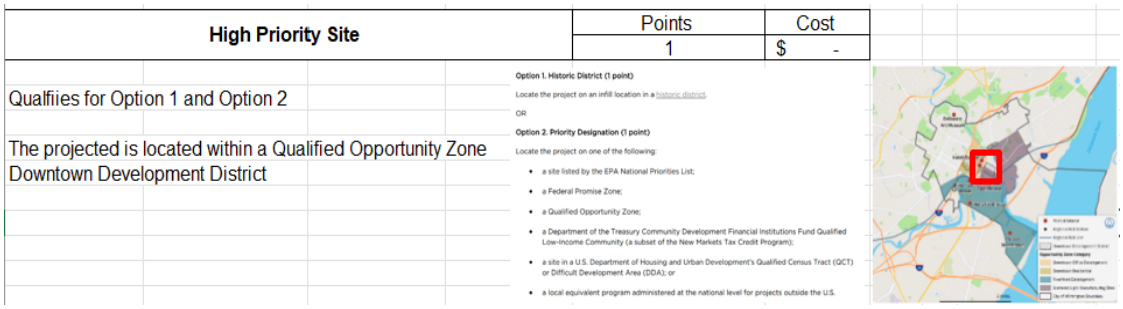
Locate the development footprint on land that does not meet the following criteria for sensitive land:

- *Prime farmland.* Prime farmland, unique farmland, or farmland of statewide or local importance as defined by the U.S. Code of Federal Regulations, Title 7, Volume 6, Parts 400 to 699, Section 657.5 (or local equivalent for projects outside the U.S.) and identified in a state Natural Resources Conservation Service soil survey (or local equivalent for projects outside the U.S.).
- *Floodplains.* A flood hazard area shown on a legally adopted flood hazard map or otherwise legally designated by the local jurisdiction or the state. For projects in places without legally adopted flood hazard maps or legal designations, locate on a site that is entirely outside any floodplain subject to a 1% or greater chance of flooding in any given year.
- *Habitat.* Land identified as habitat for the following:
  - species listed as threatened or endangered under the U.S. Endangered Species Act or the state's endangered species act, or
  - species or ecological communities classified by NatureServe as GH (possibly extinct), G1 (critically imperiled), or G2 (imperiled), or
  - species listed as threatened or endangered specifies under local equivalent standards (for projects outside the U.S.) that are not covered by NatureServe data.
- *Water bodies.* Areas on or within 100 feet (30 meters) of a *water body*, except for minor improvements.
- *Wetlands.* Areas on or within 50 feet (15 meters) of a *wetland*, except for minor improvements.

Figure B-2: Screenshot of Sensitive Land Protection

This project obtains 2 points for the Sensitive Land Protection category. It can obtain these points using either option. Option 1 requires the project to be located on land which has been previously developed, which by nature of adaptive reuse, the project obtains this option. Option 2 is attained by avoiding construction on prime farmland, floodplains, habitats of threatened species, water bodies, or wetland. This credit is obtained through the project's location in an urban city. The only option that would pose a threat to obtaining Option 2 is if the project exists within a floodplain as it is near a large river, however it exists outside of the floodplain.

High Priority Site



High Priority Site	Points	Cost
	1	$ -

Qualfiies for Option 1 and Option 2

The projected is located within a Qualified Opportunity Zone
Downtown Development District

Option 1. Historic District (1 point)

Locate the project on an infill location in a historic district.

OR

Option 2. Priority Designation (1 point)

Locate the project on one of the following:

- a site listed by the EPA National Priorities List;
- a Federal Promise Zone;
- a Qualified Opportunity Zone;
- a Department of the Treasury Community Development Financial Institutions Fund Qualified Low-Income Community (a subset of the New Markets Tax Credit Program);
- a site in a U.S. Department of Housing and Urban Development's Qualified Census Tract (QCT) or Difficult Development Area (DDA); or
- a local equivalent program administered at the national level for projects outside the U.S.

Figure B-3: Screenshot of High Priority Site

The High Priority Site credit can be achieved through one of three options. These options require the project to be located in a historic district (Option 1) or a Priority Designation site (Option 2) which includes Federal Promise Zones, a site from the EPA National Priorities List, Qualified Opportunity Zones. Additionally, Option 3 can be attained if the project is located on a brownfield site due for remediation. This sample project qualifies for Options 1 and 2 as it is in the Downtown Wilmington Historic District and an Opportunity Zone.

Surrounding Density and Diverse Uses

Surrounding Density and Diverse Uses			Points	Cost
			5	$ -
Uses within 1/2 mile				
			Applicable categories (yes)	
Category	**Use type**			
Food Retail	Supermarket		No	
	Grocery with produce section		Yes	
Community-serviing retails	Convenience store		Yes	
	Farmers market		No	
	Hardware store		No	
	Pharmacy		Yes	
	Other retail		Yes	
Services	Bank		Yes	
	Family entertainment venue		No	
	Gym, Health club, exercise studio		Yes	
	Hair care		Yes	
	Laundry, dry cleaner		Yes	
	Resturant, café, diner		Yes	
Civic and community facilties	Adult or senior care		Yes	
	Child care		Yes	
	Community or recreation center		Yes	
	Cultural arts facility		Yes	
	Education facility		Yes	
	Government office that serves		Yes	
	Medical clinic or office that treats		Yes	
	Place of worship		Yes	
	Police or fire station		Yes	
	Post office		Yes	
	Public library		Yes	
	Public park		Yes	
	Social services center		Yes	
Community anchor uses	Commerical office		Yes	
	Housing		Yes	

Table 1a. Points for average density within 1/4 mile of project (IP units)

Combined density	Separate residential and nonresidential densities		Points
Square feet per acre of buildable land	Residential density (DU/acre)	Nonresidential density (FAR)	Multifamily
22,000	7	0.5	2
35,000	12	0.8	3

Table 1. Points for proximity to uses

Multifamily: Uses	Points
4-7	1
≥ 8	2

Figure B-4: Screenshot of Surrounding Density and Diverse Uses

This credit category can be obtained by combing two available options for a maximum of 5 points. Option 1 requires a minimum density within ¼ mi. surrounding the site. Option 2 requires a minimum number of diverse uses within ½ mi. surrounding the project site. The project meets the minimum density criteria and diverse uses to attain the full 5 points.

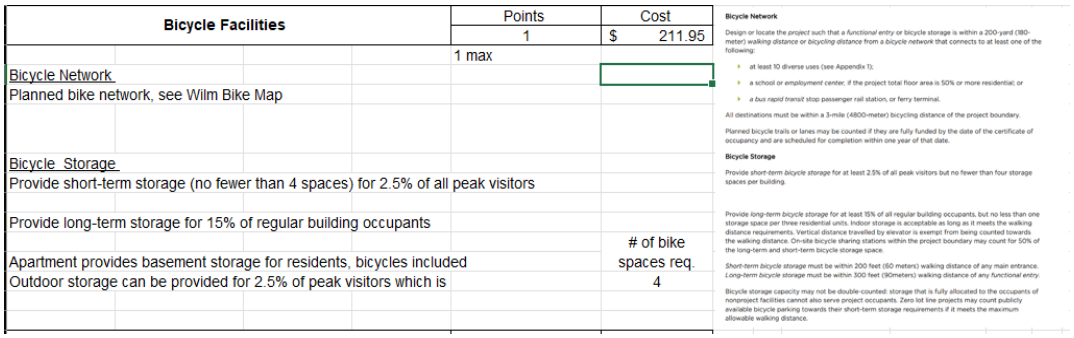
Access to Quality Transit

Access to Quality Transit				Points	Cost
				2	$ -
Distance to stops is not an issue				3 max	
	Weekday Trips	Weekend Trips			
Bus Trips (directly outside)	155	34	MKT St and 9th route for weekday, MKT and Lea Blvd for weekend		
Rail Trips (1/2 mi walk)	210	68	Wilmington Region Rail SEPTA	17 weekday	9 weekend
Total(s)	365	102	AMTRAK	125 weekday	25 weekend

Figure B-5: Screenshot of Access to Quality Transit

Projects are awarded points based on a minimum number of weekday and weekend trips from transit stops within ¼ to ½ mi. depending on the type of transit for project end-users. This project meets the requirements for Access to Quality Transit and obtains 2 points. The project is located within short walking distances to multiple bus routes and was determined using Google Earth to reside within the ½ mi. walking distance limit of a rail station.

Bicycle Facilities

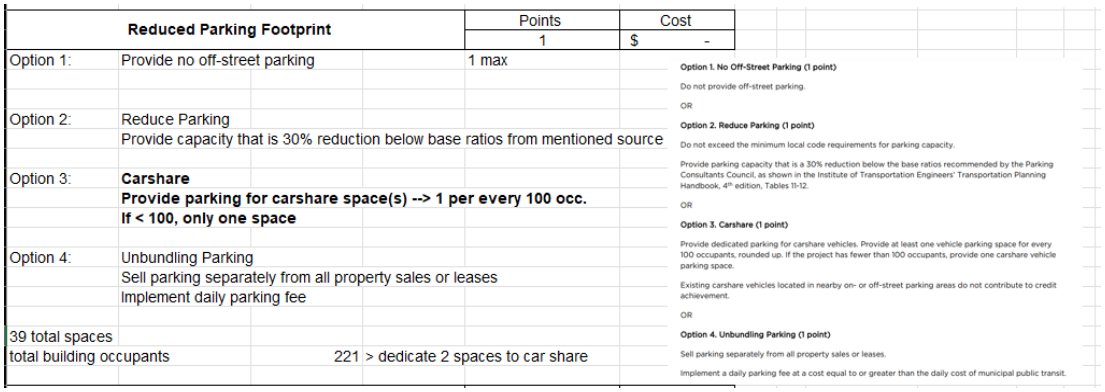


Bicycle Facilities	Points	Cost
	1	$ 211.95
	1 max	
Bicycle Network		
Planned bike network, see Wilm Bike Map		
Bicycle Storage		
Provide short-term storage (no fewer than 4 spaces) for 2.5% of all peak visitors		
Provide long-term storage for 15% of regular building occupants		
		# of bike
Apartment provides basement storage for residents, bicycles included		spaces req.
Outdoor storage can be provided for 2.5% of peak visitors which is		4

Figure B-6: Screenshot of Bicycle Facilities

The Bicycle Facilities Point is achieved through locating a project within 200 yd. of a bicycle network that connects to at least 10 diverse uses, a school or employment center, or a bus or passenger rail station. The project must also supply bicycle storage for 2.5% of peak visitors to the site and 15% of regular building occupants. The sample project achieves this point by being located within 200 yd. of a bicycle network, providing basement storage for regular building occupants and provides enough storage for the 2.5% of the 160 peak visitors (4 storage units). The cost of the added storage is $211.95 as per market quotation.

Reduced Parking Footprint



Reduced Parking Footprint		Points	Cost
		1	$ -
Option 1:	Provide no off-street parking	1 max	
Option 2:	Reduce Parking		
	Provide capacity that is 30% reduction below base ratios from mentioned source		
Option 3:	**Carshare**		
	Provide parking for carshare space(s) --> 1 per every 100 occ.		
	If < 100, only one space		
Option 4:	Unbundling Parking		
	Sell parking separately from all property sales or leases		
	Implement daily parking fee		
39 total spaces			
total building occupants	221 > dedicate 2 spaces to car share		

Option 1. No Off-Street Parking (1 point)

Do not provide off-street parking.

OR

Option 2. Reduce Parking (1 point)

Do not exceed the minimum local code requirements for parking capacity.

Provide parking capacity that is a 30% reduction below the base ratios recommended by the Parking Consultants Council, as shown in the Institute of Transportation Engineers' Transportation Planning Handbook, 4th edition, Tables 11-12.

OR

Option 3. Carshare (1 point)

Provide dedicated parking for carshare vehicles. Provide at least one vehicle parking space for every 100 occupants, rounded up. If the project has fewer than 100 occupants, provide one carshare vehicle parking space.

Existing carshare vehicles located in nearby on- or off-street parking areas do not contribute to credit achievement.

OR

Option 4. Unbundling Parking (1 point)

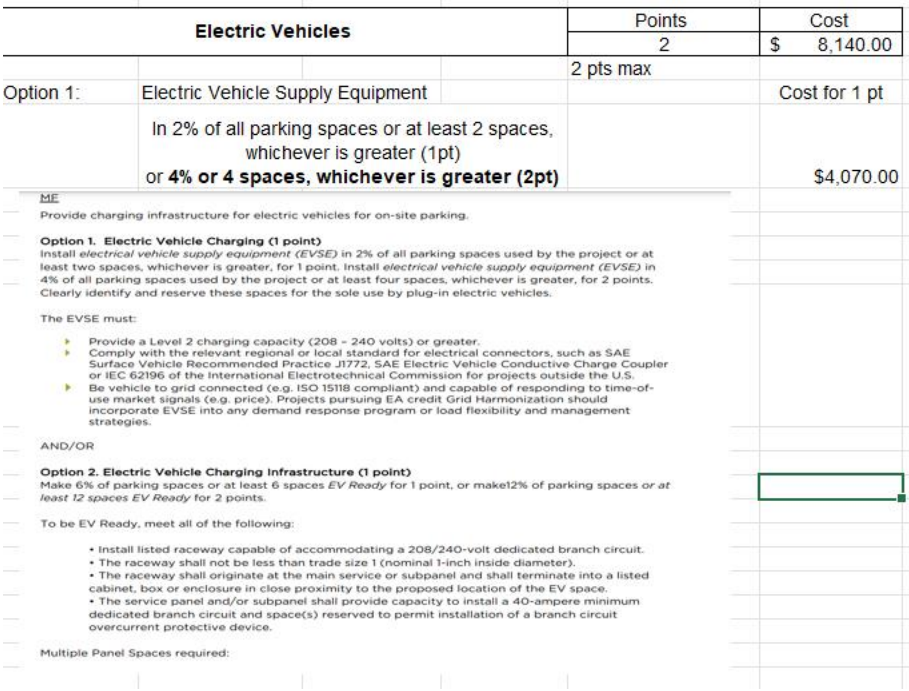
Sell parking separately from all property sales or leases.

Implement a daily parking fee at a cost equal to or greater than the daily cost of municipal public transit.

Figure B-7: Screenshot of Reduced Parking Footprint

This credit is attained through the implementation of one of four options. These options are to provide zero off-street parking, reduce parking by 30% base ratios, provide carsharing spaces (1 per every 100 occupant), or selling parking separately from property sales or leases. The studied project obtains the point by providing 2 carsharing spaces of its original 39 spaces to the 221 building occupants.

Electric Vehicles



Electric Vehicles		Points	Cost
		2	$ 8,140.00
		2 pts max	
Option 1:	Electric Vehicle Supply Equipment		Cost for 1 pt
	In 2% of all parking spaces or at least 2 spaces, whichever is greater (1pt) or **4% or 4 spaces, whichever is greater (2pt)**		$4,070.00

ME

Provide charging infrastructure for electric vehicles for on-site parking.

Option 1. Electric Vehicle Charging (1 point)
Install *electrical vehicle supply equipment (EVSE)* in 2% of all parking spaces used by the project or at least two spaces, whichever is greater, for 1 point. Install *electrical vehicle supply equipment (EVSE)* in 4% of all parking spaces used by the project or at least four spaces, whichever is greater, for 2 points. Clearly identify and reserve these spaces for the sole use by plug-in electric vehicles.

The EVSE must:

- Provide a Level 2 charging capacity (208 – 240 volts) or greater.
- Comply with the relevant regional or local standard for electrical connectors, such as SAE Surface Vehicle Recommended Practice J1772, SAE Electric Vehicle Conductive Charge Coupler or IEC 62196 of the International Electrotechnical Commission for projects outside the U.S.
- Be vehicle to grid connected (e.g. ISO 15118 compliant) and capable of responding to time-of-use market signals (e.g. price). Projects pursuing EA credit Grid Harmonization should incorporate EVSE into any demand response program or load flexibility and management strategies.

AND/OR

Option 2. Electric Vehicle Charging Infrastructure (1 point)
Make 6% of parking spaces or at least 6 spaces *EV Ready* for 1 point, or make12% of parking spaces *or at least 12 spaces EV Ready* for 2 points.

To be EV Ready, meet all of the following:

- Install listed raceway capable of accommodating a 208/240-volt dedicated branch circuit.
- The raceway shall not be less than trade size 1 (nominal 1-inch inside diameter).
- The raceway shall originate at the main service or subpanel and shall terminate into a listed cabinet, box or enclosure in close proximity to the proposed location of the EV space.
- The service panel and/or subpanel shall provide capacity to install a 40-ampere minimum dedicated branch circuit and space(s) reserved to permit installation of a branch circuit overcurrent protective device.

Multiple Panel Spaces required:

Figure B-8: Screenshot of Electric Vehicles

The Electric Vehicles credit requires projects to supply electric vehicle charging stations (Option1) or install infrastructure for future stations (Option 2). The project chose to attain points via Option 1 as it was determined to be the less expensive route and more valuable point route. To achieve Option 1 the project must provide, charging supply for 2% of parking spaces for 1 point or 4% of parking spaces for 2 points. This point was achieved through the installation of Electric Vehicle (EV) charging points for 4 spaces in the available parking lot. The cost to install EV each charging station was estimated to be $2035 (Idaho National Laboratory, 2015) which brings the total added cost to $8,140.

Sustainable Sites

Construction Activity Pollution Prevention

MF

Stockpile and protect disturbed topsoil from erosion (for reuse).

Control the path and velocity of runoff with silt fencing or comparable measures.

Protect on-site storm sewer inlets, streams, and lakes with straw bales, silt fencing, silt sacks, rock filters, or comparable measures.

Provide swales to divert surface water from hillsides.

Use tiers, erosion blankets, compost blankets, filter socks, berms, or comparable measures to stabilize soils in any area with a slope of 15% (6.6:1) or more that is disturbed during construction.

Projects in locations that have construction activity air pollution rules must prevent air pollution from dust and particulate matter.

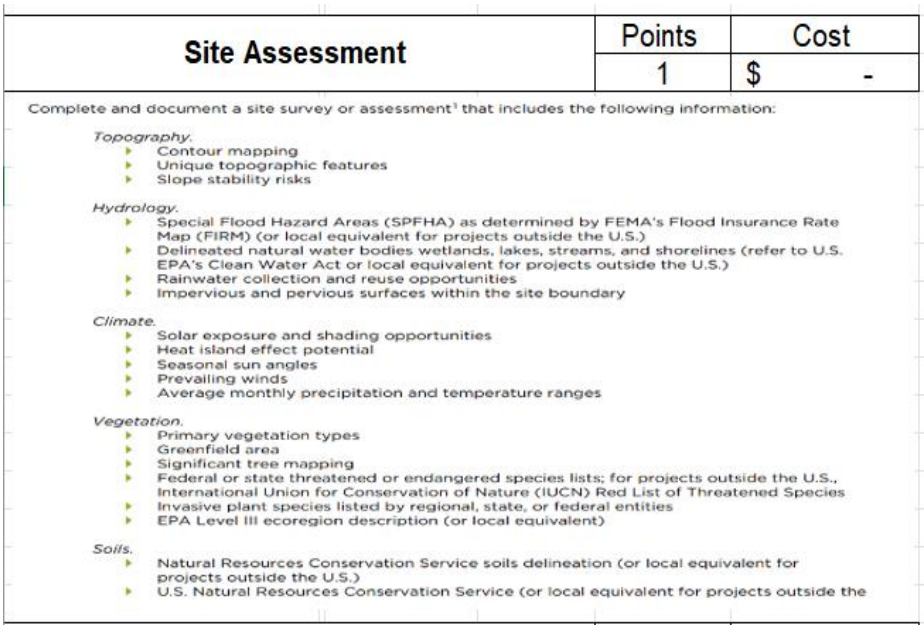
OR

Create and implement an erosion and sedimentation control plan for all construction activities associated with the project. The plan must conform to the erosion and sedimentation requirements of the 2017 U.S. Environmental Protection Agency (EPA) Construction General Permit (CGP) or local equivalent, whichever is more stringent. Projects must apply the CGP regardless of size. The plan must describe the measures implemented.

Figure B-9: Screenshot of Construction Activity Pollution Prevention

This category is a prerequisite which requires the creation and implementation of a sedimentation and erosion control plan. If not fully covered by the City of Wilmington building code, the project team can create a unique plan to prevent erosion and sedimentation from construction activity at no additional cost.

Site Assessment



Site Assessment	Points	Cost
	1	$ -

Complete and document a site survey or assessment[1] that includes the following information:

Topography.
- Contour mapping
- Unique topographic features
- Slope stability risks

Hydrology.
- Special Flood Hazard Areas (SPFHA) as determined by FEMA's Flood Insurance Rate Map (FIRM) (or local equivalent for projects outside the U.S.)
- Delineated natural water bodies wetlands, lakes, streams, and shorelines (refer to U.S. EPA's Clean Water Act or local equivalent for projects outside the U.S.)
- Rainwater collection and reuse opportunities
- Impervious and pervious surfaces within the site boundary

Climate.
- Solar exposure and shading opportunities
- Heat island effect potential
- Seasonal sun angles
- Prevailing winds
- Average monthly precipitation and temperature ranges

Vegetation.
- Primary vegetation types
- Greenfield area
- Significant tree mapping
- Federal or state threatened or endangered species lists; for projects outside the U.S., International Union for Conservation of Nature (IUCN) Red List of Threatened Species
- Invasive plant species listed by regional, state, or federal entities
- EPA Level III ecoregion description (or local equivalent)

Soils.
- Natural Resources Conservation Service soils delineation (or local equivalent for projects outside the U.S.)
- U.S. Natural Resources Conservation Service (or local equivalent for projects outside the

Figure B-10: Screenshot of Site Assessment

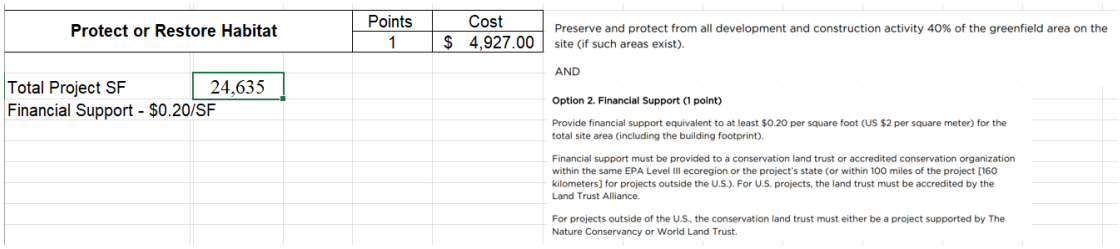
The Site Assessment credit requires the creation and completion of a site survey including:

- Topography: contour mapping, slope stability risks
- Hydrology: rainwater collection and reuse opportunities, flood hazard areas, pervious and impervious surfaces
- Climate: heat island effect potential, solar exposure and shading, prevailing winds
- Vegetation: primary vegetation types, significant tree mapping, invasive plant species
- Soils: previous development, healthy soils, disturbed soils

- Human Use: views, adjacent transportation infrastructure, adjacent diverse uses
- Human Health Effects: proximity to vulnerable populations, proximity to sources of air and water pollution

A site assessment can be completed at little-to-no additional cost to the project.

Protect or Restore Habitat



Protect or Restore Habitat	Points	Cost
	1	$ 4,927.00

Total Project SF 24,635
Financial Support - $0.20/SF

Preserve and protect from all development and construction activity 40% of the greenfield area on the site (if such areas exist).

AND

Option 2. Financial Support (1 point)

Provide financial support equivalent to at least $0.20 per square foot (US $2 per square meter) for the total site area (including the building footprint).

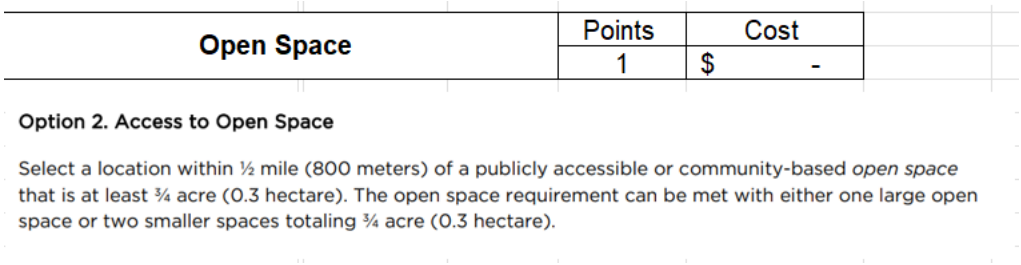
Financial support must be provided to a conservation land trust or accredited conservation organization within the same EPA Level III ecoregion or the project's state (or within 100 miles of the project [160 kilometers] for projects outside the U.S.). For U.S. projects, the land trust must be accredited by the Land Trust Alliance.

For projects outside of the U.S., the conservation land trust must either be a project supported by The Nature Conservancy or World Land Trust.

Figure B-11: Screenshot of Protect or Restore Habitat

Option 1 of Protect or Restore Habitat is not applicable as the site is a Zero Lot Line project, therefore it must achieve Option 2: Financial Support. This option can be attained by providing the equivalent to at least $0.20 per square foot of the total site area to a conservation land trust or accredited conservation organization withing the same EPA Level III ecoregion or the state which the project is located within. For this project that cost amounts to $4,927.

Open Space



Open Space	Points	Cost
	1	$ -

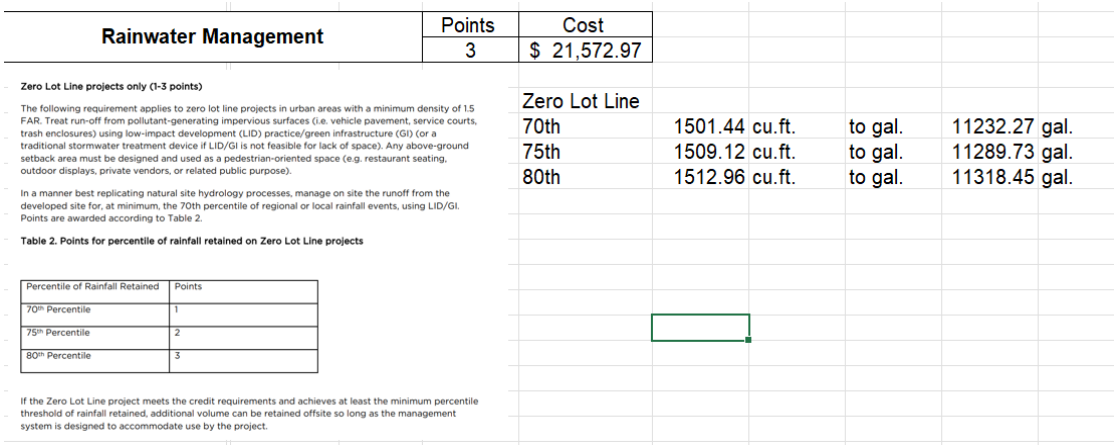
Option 2. Access to Open Space

Select a location within ½ mile (800 meters) of a publicly accessible or community-based *open space* that is at least ¾ acre (0.3 hectare). The open space requirement can be met with either one large open space or two smaller spaces totaling ¾ acre (0.3 hectare).

Figure B-12: Screenshot of Open Space

Option 1 of Open Space is not applicable as the project is a Zero Lot Line site, therefore it must obtain Option 2. Option 2 requires access to a publicly accessible or community-based open space within ½ mi. and at least ¾ acre. This project attains the credit as it is located within ½ mi. of two publicly accessible parks that total at least ¾ acre.

Rainwater Management



Rainwater Management	Points	Cost
	3	$ 21,572.97

Zero Lot Line projects only (1-3 points)

The following requirement applies to zero lot line projects in urban areas with a minimum density of 1.5 FAR. Treat run-off from pollutant-generating impervious surfaces (i.e. vehicle pavement, service courts, trash enclosures) using low-impact development (LID) practice/green infrastructure (GI) (or a traditional stormwater treatment device if LID/GI is not feasible for lack of space). Any above-ground setback area must be designed and used as a pedestrian-oriented space (e.g. restaurant seating, outdoor displays, private vendors, or related public purpose).

In a manner best replicating natural site hydrology processes, manage on site the runoff from the developed site for, at minimum, the 70th percentile of regional or local rainfall events, using LID/GI. Points are awarded according to Table 2.

Table 2. Points for percentile of rainfall retained on Zero Lot Line projects

Percentile of Rainfall Retained	Points
70th Percentile	1
75th Percentile	2
80th Percentile	3

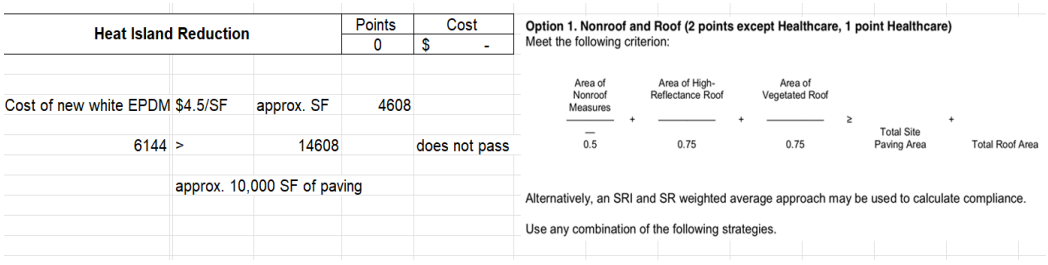
If the Zero Lot Line project meets the credit requirements and achieves at least the minimum percentile threshold of rainfall retained, additional volume can be retained offsite so long as the management system is designed to accommodate use by the project.

Zero Lot Line				
70th	1501.44	cu.ft.	to gal.	11232.27 gal.
75th	1509.12	cu.ft.	to gal.	11289.73 gal.
80th	1512.96	cu.ft.	to gal.	11318.45 gal.

Figure B-13: Screenshot of Rainwater Management

To attain this credit, the project must either retain or collect a minimum percentile of rainfall events (Option 1) or utilize permeable lot areas (Option 2). It was determined that the option to install rainwater collection devices was the most cost-effective method to achieve the possible 3 points. As shown in Figure B-13, this project achieves 3 points by collecting the 80th percentile of rainfall events through water collection tanks in the basement. The cost of rainwater collection tanks was determined from the current market and was priced at $7,190.99/each for a 5000 gal. tank. To collect the 80th percentile the project would require three tanks, with a total cost of $21,572.97.

Heat Island Reduction



Heat Island Reduction			Points	Cost
			0	$ -
Cost of new white EPDM	$4.5/SF	approx. SF	4608	
6144	>	14608		does not pass
	approx. 10,000 SF of paving			

Option 1. Nonroof and Roof (2 points except Healthcare, 1 point Healthcare)
Meet the following criterion:

$$\frac{\text{Area of Nonroof Measures}}{0.5} + \frac{\text{Area of High-Reflectance Roof}}{0.75} + \frac{\text{Area of Vegetated Roof}}{0.75} \geq \text{Total Site Paving Area} + \text{Total Roof Area}$$

Alternatively, an SRI and SR weighted average approach may be used to calculate compliance.

Use any combination of the following strategies.

Figure B-14: Screenshot of Heat Island Reduction

This project does not qualify for the Heat Island Reduction credit as it does not provide shad for hardscapes areas (i.e. parking lot) nor does it meet the requirements given by the equation shown in Figure B-14, as provided by the LEED Guidelines.

Light Pollution Reduction

The Light Pollution Reduction credit requires projects to pass the BUG rating method or use the LEED Calculation method to pass lighting requirements for the project's specific lighting zone. This project does not pass either as it includes uplighting on the exterior of the building.

Water Efficiency

Water Use Reduction

Requirements

MF

Reduce aggregate water consumption by 20% from the baseline, or earn 3 points in WE credit Water Use Reduction.

For indoor water savings, use the Water Reduction Calculator to determine the average flush or flow rate for each fixture type and the estimated daily usage. The baselines for indoor water consumption are shown in Table 1.

Table 1. Baseline water consumption of fixtures and fittings

Fixture or fitting	*Baseline (IP units)*	*Baseline (SI units)*
Toilet (water closet)	1.6 gpf	6 lpf
Urinal	1.0 gpf	3.8 lpf
Public lavatory (restroom) faucet	0.5 gpm*	1.9 lpm*
Dwelling unit lavatory, and public and private kitchen faucets (excluding faucets used exclusively for filling operations)	2.2 gpm*	8.3 lpm*
Showerhead	2.5 gpm**per shower stall or compartment	9.5 lpm**per shower stall or compartment
Clothes washer	9.5 IWF	9.5 IWF
Dishwasher	6.5 gpc	24 lpc

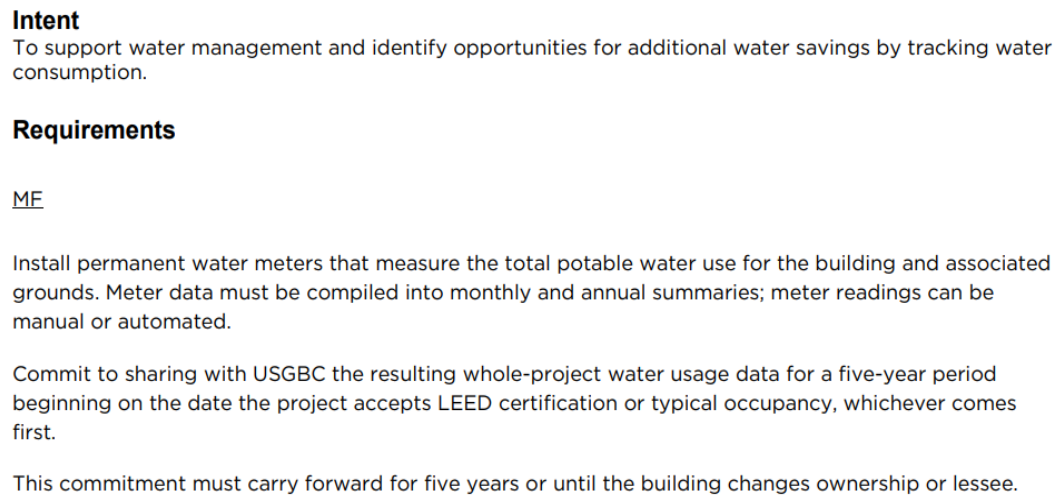
* as tested at 60 psi or 415 kPa

** as tested at 80 psi or 550 kPa

Figure B-15: Screenshot of Water Use Reduction Prerequisite

The Water Use Reduction Prerequisite has two paths to compliance. The first path is for the project to reduce water consumption by 20% from the baseline and the second path can be attained by achieving at least 3 credits in the Water Use Reduction credit category. The studied project achieves this prerequisite through both paths as it complies with the 20% reduction due to its plumbing fixtures and it receives 5 points in the Water Use Reduction credit.

Building-Level Water Metering



Intent
To support water management and identify opportunities for additional water savings by tracking water consumption.

Requirements

MF

Install permanent water meters that measure the total potable water use for the building and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated.

Commit to sharing with USGBC the resulting whole-project water usage data for a five-year period beginning on the date the project accepts LEED certification or typical occupancy, whichever comes first.

This commitment must carry forward for five years or until the building changes ownership or lessee.

Figure B-16: Screenshot of Building-Level Water Metering Prerequisite

To attain the Building-Level Water Metering Prerequisite the project must install permanent water meters that measure total potable water use for the building and compile the data into monthly and annual summaries. This project automatically achieves this prerequisite as water meters are required in accordance with the Wilmington, DE Building code Chapter 45 – Utilities.

Water Use Reduction

Path 2. Indoor Water Use Reduction (6 points)

Multifamily

Each lavatory faucet or faucet aerator must be WaterSense labeled. The average rated flow volume across all lavatory faucets must not exceed 1.5 gallons per minute (5.6 liters per minute) for 1 point

Each showerhead fixture and fitting must be WaterSense labeled. The average rated flow volume per shower compartment must not exceed 2.0 gallons per minute (11.2 liters per minute) for 1 point, 1.75 gallons per minute (6.6 liters per minute) for 2 points

Each toilet fixture and fitting must be WaterSense labeled. The average rated flush volume across all toilets must not exceed 1.28 gallons per flush (4.8 liters) for 1 point, or 1.1 gallons (4.1 liters) per flush for 2 points.

Each clothes washer must be ENERGY STAR certified or performance equivalent for projects outside the U.S. (1 point). Projects in Europe may install residential appliances meeting the EU A+++ label.

For projects outside the United States, a local equivalent to WaterSense may be used.

Multifamily projects must meet the above requirements for all *dwelling unit spaces* and *non-unit* (*residential-associated* and *nonresidential*) spaces. No additional credit is awarded if the fixtures and fittings in non-dwelling unit spaces are more efficient than those of dwelling unit spaces.

PLUMBING FIXTURE & CONNECTION SCHEDULE

SYMBOL	FIXTURE	MANUFACTURER/MODEL #	TRIM	COLOR	DRAIN	VENT	CW	HW	REMARKS
P-1	WATER CLOSET	KOHLER WELLWORTH ELONGATED TOILET K4198-0	PROVIDE WELLWORTH TANK K4467-0	WHITE	4"	2"	1"	-	PROVIDE PROFLO ED CLST SEAT SLOW w/ED-COLOR: WHITE
P-2	LAVATORY	VANITY TOP BY G.C. PROVIDE FAUCET LEDGE & FAUCET HOLES ON 4" CENTERS WITH PLUNGER DRAIN	FAUCET: MOEN WL84121 SINGLE HANDLE LEVER, PULL UP PLUNGER DRAIN STOPPER, POLISHED CHROME.	POLISHED CHROME	1½"	1¼"	½"	½"	PROVIDE LAV-GUARD TRUEBRO #102, THERMOSTATIC MIXING VALVE LFLM-495
P-3	BATH TUB & SHOWER	BATH TUB: STERLING-ST15411120	PROVIDE MOEN M62330 SHOWER PRESSURE VALVE AND MOEN MTL183 (POLISHED CHROME)	WHITE	2"	2"	½"	½"	-
P-4	KITCHEN SINK	ELKAY: CELEBRITY CR3322, POLISHED FINISH	PROVIDE FAUCET: MOEN CHATEAU MET425	-	2"	1½"	½"	½"	-
P-5	ELECTRIC WATER HEATER	BRADFORD WHITE: RE340S6, 40GAL	-	-	-	-	½"	½"	PROVIDE EMERGENCY OVERFLOW DRAIN PAN

NOTES: ALL ABOVE FIXTURES AND RELATED EQUIPMENT ABOVE SHALL BE SUBMITTED FOR APPROVAL, OR, EQUIVALENT EQUALS MAY BE SUBMITTED. SEE SPECIFICATIONS FOR FIXTURE SUBSTITUIONS. PROVIDE FIXTURE STOPS FOR ALL EQUIPMENT.

Figure B-17: Screenshot of Water Use Reduction

The Water Use Reduction credit can be achieved through two options. Option 1 can be earned by reducing indoor and outdoor water use at minimum percentage reductions from a baseline for a total of 10 points. Option 2 is earned by a combination of increasing native plantings as a percentage of total landscape area and/or reducing indoor water use through the implementation of plumbing fixtures that perform below a baseline water flow for a total of 9 points. This project attained a maximum of 5 points through Option 2 for its plumbing fixtures.

Water Metering

Option 1. Meter Water Subsystems (1 point)

Install permanent water meters for two or more of the following water subsystems, as applicable to the project:

Irrigation. Meter water systems serving at least 80% of the irrigated landscaped area. Calculate the percentage of irrigated landscape area served as the total metered irrigated landscape area divided by the total irrigated landscape area. Landscape areas fully covered with xeriscaping or native vegetation that requires no routine irrigation may be excluded from the calculation.

Indoor plumbing fixtures and fittings. Meter water systems serving at least 80% of the indoor fixtures and fitting described in WE Prerequisite Indoor Water Use Reduction, either directly or by deducting all other measured water use from the measured total water consumption of the building and grounds.

Domestic hot water. Meter water use of at least 80% of the installed domestic hot water heating capacity (including both tanks and on-demand heaters). A single makeup meter may record flows for multiple water heaters.

Boilers. A single makeup meter may record flows for multiple boilers.

Reclaimed water. Meter reclaimed water, regardless of rate. A reclaimed water system with a makeup water connection must also be metered so that the true reclaimed water component can be determined.

Other process water. Meter water use of pools, and other significant water uses.

Cooling Towers. Meter cooling towers.

AND/OR

Option 2. Meter Dwelling Units (1 point)

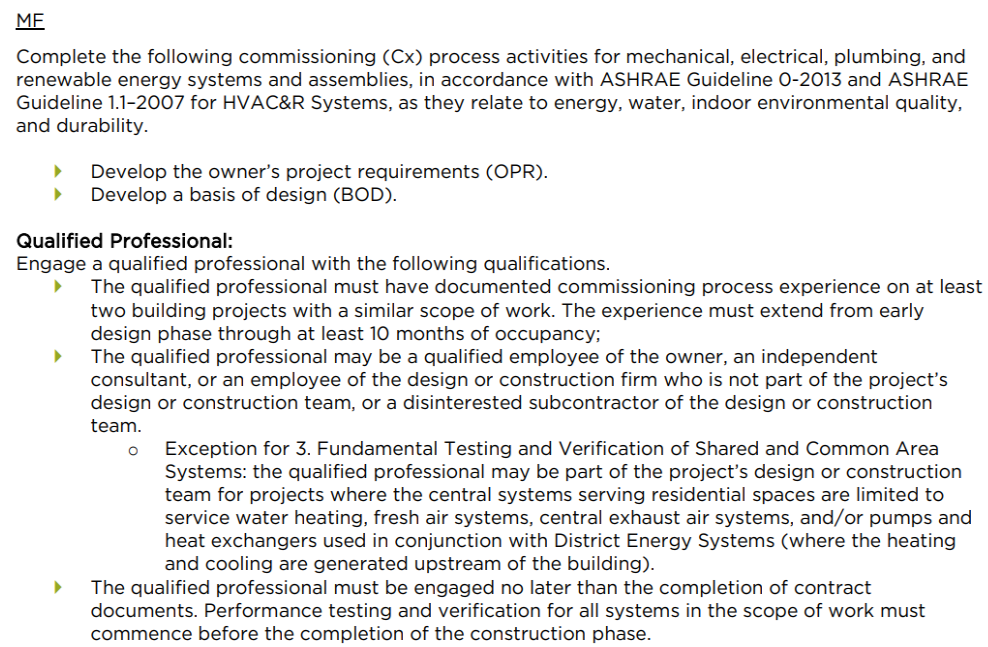
Install a permanent water meter for each residential dwelling unit that measures total potable water use for the unit. These meters need not be utility-owned/utility-grade.

Figure B-18: Screenshot of Water Metering Credit

This credit is attained by installing permanent water meters for two or more subsystems and for metering individual residential dwelling units for a maximum total of 2 points. This project achieves maximum points, first as it was estimated to cost $1,700 to install an additional meter that would record data in addition to the original. The second point is achieved for no additional cost as each dwelling unit is already metered separately and the cost is already considered in the given project cost.

Energy & Atmosphere

Fundamental Systems Testing and Verification



MF

Complete the following commissioning (Cx) process activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies, in accordance with ASHRAE Guideline 0-2013 and ASHRAE Guideline 1.1–2007 for HVAC&R Systems, as they relate to energy, water, indoor environmental quality, and durability.

- Develop the owner's project requirements (OPR).
- Develop a basis of design (BOD).

Qualified Professional:
Engage a qualified professional with the following qualifications.

- The qualified professional must have documented commissioning process experience on at least two building projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy;
- The qualified professional may be a qualified employee of the owner, an independent consultant, or an employee of the design or construction firm who is not part of the project's design or construction team, or a disinterested subcontractor of the design or construction team.
    - Exception for 3. Fundamental Testing and Verification of Shared and Common Area Systems: the qualified professional may be part of the project's design or construction team for projects where the central systems serving residential spaces are limited to service water heating, fresh air systems, central exhaust air systems, and/or pumps and heat exchangers used in conjunction with District Energy Systems (where the heating and cooling are generated upstream of the building).
- The qualified professional must be engaged no later than the completion of contract documents. Performance testing and verification for all systems in the scope of work must commence before the completion of the construction phase.

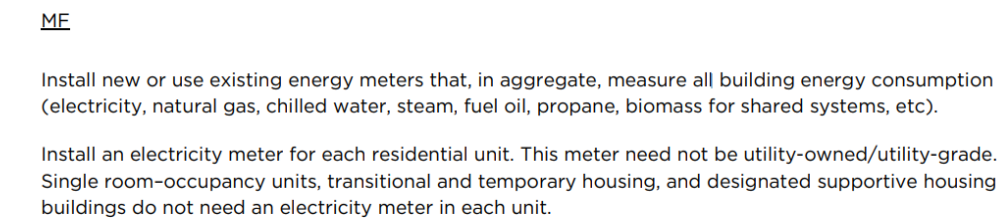
Figure B-19: Screenshot of Fundamental Systems Testing and Verification

The Fundamental Systems Testing Verification Prerequisite requires the commissioning of mechanical, electrical, plumbing, and renewable energy systems and assemblies. The commissioning follows the ASHRAE Guideline 0-2013 and ASHRAE Guideline 1.1-2007 for HVAC&R Systems. The commissioning agent can be a party that is involved with the project or an independent consultant. Projects in Wilmington, DE are required to have inspections and permits granted to under ASHRAE guidelines to be certified for occupation.

Minimum Energy Performance

The Minimum Energy Performance Prerequisite requires buildings complete unit by unit load calculations for each unique type and requires one of three other options. Option 1 requires projects to comply with ANSI/ASHRAE/IESNA Standard 90.1-2016, Option 2 requires projects to comply with the requirements of the New Buildings Institute Multifamily Guide, and Option 3 requires projects to perform dwelling unit energy simulations. Since most of the projects constructed in this study were built prior to 2016, Options 1 and 2 are unobtainable unless otherwise permitted by USGBC. Option 3: Case 2 for Major Renovation is the path chosen for this project which requires the project to exceed a HERS rating of 85. This project could not calculate the official HERS rating however, as hiring a RESNET employee to evaluate the studied projects is beyond the scope of this research. However, for the intents and purposes of this study, it is assumed that each project attains this prerequisite by following the required building and energy codes required for the city of Wilmington.

Energy Metering


MF

Install new or use existing energy meters that, in aggregate, measure all building energy consumption (electricity, natural gas, chilled water, steam, fuel oil, propane, biomass for shared systems, etc).

Install an electricity meter for each residential unit. This meter need not be utility-owned/utility-grade. Single room–occupancy units, transitional and temporary housing, and designated supportive housing buildings do not need an electricity meter in each unit.

Figure B-20: Screenshot of Energy Metering

The Energy Metering Prerequisite requires projects to install new or use existing energy meters that measure total building energy consumption. In addition, meters are required for each residential dwelling unit. This project complies with the prerequisite as the entire building as well as each dwelling unit are metered with no additional cost as the cost of installation is included in the original cost of construction provided.

Fundamental Refrigerant Management

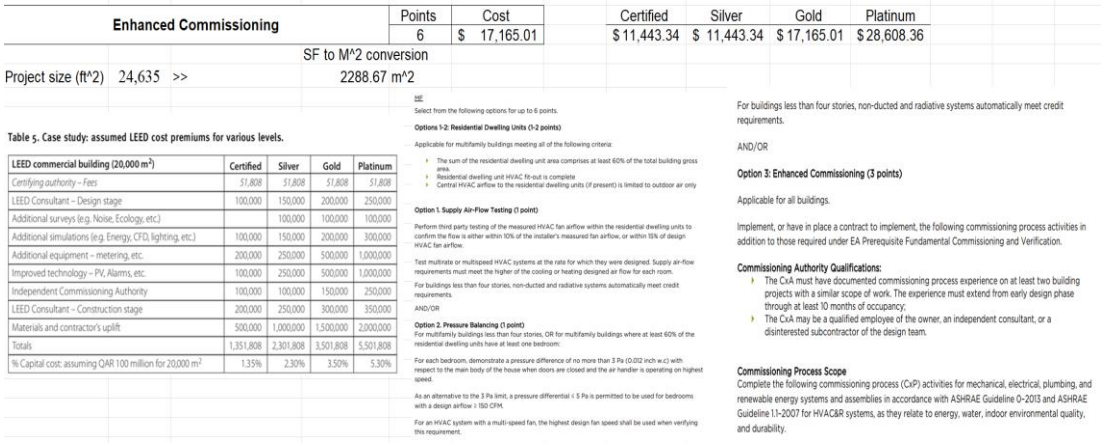
Do not use chlorofluorocarbon (CFC)-based refrigerants in new heating, ventilating, air-conditioning, and refrigeration (HVAC&R) systems. When reusing existing HVAC&R equipment, complete a comprehensive CFC phase-out conversion before project completion. Phase-out plans extending beyond the project completion date will be considered on their merits.

Existing small HVAC&R units (defined as containing less than 0.5 pound [225 grams] of refrigerant) and other equipment, such as standard refrigerators, small water coolers, and any other equipment that contains less than 0.5 pound (225 grams) of refrigerant, are exempt.

Figure B-21: Screenshot of Fundamental Refrigerant Management

This prerequisite prohibits the use of chlorofluorocarbon (CFC)-based refrigerants in new heating, ventilating, air-conditioning, and refrigeration systems. This project, as well as the rest of the projects unless otherwise indicated, is uses R-410A refrigerant which is not classified as a CFC-based refrigerant.

Enhanced Commissioning



Enhanced Commissioning	Points	Cost	Certified	Silver	Gold	Platinum
	6	$ 17,165.01	$ 11,443.34	$ 11,443.34	$ 17,165.01	$ 28,608.36

SF to M^2 conversion

Project size (ft^2) 24,635 >> 2288.67 m^2

Table 5. Case study: assumed LEED cost premiums for various levels.

LEED commercial building (20,000 m²)	Certified	Silver	Gold	Platinum
Certifying authority – Fees	*51,808*	*51,808*	*51,808*	*51,808*
LEED Consultant – Design stage	100,000	150,000	200,000	250,000
Additional surveys (e.g. Noise, Ecology, etc.)		100,000	100,000	100,000
Additional simulations (e.g. Energy, CFD, lighting, etc.)	100,000	150,000	200,000	300,000
Additional equipment – metering, etc.	200,000	250,000	500,000	1,000,000
Improved technology – PV, Alarms, etc.	100,000	250,000	500,000	1,000,000
Independent Commissioning Authority	100,000	100,000	150,000	250,000
LEED Consultant – Construction stage	200,000	250,000	300,000	350,000
Materials and contractor's uplift	500,000	1,000,000	1,500,000	2,000,000
Totals	1,351,808	2,301,808	3,501,808	5,501,808
% Capital cost: assuming QAR 100 million for 20,000 m²	1.35%	2.30%	3.50%	5.30%

HE

Select from the following options for up to 6 points.

Options 1-2: Residential Dwelling Units (1-2 points)

Applicable for multifamily buildings meeting all of the following criteria:

- The sum of the residential dwelling unit area comprises at least 60% of the total building gross area.
- Residential dwelling unit HVAC fit-out is complete
- Central HVAC airflow to the residential dwelling units (if present) is limited to outdoor air only

Option 1. Supply Air-Flow Testing (1 point)

Perform third party testing of the measured HVAC fan airflow within the residential dwelling units to confirm the flow is either within 10% of the installer's measured fan airflow, or within 15% of design HVAC fan airflow.

Test multirate or multispeed HVAC systems at the rate for which they were designed. Supply air-flow requirements must meet the higher of the cooling or heating designed air flow for each room.

For buildings less than four stories, non-ducted and radiative systems automatically meet credit requirements

AND/OR

Option 2. Pressure Balancing (1 point)

For multifamily buildings less than four stories, OR for multifamily buildings where at least 60% of the residential dwelling units have at least one bedroom:

For each bedroom, demonstrate a pressure difference of no more than 3 Pa (0.012 inch w.c) with respect to the main body of the house when doors are closed and the air handler is operating on highest speed.

As an alternative to the 3 Pa limit, a pressure differential ≤ 5 Pa is permitted to be used for bedrooms with a design airflow ≥ 150 CFM.

For an HVAC system with a multi-speed fan, the highest design fan speed shall be used when verifying this requirement.

For buildings less than four stories, non-ducted and radiative systems automatically meet credit requirements.

AND/OR

Option 3: Enhanced Commissioning (3 points)

Applicable for all buildings.

Implement, or have in place a contract to implement, the following commissioning process activities in addition to those required under EA Prerequisite Fundamental Commissioning and Verification.

Commissioning Authority Qualifications:

- The CxA must have documented commissioning process experience on at least two building projects with a similar scope of work. The experience must extend from early design phase through at least 10 months of occupancy;
- The CxA may be a qualified employee of the owner, an independent consultant, or a disinterested subcontractor of the design team.

Commissioning Process Scope

Complete the following commissioning process (CxP) activities for mechanical, electrical, plumbing, and renewable energy systems and assemblies in accordance with ASHRAE Guideline 0-2013 and ASHRAE Guideline 1.1-2007 for HVAC&R systems, as they relate to energy, water, indoor environmental quality, and durability.

Figure B-22: Screenshot of Enhanced Commissioning

Figure B-22 shows the estimate cost to achieve the Enhanced Commissioning credit at each LEED tier. The model relies on a study performed in 2017 by David Mckenna, Director of Sustainability Performance, at The Red Sea Development Company & AMAALA and estimates the cost based on project size.

Optimize Energy Performance

Area of Case Study Building				Area of Project 1					
3995 m^2				2288.67	m^2			Conservative Estimate using 1.3 multiplier	
Data		Cost ($) per m^2	Points	Cost for P1	Cost ($) per Point	Equivalence to v4 NC	Points v4.1	GHG NC	Points
431685	431685	$0.00	0	$0.00					
472005	431685	$10.09	0	$23,098.67					
482140	431685	$12.63	1	$28,904.84	$28,904.84	6%	2	7.80%	2
446685	431685	$3.75	2	$8,593.25	$4,296.63	8%	2	10.40%	3
487005	431685	$13.85	2	$31,691.92	$15,845.96	8%	2	10.40%	3
497140	431685	$16.38	4	$37,498.10	$9,374.52	12%	3	15.60%	4
497684	431685	$16.52	4	$37,809.75	$9,452.44	12%	3	15.60%	4
517004	431685	$21.36	6	$48,877.86	$8,146.31	16%	4	20.80%	4
527140	431685	$23.89	7	$54,684.60	$7,812.09	18%	4	23.40%	4
490965	431685	$14.84	8	$33,960.54	$4,245.07	20%	5	26.00%	5
531285	431685	$24.93	8	$57,059.21	$7,132.40	20%	5	26.00%	5
541420	431685	$27.47	9	$62,865.38	$6,985.04	22%	5	28.60%	6
505965	431685	$18.59	10	$42,553.79	$4,255.38	24%	5	31.20%	5
546285	431685	$28.69	12	$65,652.46	$5,471.04	29%	6	37.70%	6
556420	431685	$31.22	12	$71,458.64	$5,954.89	29%	6	37.70%	6
535964	431685	$26.10	13	$59,739.73	$4,595.36	32%	7	41.60%	7
576284	431685	$36.19	13	$82,838.40	$6,372.18	32%	7	41.60%	7
586420	431685	$38.73	13	$88,645.14	$6,818.86	32%	7	41.60%	7
787365	431685	$89.03	14	$203,763.24	$14,554.52	35%	8	45.50%	7
827685	431685	$99.12	14	$226,861.91	$16,204.42	35%	8	45.50%	7
837820	431685	$101.66	14	$232,668.08	$16,619.15	35%	8	45.50%	7
802365	431685	$92.79	15	$212,356.49	$14,157.10	38%	8	49.40%	7
842685	431685	$102.88	15	$235,455.16	$15,697.01	38%	8	49.40%	7
852820	431685	$105.42	15	$241,261.34	$16,084.09	38%	8	49.40%	7
832364	431685	$100.30	15	$229,542.43	$15,302.83	38%	8	49.40%	7
872684	431685	$110.39	16	$252,641.10	$15,790.07	42%	9	54.60%	8
882820	431685	$112.92	16	$258,447.84	$16,152.99	42%	9	54.60%	8

Table 1. Points for percentage improvement in energy performance – % Cost PCI below PCI$_t$ (1-9 points)

Multifamily	Points
2%	1
5%	2
10%	3
15%	4
20%	5
25%	6
30%	7
35%	8
40%	9
45%	EP

When DOLS and FMOLS test results were evaluated, it was found that energy efficiency had a negative and significant effect on greenhouse gas emission. Growth in GDP has been found to have a positive effect on greenhouse gas emissions. Based on the findings, a 1-unit increase in energy efficiency leads to a decrease in greenhouse gas emissions of between 1.3 and 1.4. However, a 1-unit increase in GDP appears to result in an increase of approximately 1.5–2 units in greenhouse gas emissions.

In Table 6, the panel causality results of Emirmahmutoglu and Kose (2011) are given from energy efficiency to greenhouse gas emission.

On-site renewable energy may be subtracted from proposed greenhouse gas emissions prior to calculating proposed building performance per ASHRAE Standard 90.1-2016 Section G 2.4.1. New off-site renewable energy as defined in EA credit Renewable Energy may be subtracted from proposed greenhouse gas emissions prior to calculating proposed building performance.

Table 2. Points for percentage improvement in energy performance – % Greenhouse Gas Emissions PCI below PCI$_t$ (1-9 points)

Multifamily	Points
2%	1
5%	2
10%	3
16%	4
24%	5
32%	6
40%	7
50%	8
65%	9
80%	EP

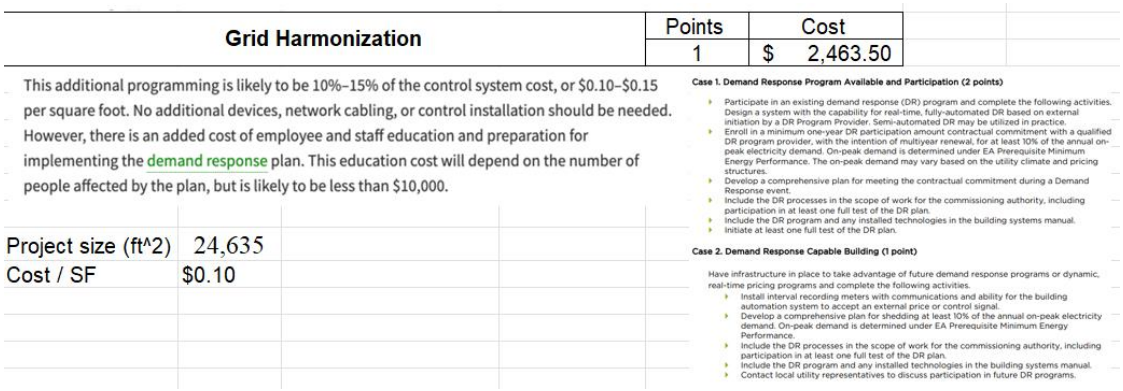
Figure B-23: Screenshot of Optimize Energy Performance

The Optimize Energy Performance credit can be obtained through three options with to a maximum of 18 points. This project utilized Option 1: Energy Performance Compliance. This option requires the project to improve energy performance and reduce Greenhouse Gas emissions. To estimate the cost of the credit, the model relies on a study that tests 81 different cases to measure cost savings from ASHRAE 90.1. Pictured in Figure B-23, two rows are highlighted which show the optimized number of points that can be obtained when attaining the Gold and Platinum Tiers when considering costs.

Whole Building Energy Modeling and Reporting

The Whole Building Energy Modeling and Reporting credit is achieved through installing new or using existing energy meters that measure all building energy consumption as well as committing to sharing that information with USGBC for a five-year period. This project accomplishes this point by already having energy meters that measure total energy consumption. In addition, it would come at zero additional cost to share information with USGBC.

Grid Harmonization



Grid Harmonization	Points	Cost
	1	$ 2,463.50

This additional programming is likely to be 10%–15% of the control system cost, or $0.10–$0.15 per square foot. No additional devices, network cabling, or control installation should be needed. However, there is an added cost of employee and staff education and preparation for implementing the demand response plan. This education cost will depend on the number of people affected by the plan, but is likely to be less than $10,000.

Project size (ft^2)	24,635
Cost / SF	$0.10

Case 1. Demand Response Program Available and Participation (2 points)

- Participate in an existing demand response (DR) program and complete the following activities. Design a system with the capability for real-time, fully-automated DR based on external initiation by a DR Program Provider. Semi-automated DR may be utilized in practice.
- Enroll in a minimum one-year DR participation amount contractual commitment with a qualified DR program provider, with the intention of multiyear renewal, for at least 10% of the annual on-peak electricity demand. On-peak demand is determined under EA Prerequisite Minimum Energy Performance. The on-peak demand may vary based on the utility climate and pricing structures.
- Develop a comprehensive plan for meeting the contractual commitment during a Demand Response event.
- Include the DR processes in the scope of work for the commissioning authority, including participation in at least one full test of the DR plan.
- Include the DR program and any installed technologies in the building systems manual.
- Initiate at least one full test of the DR plan.

Case 2. Demand Response Capable Building (1 point)

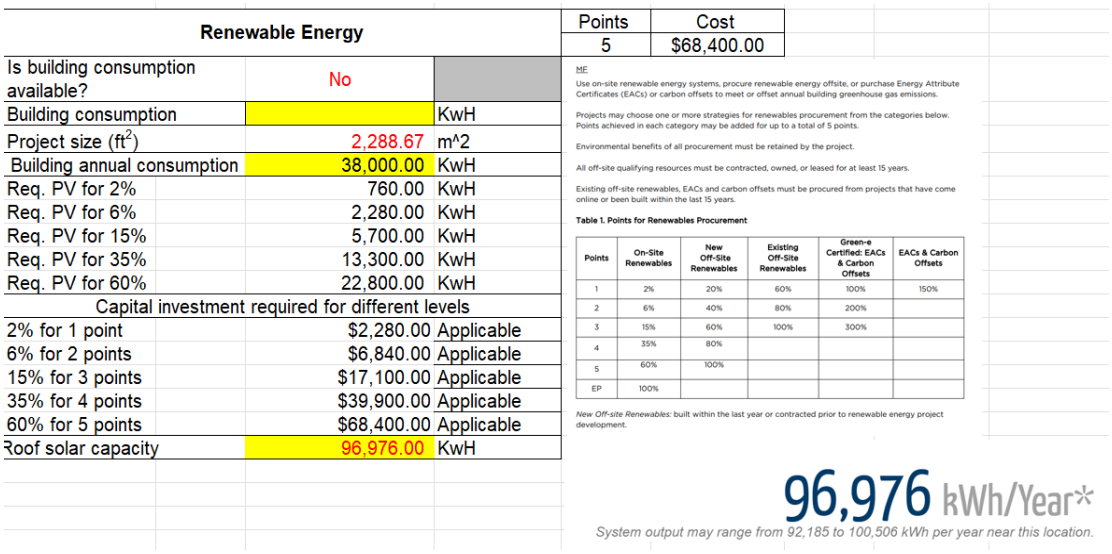
Have infrastructure in place to take advantage of future demand response programs or dynamic, real-time pricing programs and complete the following activities.

- Install interval recording meters with communications and ability for the building automation system to accept an external price or control signal.
- Develop a comprehensive plan for shedding at least 10% of the annual on-peak electricity demand. On-peak demand is determined under EA Prerequisite Minimum Energy Performance.
- Include the DR processes in the scope of work for the commissioning authority, including participation in at least one full test of the DR plan.
- Include the DR program and any installed technologies in the building systems manual.
- Contact local utility representatives to discuss participation in future DR programs.

Figure B-24: Screenshot of Grid Harmonization

The Grid Harmonization credit requires the project to be capable of participating in a Demand Response program, participating in said program, and/or implement one or more load flexibility and management strategies for a maximum of 2 points. This project elected to choose Case 2 for 1 point, which requires the building to be Demand Response capable. The cost estimate for installing the necessary control system is between $0.10 and $0.15 (Piette, Schetrit, Kiliccote, Iris, & Li, 2017) and is based on project size. The added cost to achieve this credit is $2,463.50.

Renewable Energy



Renewable Energy		
Is building consumption available?	No	
Building consumption		KwH
Project size (ft^2)	2,288.67	m^2
Building annual consumption	38,000.00	KwH
Req. PV for 2%	760.00	KwH
Req. PV for 6%	2,280.00	KwH
Req. PV for 15%	5,700.00	KwH
Req. PV for 35%	13,300.00	KwH
Req. PV for 60%	22,800.00	KwH
Capital investment required for different levels		
2% for 1 point	$2,280.00	Applicable
6% for 2 points	$6,840.00	Applicable
15% for 3 points	$17,100.00	Applicable
35% for 4 points	$39,900.00	Applicable
60% for 5 points	$68,400.00	Applicable
Roof solar capacity	96,976.00	KwH

Points	Cost
5	$68,400.00

ME

Use on-site renewable energy systems, procure renewable energy offsite, or purchase Energy Attribute Certificates (EACs) or carbon offsets to meet or offset annual building greenhouse gas emissions.

Projects may choose one or more strategies for renewables procurement from the categories below. Points achieved in each category may be added for up to a total of 5 points.

Environmental benefits of all procurement must be retained by the project.

All off-site qualifying resources must be contracted, owned, or leased for at least 15 years.

Existing off-site renewables, EACs and carbon offsets must be procured from projects that have come online or been built within the last 15 years.

Table 1. Points for Renewables Procurement

Points	On-Site Renewables	New Off-Site Renewables	Existing Off-Site Renewables	Green-e Certified: EACs & Carbon Offsets	EACs & Carbon Offsets
1	2%	20%	60%	100%	150%
2	6%	40%	80%	200%	
3	15%	60%	100%	300%	
4	35%	80%			
5	60%	100%			
EP	100%				

New Off-site Renewables: built within the last year or contracted prior to renewable energy project development.

96,976 kWh/Year*

System output may range from 92,185 to 100,506 kWh per year near this location.

Figure B-25: Screenshot of Renewable Energy

This project uses an equation table to calculate the points gained for the Renewable Energy credit. The maximum of 5 points can be achieved by increasing renewable energy consumption as a percentage of total building consumption. Since this project has a large solar capacity compared to its total energy consumption, it was able to attain all 5 points at a total added cost of $68,400. Solar capacity was calculated using PVWatts.com calculator.

Enhanced Refrigerant Management

Like the Fundamental Refrigerant Management credit, this credit earns 1 point for the project by merit of using low-impact refrigerants. Since this specific project uses R-410A refrigerant, it automatically qualifies for this point at no additional cost.

Domestic Hot Water Pipe Insulation

The Domestic Hot Water Pipe Insulation credit requires at least R-4 installation on all domestic hot water piping for projects to earn 1 point. In accordance with International Energy Conservation Code C403.11.3 Piping Insulation, which the Wilmington Building Code follows, this project qualifies for point.

Materials & Resources

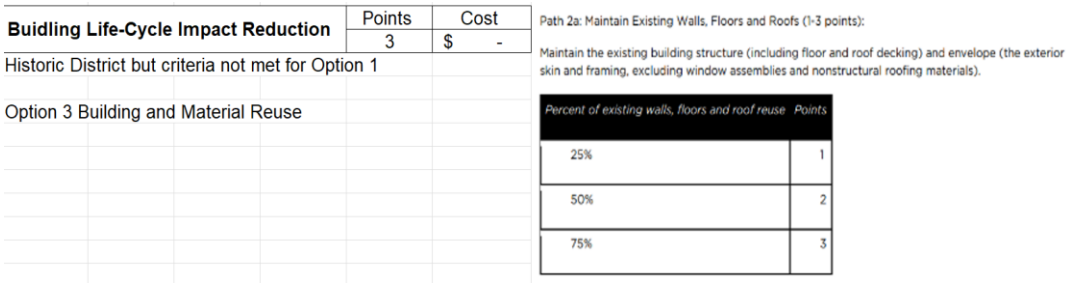
Storage and Collection of Recyclables

The Storage and Collection of Recycles Prerequisite requires project to provide dedicated areas accessible to waste haulers and building occupants for the collection and storage of recyclable materials. This prerequisite is achieved at no additional cost as recycled waste is already included within the original project scope and occupancy.

Construction and Demolition Waste Management Planning

The Construction and Demolition Waste Management Planning Prerequisite requires projects to develop and implement a construction and demolition waste management plan and provide a final report detailing all major waste streams with disposal and diversion rates. This credit can be achieved at no additional cost to the project by simply planning and tracking where construction waste gets diverted to and disposed of.

Building Life-Cycle Impact Reduction



Buidling Life-Cycle Impact Reduction	Points	Cost
	3	$ -
Historic District but criteria not met for Option 1		
Option 3 Building and Material Reuse		

Path 2a: Maintain Existing Walls, Floors and Roofs (1-3 points):

Maintain the existing building structure (including floor and roof decking) and envelope (the exterior skin and framing, excluding window assemblies and nonstructural roofing materials).

Percent of existing walls, floors and roof reuse	*Points*
25%	1
50%	2
75%	3

Figure B-26: Screenshot of Building Life-Cycle Impact Reduction

This credit can be achieved up to a maximum of 5 credits by performing one of four options. These options include:

- Historic Building Reuse
- Renovation of Abandoned or Blighted Building
- Building and Material Reuse
- Whole Building Life-Cycle Assessment

It was determined that the Historic Building and Renovation of Abandoned or Blighted Buildings options did not apply and that a Whole Building Life-Cycle Assessment could not be reasonably estimated post-construction. Therefore, the project acquired 3 points from Option 3: Building and Material Reuse for using 75% of existing floors, walls, and roof. These points were relatively easy to obtain as the building itself only received a gut renovation and minor changes to roof and floor structure.

Environmentally Preferable Products

The Environmental Preferable Products credit is achieved through four options regarding the usage of materials and their sourcing. This project opted to go for Option 1: Environmentally Preferable products which requires products that meet at least one of the following requirements up to 70% by weight or volume:

- Product contains at least 25% reclaimed material. For renovation projects, existing components are considered reclaimed.
- Product contains at least 25% postconsumer or 50% preconsumer content
- Wood products must be Forest Stewardship Council Certified or a USGBC-approved equivalent
- Bio-based materials must meet the Sustainable Agriculture Network's Sustainable Agriculture Standard
- Concrete that consists of at least 30% fly ash or slag as a cement substitute
- Products produced from a manufacturer that participates in an extended producer responsibility program

Since this project is of a renovation of an existing building and after studying the project drawings and contract documents, it can be reasonably assumed that 70% of framing/structural systems, concrete, roofing, and interior masonry walls are reused or reclaimed, therefore earning the project 4 points free of additional charge.

Construction and Demolition Waste Management

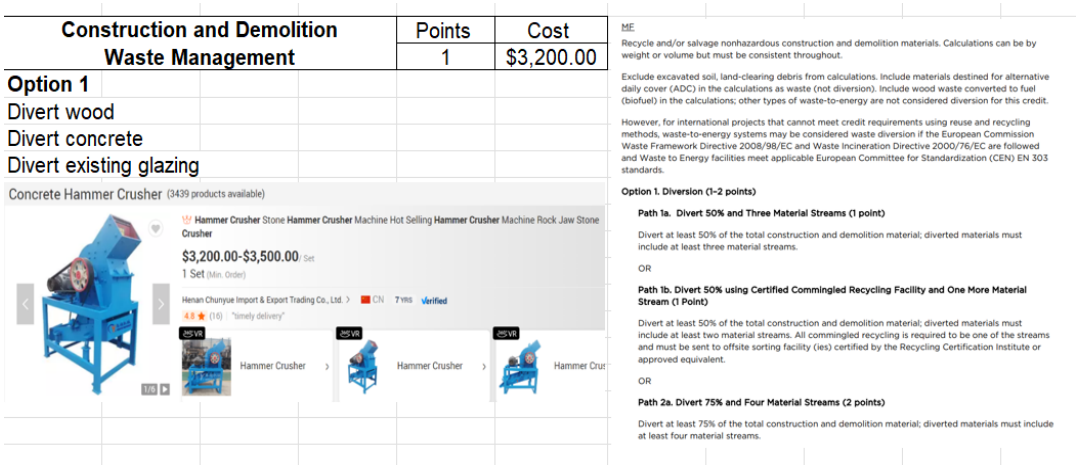
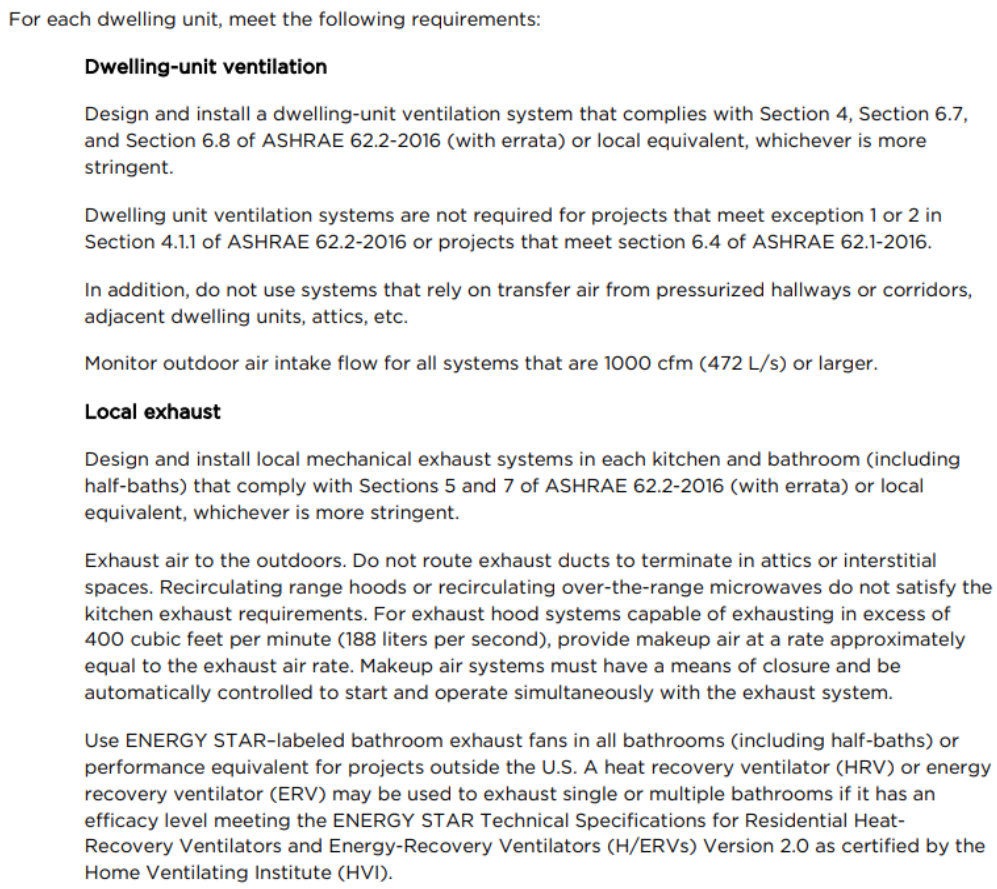


Figure B-27: Screenshot of Construction Demolition and Waste Management

The Construction and Demolition Waste Management credit requires projects to recycle and/or salvage nonhazardous construction and demolition materials for a maximum of 2 points. This project followed Option 1's Path 1 which requires the diversion of 50% of total construction and demolition material among three streams. A concrete and brick crusher were found online to cost $3,200 which could be used to break down concrete, stone, or glass for future recycled use as aggregates. These three streams make up at least 50% of the demolition material from the project.

Indoor Environmental Quality

Minimum Indoor Air Quality Performance



For each dwelling unit, meet the following requirements:

Dwelling-unit ventilation

Design and install a dwelling-unit ventilation system that complies with Section 4, Section 6.7, and Section 6.8 of ASHRAE 62.2-2016 (with errata) or local equivalent, whichever is more stringent.

Dwelling unit ventilation systems are not required for projects that meet exception 1 or 2 in Section 4.1.1 of ASHRAE 62.2-2016 or projects that meet section 6.4 of ASHRAE 62.1-2016.

In addition, do not use systems that rely on transfer air from pressurized hallways or corridors, adjacent dwelling units, attics, etc.

Monitor outdoor air intake flow for all systems that are 1000 cfm (472 L/s) or larger.

Local exhaust

Design and install local mechanical exhaust systems in each kitchen and bathroom (including half-baths) that comply with Sections 5 and 7 of ASHRAE 62.2-2016 (with errata) or local equivalent, whichever is more stringent.

Exhaust air to the outdoors. Do not route exhaust ducts to terminate in attics or interstitial spaces. Recirculating range hoods or recirculating over-the-range microwaves do not satisfy the kitchen exhaust requirements. For exhaust hood systems capable of exhausting in excess of 400 cubic feet per minute (188 liters per second), provide makeup air at a rate approximately equal to the exhaust air rate. Makeup air systems must have a means of closure and be automatically controlled to start and operate simultaneously with the exhaust system.

Use ENERGY STAR–labeled bathroom exhaust fans in all bathrooms (including half-baths) or performance equivalent for projects outside the U.S. A heat recovery ventilator (HRV) or energy recovery ventilator (ERV) may be used to exhaust single or multiple bathrooms if it has an efficacy level meeting the ENERGY STAR Technical Specifications for Residential Heat-Recovery Ventilators and Energy-Recovery Ventilators (H/ERVs) Version 2.0 as certified by the Home Ventilating Institute (HVI).

Figure B-28: Screenshot of Minimum Indoor Air Quality Performance

Wilmington Building Code complies with ASHRAE 62-89 and thus qualifies for the Minimum Indoor Air Quality Performance Prerequisite.

Combustion Venting

The Combustion Venting Prerequisite prohibits the use of any unvented combustion appliances excluding ovens and ranges. Additionally, all dwelling units are required to have carbon monoxide monitors. This project automatically qualifies for this prerequisite as it does not include combustion appliances (except for stove and ranges) and it includes carbon monoxide sensors.

Garage Pollution Prevention

The Garage Pollution Prerequisite requires air-handling equipment and ductwork to be placed outside of the envelope of the garage. This category does not apply to this project as it does not include a garage.

Radon-Resistant Construction

The Radon-Resistant Construction Prerequisite requires special action taken if a project is in EPA Radon Zone 1. However, none of the projects listed in this study exist in this zone, therefore the prerequisite does not apply.

Indoor Moisture Management

Install all the applicable indoor moisture control measures listed in Table 1.

Table 1. Required interior moisture control measures for homes

Location or equipment	*Required measure*
Area directly above bathtub, spa, or shower (extending to ceiling), exposed wall or area behind fiberglass enclosure if wallboard is installed	Use nonpaper-faced backer board or paper-faced product or coating over wallboard that meets standard ASTM D 3273
Kitchen, bathroom, laundry room, spa area	Use water-resistant flooring; do not install carpet
Entryway within 3 feet (900 mm) of exterior door accessible from ground	Use water-resistant flooring; do not install carpet (carpet tiles are permitted)
Tank water heater in or over living space	Install drain and drain pan, drain pan and automatic water shut-off or flow restrictor, or floor drain with floor sloped to drain
Conventional clothes washer in or over living space	Install a braided washer hose or one of the following: drain and drain pan; drain pan and automatic water shut-off or flow restrictor; or floor drain with floor sloped to drain
Conventional clothes dryer	Exhaust directly to outdoors
Plumbing systems for building and irrigation	After completion of construction, test to verify that there are no detectable water leaks

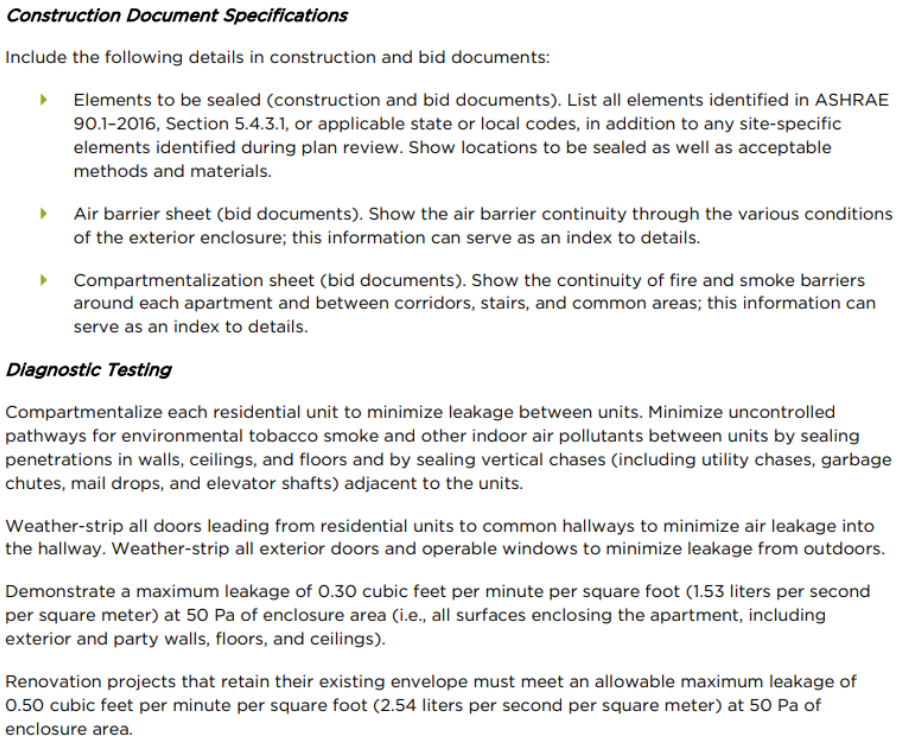
Figure B-29: Screenshot of Indoor Moisture Management

The Indoor Moisture Management Prerequisite requires several moisture control measures to be installed in dwelling spaces as pictured in Figure B-29. This project complies with all the applicable moisture control measures mentioned above and therefore qualifies for this prerequisite.

Environmental Tobacco Smoke Control

Environmental Tobacco Smoke Control Prerequisite requires projects to prohibit smoking inside and outside of the building (at least 25ft from all entries). Each project listed in this study has a no tobacco smoking policy and therefore achieves this prerequisite.

Compartmentalization



Construction Document Specifications

Include the following details in construction and bid documents:

- Elements to be sealed (construction and bid documents). List all elements identified in ASHRAE 90.1–2016, Section 5.4.3.1, or applicable state or local codes, in addition to any site-specific elements identified during plan review. Show locations to be sealed as well as acceptable methods and materials.
- Air barrier sheet (bid documents). Show the air barrier continuity through the various conditions of the exterior enclosure; this information can serve as an index to details.
- Compartmentalization sheet (bid documents). Show the continuity of fire and smoke barriers around each apartment and between corridors, stairs, and common areas; this information can serve as an index to details.

Diagnostic Testing

Compartmentalize each residential unit to minimize leakage between units. Minimize uncontrolled pathways for environmental tobacco smoke and other indoor air pollutants between units by sealing penetrations in walls, ceilings, and floors and by sealing vertical chases (including utility chases, garbage chutes, mail drops, and elevator shafts) adjacent to the units.

Weather-strip all doors leading from residential units to common hallways to minimize air leakage into the hallway. Weather-strip all exterior doors and operable windows to minimize leakage from outdoors.

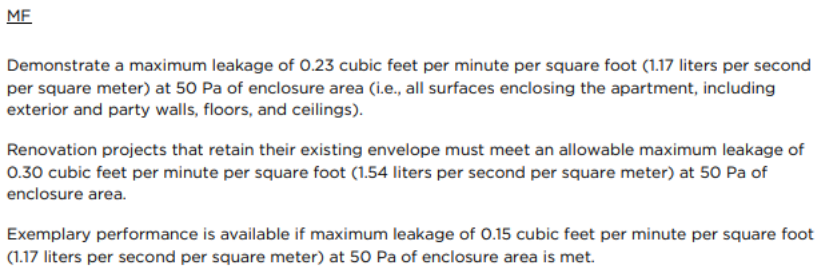
Demonstrate a maximum leakage of 0.30 cubic feet per minute per square foot (1.53 liters per second per square meter) at 50 Pa of enclosure area (i.e., all surfaces enclosing the apartment, including exterior and party walls, floors, and ceilings).

Renovation projects that retain their existing envelope must meet an allowable maximum leakage of 0.50 cubic feet per minute per square foot (2.54 liters per second per square meter) at 50 Pa of enclosure area.

Figure B-30: Screenshot of Compartmentalization Prerequisite

The Compartmentalization prerequisite is accomplished through proper sealing of doorways and minimizing leakage between adjacent units and from the outdoors. This project utilizes and weatherstripping for doorways and could add Compartmentalization data collecting requirements at no added cost.

Enhanced Compartmentalization


MF

Demonstrate a maximum leakage of 0.23 cubic feet per minute per square foot (1.17 liters per second per square meter) at 50 Pa of enclosure area (i.e., all surfaces enclosing the apartment, including exterior and party walls, floors, and ceilings).

Renovation projects that retain their existing envelope must meet an allowable maximum leakage of 0.30 cubic feet per minute per square foot (1.54 liters per second per square meter) at 50 Pa of enclosure area.

Exemplary performance is available if maximum leakage of 0.15 cubic feet per minute per square foot (1.17 liters per second per square meter) at 50 Pa of enclosure area is met.

Figure B-31: Screenshot of Enhanced Compartmentalization

Enhanced Compartmentalization can be accomplished by successfully testing leakage through project envelope at minimum cubic feet per minute flow rates for new construction or renovation projects. This project did not attempt the Enhanced Compartmentalization credit no data was available regarding air leakage and nor significant means of testing.

No Environmental Tobacco Smoke

The No Environmental Tobacco Smoke credit can be obtained without any additional cost to the project. This credit requires projects to prohibit smoking inside the entire building and on private balconies. It also requires the project owners to communicate a no-smoking policies in building rental or lease agreements. This project already has a no smoking policy; therefore, it earns 1 credit.

Enhanced Indoor Air Quality Strategies

The Enhanced Indoor Air Quality Strategies credit can be achieved through adopting several strategies for technologies that will assist in minimizing pollutants leaking into indoor air and filtering air that is already flowing through the building. There is a maximum of 4 available points. This project already includes air filters for dwelling spaces, so it achieves 1 credit for no additional cost. To attain 2 more credit this project invested in walk-off mats at exterior access points and occupancy sensors for each bathroom. Prices for walk-off mats and occupancy sensors were acquired at current markets rates. Their total cost increases project investment cost by $849.96.

Low-Emitting Materials

Use materials on the building interior (everything within the waterproofing membrane) that meet the low-emitting criteria below. Points are awarded according to Table 1:

Table 1. Points for low-emitting materials	
2 product categories	1 point
3 product categories	2 points
4 product categories	3 points
5 product categories	4 points
Reach 90% threshold in at least three product categories	Exemplary performance *or 1 additional point if only 1-3 points achieved above.*
For 2 product categories, at least 25% of the products comply with the VOC emissions evaluation via the CDPH v1.2-2012 Appendix B, New Single-Family Residence Scenario	Exemplary performance *or 1 additional point if only 1-3 points achieved above.*

Figure B-32: Screenshot of Low-Emitting Materials

Cost estimation for this project was not required as the state of Delaware already has Volatile Organic Compound restrictions in its building code; 1141 Limiting Emissions of Volatile Organic Compounds from Consumer and Commercial Products. It is assumed that for at least 5 product categories that this project passes Delaware's requirements for low-emitting materials and therefore earns 4 points.

Indoor Air Quality Assessment

Indoor Air Quality Assessment requires projects to perform air cleaning, a flush-out, and air testing prior to occupancy. When completed these options combine for a maximum of 2 points. These tests can be accomplished at no significant additional cost to the project. This project earns 2 points.

Thermal Comfort

The Thermal Comfort credit is attained through one of three methods for a maximum of 1 point. These three methods are as follows:

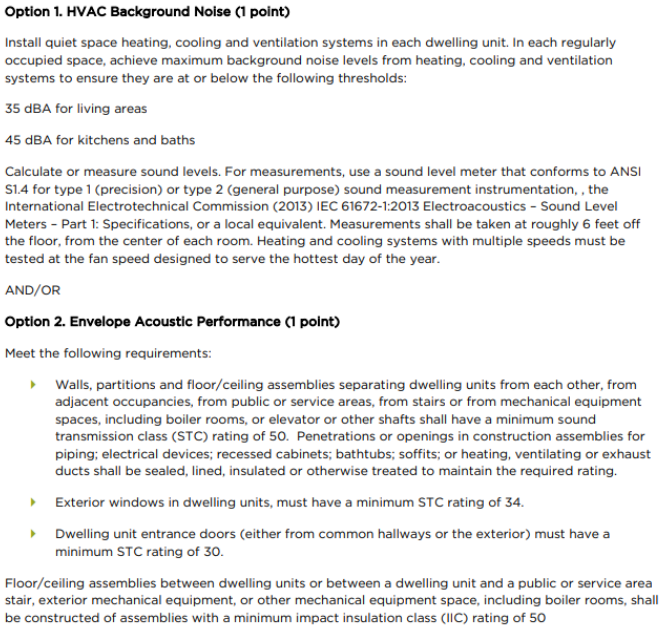
- Option 1: Radiant Comfort
    - Utilize heating and cooling controls in every unit, walls, floor, and roof components must meet 2009 IECC Commercial code, have no thermal bridges in envelope, and windows to meet minimum U-Values and SHGC-Values
- Option 2: ASHRAE Standard 55-2017
    - Design HVAC system in accordance with ASHRAE Standard 55-2017
- Option 3: ISO Standards
    - Design HVAC systems and building envelope in accordance with ISO 7730:2005 and ISO 17772-2017

It was determined that this project did not meet the requirements for Option 1 or Option 3, and indeterminate that the requirement for Option 2 was met. Therefore, this project is assumed to earn 0 points for Thermal Comfort.

Daylight and Quality Views

The Daylight and Quality Views credit can be achieved through one of two options for 1 point. Option 1 requires projects to perform a computer modeling simulation or illuminance measurements to determine if it meets minimum access or adequacy requirements for daylight. Option 2 requires at least 50% of regularly occupied spaces in projects to have one window that includes either flora/fauna/sky or objects that are at least 25 feet from the exterior of the window. This project succeeds in accomplishing Option 2 has most windows have access to the sky and have objects further than 25 feet away. Option 1 was not attempted as modeling the entire scope of the project was not feasible for this research.

Acoustic Performance



Option 1. HVAC Background Noise (1 point)

Install quiet space heating, cooling and ventilation systems in each dwelling unit. In each regularly occupied space, achieve maximum background noise levels from heating, cooling and ventilation systems to ensure they are at or below the following thresholds:

35 dBA for living areas

45 dBA for kitchens and baths

Calculate or measure sound levels. For measurements, use a sound level meter that conforms to ANSI S1.4 for type 1 (precision) or type 2 (general purpose) sound measurement instrumentation, , the International Electrotechnical Commission (2013) IEC 61672-1:2013 Electroacoustics – Sound Level Meters – Part 1: Specifications, or a local equivalent. Measurements shall be taken at roughly 6 feet off the floor, from the center of each room. Heating and cooling systems with multiple speeds must be tested at the fan speed designed to serve the hottest day of the year.

AND/OR

Option 2. Envelope Acoustic Performance (1 point)

Meet the following requirements:

- Walls, partitions and floor/ceiling assemblies separating dwelling units from each other, from adjacent occupancies, from public or service areas, from stairs or from mechanical equipment spaces, including boiler rooms, or elevator or other shafts shall have a minimum sound transmission class (STC) rating of 50. Penetrations or openings in construction assemblies for piping; electrical devices; recessed cabinets; bathtubs; soffits; or heating, ventilating or exhaust ducts shall be sealed, lined, insulated or otherwise treated to maintain the required rating.
- Exterior windows in dwelling units, must have a minimum STC rating of 34.
- Dwelling unit entrance doors (either from common hallways or the exterior) must have a minimum STC rating of 30.

Floor/ceiling assemblies between dwelling units or between a dwelling unit and a public or service area stair, exterior mechanical equipment, or other mechanical equipment space, including boiler rooms, shall be constructed of assemblies with a minimum impact insulation class (IIC) rating of 50

Figure B-33: Screenshot of Acoustic Performance

Acoustic Performance credit is attained through two options for a maximum of 2 points. Option 1 requires projects to install quiet HVAC systems in each dwelling unit and to minimize background noise in regularly occupied spaces. Option 2 requires building envelope to meet Sound Transmission Class (STC) requirements. This project achieves both options and receives 2 points for meeting Option 1 requirements of installing quiet HVAC systems and ensuring sound levels are below 35 dBA for living areas and 45 dBA for kitchens/baths. Option 2 is achieved using walls with an STC rating of 50 or greater (depending on location), exterior windows with an STC rating above 34, and entrance doors with an STC rating equivalent or greater than 30.

Innovation

The Innovation credit(s) is achieved through completing the requirements of innovative performance as prescribed in the LEED Innovation catalog for the project's particular certification category. Pilot credit(s) are similarly achieved through accomplishing requirements prescribed in the LEED Pilot Credit Library. For a maximum of 5 points, projects can complete a combination of Innovation credits, Pilot credits, and no more than two Exemplary Performance credits. Additionally, 1 more point can be achieved through the inclusion of a LEED Accredited Professional throughout the application and certification process, which can be accomplished at no additional cost if the project team has an employee in-house. The following are examples of available credits that this project can attain:

Innovation Credit

Innovation: Occupant Comfort Survey	Points	Cost
	1	$ -

Requirements

Establishment

None

Performance

Administer at least one occupant comfort survey to collect anonymous responses regarding at least the following:

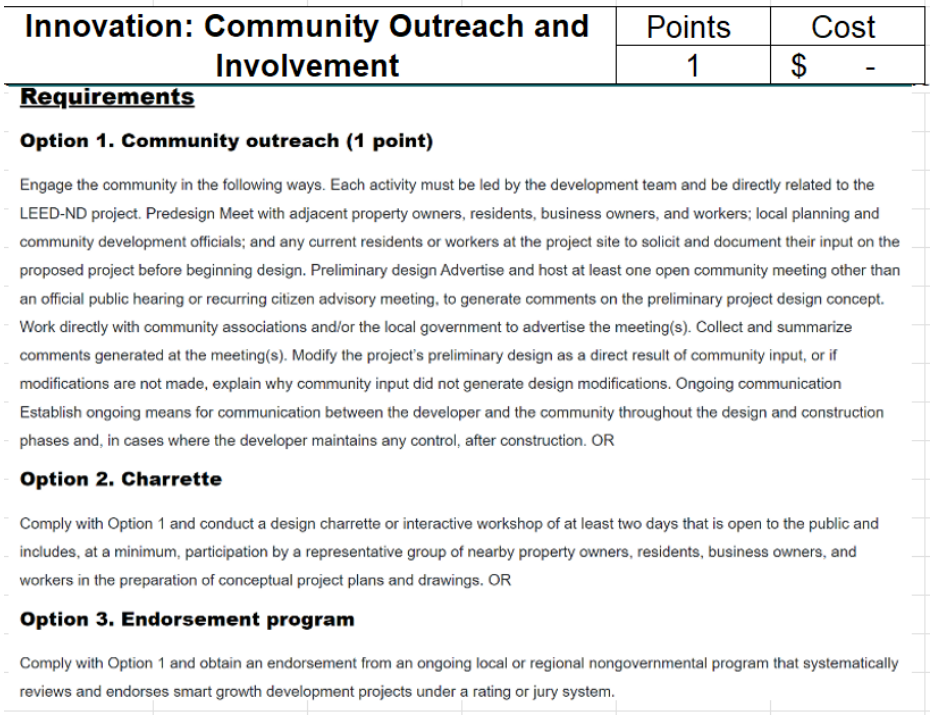
- acoustics;
- building cleanliness;
- indoor air quality;
- lighting;
- thermal comfort; and

The responses must be collected from a representative sample of building occupants making up at least 30% of the total occupants. Document survey results. Develop and implement a corrective action plan to address comfort issues if the results indicate that more than 20% of occupants are dissatisfied. Perform at least one survey and implement corrective actions. At a minimum, perform one new survey at least once every 2 years.

Figure B-34: Screenshot of Occupant Comfort Survey

This Innovation credit can be achieved through project owners distributing and collecting an anonymous survey given to building occupants on their comfort regarding acoustics, building cleanliness, air quality, lighting, and thermal comfort. If more than 20% of occupants are dissatisfied, then project owners must implement corrective action. This project can be attained at no extra charge so long as building occupant comfort remains satisfactory.

Innovation Credit



Innovation: Community Outreach and Involvement	Points	Cost
	1	$ -

Requirements

Option 1. Community outreach (1 point)

Engage the community in the following ways. Each activity must be led by the development team and be directly related to the LEED-ND project. Predesign Meet with adjacent property owners, residents, business owners, and workers; local planning and community development officials; and any current residents or workers at the project site to solicit and document their input on the proposed project before beginning design. Preliminary design Advertise and host at least one open community meeting other than an official public hearing or recurring citizen advisory meeting, to generate comments on the preliminary project design concept. Work directly with community associations and/or the local government to advertise the meeting(s). Collect and summarize comments generated at the meeting(s). Modify the project's preliminary design as a direct result of community input, or if modifications are not made, explain why community input did not generate design modifications. Ongoing communication Establish ongoing means for communication between the developer and the community throughout the design and construction phases and, in cases where the developer maintains any control, after construction. OR

Option 2. Charrette

Comply with Option 1 and conduct a design charrette or interactive workshop of at least two days that is open to the public and includes, at a minimum, participation by a representative group of nearby property owners, residents, business owners, and workers in the preparation of conceptual project plans and drawings. OR

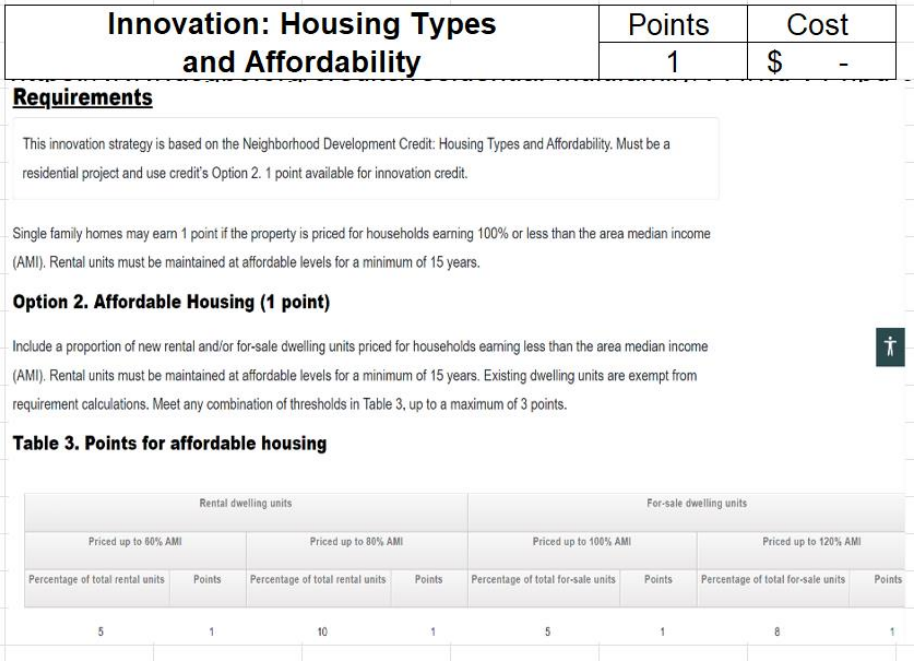
Option 3. Endorsement program

Comply with Option 1 and obtain an endorsement from an ongoing local or regional nongovernmental program that systematically reviews and endorses smart growth development projects under a rating or jury system.

Figure B-35: Screenshot of Community Outreach and Involvement

The Community Outreach Innovation credit can be obtained through three options. Option 1 requires the project team to engage the community in project design and development. Option 2 requires the completion of Option 1 and for the project team to host a design charette that lasts at least two days. A charette allows local community members to have a direct say in how the project is designed. Option 3 requires the completion of Option 1 and for the project team to obtain an endorsement from a local or regional nongovernmental program that reviews smart growth development projects. This point is achieved at negligible costs as community engagement is already common practice in design.

Innovation Credit



Innovation: Housing Types and Affordability	Points	Cost
	1	$ -

Requirements

This innovation strategy is based on the Neighborhood Development Credit: Housing Types and Affordability. Must be a residential project and use credit's Option 2. 1 point available for innovation credit.

Single family homes may earn 1 point if the property is priced for households earning 100% or less than the area median income (AMI). Rental units must be maintained at affordable levels for a minimum of 15 years.

Option 2. Affordable Housing (1 point)

Include a proportion of new rental and/or for-sale dwelling units priced for households earning less than the area median income (AMI). Rental units must be maintained at affordable levels for a minimum of 15 years. Existing dwelling units are exempt from requirement calculations. Meet any combination of thresholds in Table 3, up to a maximum of 3 points.

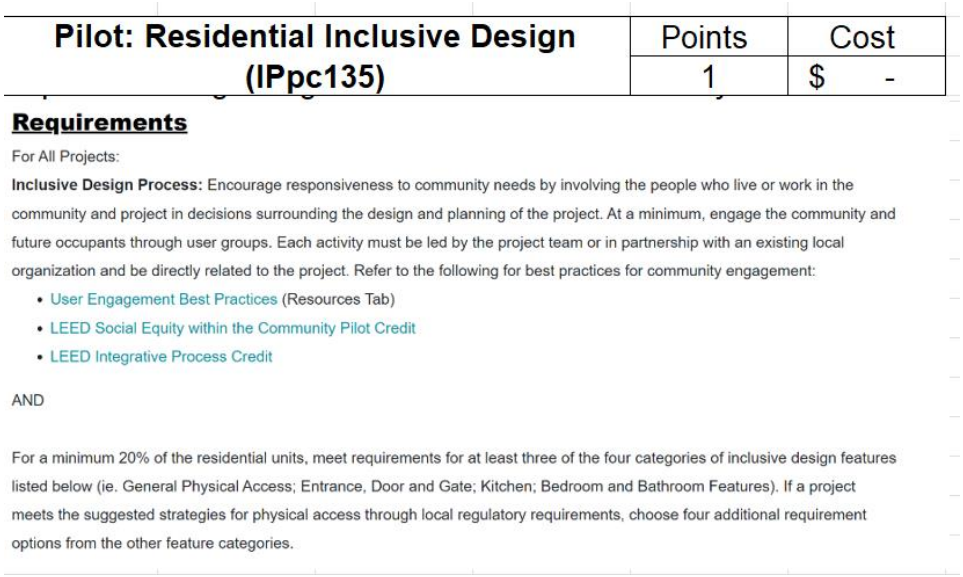
Table 3. Points for affordable housing

Rental dwelling units				For-sale dwelling units			
Priced up to 60% AMI		Priced up to 80% AMI		Priced up to 100% AMI		Priced up to 120% AMI	
Percentage of total rental units	Points	Percentage of total rental units	Points	Percentage of total for-sale units	Points	Percentage of total for-sale units	Points
5	1	10	1	5	1	8	1

Figure B-36: Screenshot of Housing Types and Affordability

The Housing Types and Affordability Innovation credit requires projects to include a proportion of new dwelling units priced for households earning less than the median income of the area. These units must be maintained at affordable levels for 15 years. This credit can be achieved at zero addition to total project cost.

Pilot Credit



Pilot: Residential Inclusive Design (IPpc135)	Points	Cost
	1	$ -

Requirements

For All Projects:

Inclusive Design Process: Encourage responsiveness to community needs by involving the people who live or work in the community and project in decisions surrounding the design and planning of the project. At a minimum, engage the community and future occupants through user groups. Each activity must be led by the project team or in partnership with an existing local organization and be directly related to the project. Refer to the following for best practices for community engagement:

- User Engagement Best Practices (Resources Tab)
- LEED Social Equity within the Community Pilot Credit
- LEED Integrative Process Credit

AND

For a minimum 20% of the residential units, meet requirements for at least three of the four categories of inclusive design features listed below (ie. General Physical Access; Entrance, Door and Gate; Kitchen; Bedroom and Bathroom Features). If a project meets the suggested strategies for physical access through local regulatory requirements, choose four additional requirement options from the other feature categories.

Figure B-37: Screenshot of Residential Inclusive Design

Residential Inclusive Design Pilot Credit requires the project team to respond to community needs in its design by engaging user groups. Additionally, the project must have at minimum 20% of dwelling units that meet at least three of the listed inclusive design features. Incorporating inclusive design features into the project design would come at zero added investment cost.

Pilot Credit

Pilot: Social Equity Within the Community (IPpc89)	Points	Cost
	1	$ -

Requirements

This pilot credit* awards one point to projects that undertake a process to understand who their community includes, identify community needs related to equity for vulnerable populations, and develop and implement strategies for the project to assist the community in meeting those needs. The relationship between building project teams and social equity are complex. This pilot credit is intended as a starting place to help green building projects understand their relationships to the impacted community and implement targeted strategies that address social equity. Effective community engagement and needs assessments are critical components of social equity. Building relationships and establishing trust can take years of work on the part of skilled practitioners. For some projects, working with community members is an integral part of the design process and improving equitable access is a core part of the project mission. For others, the ability to develop, implement and respond to an effective community engagement and needs assessment process may be beyond their scope or capabilities. Therefore, this pilot credit provides two pathways for achievement - one is through a community engagement and needs assessment process using the Social Economic Environmental Design (SEED) documentation system (Option 1). The other is for projects to partner with local organizations that already have existing relationships with the community and can participate as partners to represent community needs and concerns (Option 2). Whether a project team uses the SEED program to document their own process or partners with a community organization, it must select one or more strategies to implement in order to promote social equity within disadvantaged populations.

Figure B-38: Screenshot of Social Equity Within the Community

This Pilot credit is awarded to projects that undertake a process to understand who their community includes and identify its needs and vulnerable populations to development and implement strategies to assist the community with its most important needs. This can be accomplished through two pathways which would come at a negligible added cost to the project. Option 1 requires the project team to complete a community engagement and needs assessment using the Social Economic Environmental Design (SEED) documentation system. Option 3 requires the project team to partner with local organizations that have existing relationships with the community and act as partners and representatives of the community needs and concerns.

Regional Priority

There does not exist Regional Priority credits to be achieved using this specific LEED v4.1 Residential: Multifamily, therefore this project did not consider them in its calculations.