Implementation of Net-Zero Energy Building (NZEB)

Roof Technologies in New York City

Case Study: Helen's House 309 Henry St. New York, NY 10002

Author: Adrian Ferrar

Faculty: Dr. Mark Fedkin

EME 807

Table of Contents:

Introduction:

Background -

The purpose of this report is to investigate the feasibility of implementing two sustainable technologies commonly associated with the roofs of net-zero energy buildings (NZEB) in the context of New York City. As of 2014, 54% of the world's population is located in urban settings compared to 30% in 1950 and an amazing 66% projected by 2050 **[1]**. Given the modern trend of land and resource scarcity coupled with on-going population growth it is probable that urban city planning and development projects will become the predominant form of structured housing moving into the future. Densely populated regions are often associated with high energy consumption as urbanites receive the reputation of being energy-hogs; however, cities have a lot of momentum in their favor when it comes to potential for reducing and offsetting energy demand. The U.S. Energy Information Administration (EIA) surveyed residential energy consumption in 2009 and found urban households represented 47.1 million homes and consumed approximately 10^{12} kWh aggregate per year. This quite large sum is, however, a direct result of the proportion of respective groups. When per capita consumption rates are taken into account urban localities exhibit the lowest annual energy use per household (24,999 kWh) when compared to others, such as rural groups (27,842 kWh) **[2]**.

NZEB Technology Focus -

Zero-net energy buildings comprised of numerous components associated with the construction of a building. They can be viewed as a conglomeration of various green technologies juxtaposed into structural design. The two technologies that will be evaluated for the case site are photovoltaic panel installations for generating electricity and green roof technology.

Case Site Selection Methodology -

Two data sources were utilized for the selection of the two case study sites in this report, NYC Solar Map and NYC Energy through the Sustainable Engineering Lab through Columbia University. NYC Solar Map is an interactive online map tool used to evaluate the solar energy potential for building rooftops in New York City, in addition to, the cost, incentives, and payback period associated with said installations. In addition, City University of New York (CUNY) working with the U.S. Department of Energy, NYSERDA, Con Edison, and the NYC Department of Buildings identified geographic regions in NYC, deemed "Strategic Zones", in which solar power installations are most beneficial from a technical standpoint (taking into account day-peaking energy usage profiles). The model assumed a 10 contiguous square meter area of available roof space for installation. Outputs were calibrated with typical meteorological year data gotten NREL. A default install cost of $8/W was assumed for a total system size of 4.9 kW DC **[3].**

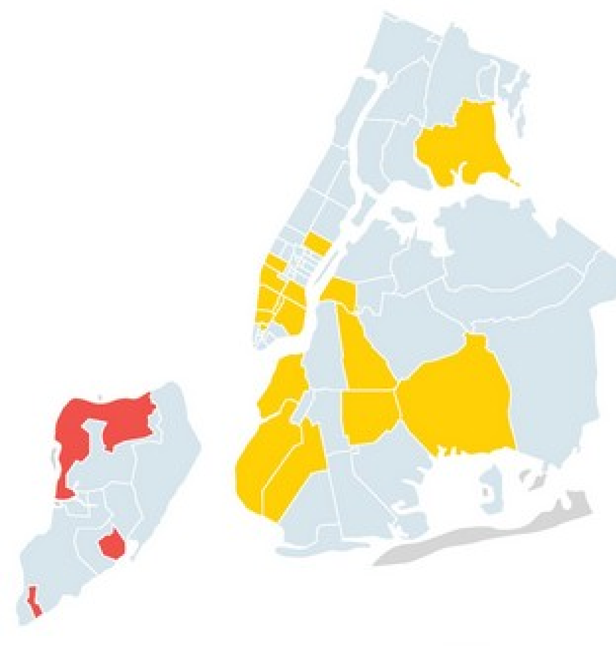

Figure 1 - Boroughs of Manhattan (Red - Location through 2015 ; Yellow - through 2017) **[4]**

NYC Energy is an interactive map tool used to represent the estimated value of total annual energy consumption per building at the block and tax lot level. The map was created based on a mathematical model rooted in statistics which used ZIP code-level energy usage data on electricity, natural gas, fuel oil, and steam consumption and correlated based on recorded building functions, listed as follows **[5]**:

- Residential, multi-family
- Residential, 1-4 family
- Education
- Health
- Warehouse
- Office
- Store

Additional information from residential energy consumption surveys and commercial building energy consumption surveys (CBECS) were used to break the energy consumption down to the following end uses **[5]**:

- Space cooling
- Space heating
- Water heating
- Base electric applications

The case site was selected based on its current electrical energy demands compared to the potential for electrical energy generation through photovoltaic installations which will be discussed more thoroughly in the economic evaluation of the project.

<u>Case Site</u>:

<u>Helen's House: 309 Henry Street New York, NY</u>

Helen's House is a transitional housing program, funded by the New York City Department of Homeless Services, which aims to provide temporary services for sixteen single parents and their pre-school children. The program provides on-site social services which includes job placement, child care, housing readiness workshops and much more **[6]**.

Figure 2 - Street view of 309 Henry Street

Figure 3 - Aerial view of 309 Henry Street roof via Google Earth.

The building was built in 1991 and is 4 stories tall, consists of 8 units/apartments, and has a total building footprint of 1,903 square feet.

Technical Review:

Background -

NZEB is a term encompassing a variety of strategies within a building whose goal is to produce as much energy (or more) as is demanded by consumers within the structure. This concept can be applied during the design and construction phases or retroactively applied to residential, educational, government, commercial and many other types of pre-existing structures. There is no one-piece-fits-all solution or standard for evaluating a NZEB as all buildings vary with regard to their energy consumption, local weather patterns, construction materials and resulting insulation, to name a few of many factors.

There are four definitions most commonly associated with the measure of ZNEBs. The first is Zero-Net Site Energy , in which the home produces as much green energy on-site as its yearly consumption. The second is Z-N Source Energy, in which the building produces as much green energy as consumed yearly (as accounted for at the energy source). The third is Z-N Energy Costs, in which the payment received from utilities for energy produced on the building site is at least equal to what the owners pay utilities. Finally, the fourth is Z-N Energy Emissions, in which the building produces or buys enough emission-free green energy to cover its yearly consumption **[7]**. For the purposes of this research, the second and fourth definitions, zero net source energy and zero net energy emissions, will be utilized.

According to Kenney and Wiehagen, a net-zero energy home, on average, must be 50-60% more energy efficient than traditional homes and have photovoltaic capacity for at least 4.8-7.6 kWe to reach net-zero **[8]**. A 1 kWe PV installation facing south will generate 800-900 kWh of electricity per year **[9]**. Accommodating a 1 kWe installation, in terms of roof space, varies depending on the solar cell material and the type of panel being used; however, generally 1 kWe can be approximated to 10 m^2 of roof space with scaling potential (2 kWe ≈ 16 m^2) **[10]**.

Photovoltaic Installations -

The photoelectric effect is the phenomenon which allows and controls how a PV device converts sunlight into electrical energy. Electrons flowing between a p-n junction create small voltage differences across the nano-scale structural environment gradient which produces a small current **[11]**. The key metric in evaluating photovoltaic systems is the net efficiency by which cells loaded on modules can convert sunlight to electricity. Tables 1 illustrates the cell efficiencies as a percentage of incident solar insolation to electricity based on the application of technology**[12]**.

Type (Flat-plate)	Field-Deployed Modules (%)	Prototype Modules (%)	Lab-Scale Experimental Cells (%)	Theoretical Limit (%)
Single-crystalline silicon (Si)	10-12	16-18	24+	30-33
Polycrystalline	8-9	-	18.2	-

silicon				
Single-junction amorphous silicon	3-5	5	6-8	27-28
Multi-junctions stabilized amorphous silicon	8	10	12	27-28
Copper indium diselenide (CIS)	-	11	14.8	23.5
Cadmium telluride (CdTe)	-	10	15.8	27-28
Stacked multi-junction amorphous silicon and CIS	-	-	15.6	42

Table 1 - Photovoltaic Cell Efficiencies **[12]**

Cell panels can be broken down into two sub-categories as follows: Crystalline silicon derivatives and thin film derivatives.

Crystalline silicon

c-Si is the most abundant material for the manufacturing of solar cells and is incorporated in panel design as either single-crystalline or poly-crystalline cells. As seen in Table 1, single or mono-crystalline cells have the highest efficiency among existing cell materials and are also the most expensive. Mono-crystalline cells are made out of silicon ingots and panels are usually comprised of rounded edges which adds to the cost due to more wasted silicon.

The silicon associated with poly-crystalline cells does not experience the same cutting process and is rather melted and poured into square molds, reducing the purity of the silicon and its efficiency, but decreasing the manufacturing costs significantly **[13]**.

Thin Film

Thin film solar cell technology reduces the amount of active material used by manufacturing the "film-like" material between two panes of glass. projects. The technology receives much attention due to the inherent flexibility associated with the product, as well as, its efficient manufacturing process when compared to c-Si technologies. Cadmium telluride (CdTe), cooper indium selenide (CIS) and amorphous silicon (a-Si) are three thin film technologies often associated with outside installations.

- CdTe cell materials are the only thin film material to reach cost-competitiveness with c-Si per cost/watt.
- a-Si or amorphous silicon is the most well applied and known thin film material/process to date using a higher bandgap than crystalline silicon which allows it to absorb more visible light more efficiently. The process of stacking, in which multiple layers of a-Si are created, can allow for higher efficiency yields.
- CIS cells demonstrate the highest prototype efficiency among the three and is typically associated with commercial applications or large scale projects.
- Multi-junction were initially researched for the purpose of satellite and space operational use; however, they are now being applied for on-land concentrated photovoltaic (CPV) use. These are comprised of multiple thin films grown atop one another **[13]**.

Technology Readiness Level (TRL) is a metrics-based approach towards measuring the maturity of a technological project. Six of the flat-plate type module technologies listed in Table 1 can be evaluated as at a level of TRL7 meaning for all technologies a minimum of prototype success in an operational environment has been achieved. Stacked multi-junction a-Si and CIS technology can be evaluated as in the technological demonstration phase at either low or high fidelity (TRL4 or TRL5).

Green Roof Installations -

Green roofing systems have existed, to our knowledge, as early as the ziggurats of the ancient civilization of Mesopotamia. Today, the utilization of vegetated green roof development on impervious surfaces is crucial to maintaining local environmental quality. Its benefits effect not only the building, by increasing roof material longevity and via energy conservation, but also the neighboring community by aiding in stormwater management and mitigating the urban heat island effect **[19]**.

Green roofs are typically divided into extensive and intensive sub-categories:

Extensive

Extensive roofs are known for their modest design and implementation, often using only a few plant species and minimal planting medium in order to maximize thermal and hydrological performance while accounting for and keeping weight load low **[19]**. These installations are generally less than 6 inches deep and support low growing succulents like sedums, meadow grasses, or perennials. Costs for installation for simple extensive roof designs start at $10 per square foot of roof space **[20]**. Figure 4 shows the components associated with green roof construction.

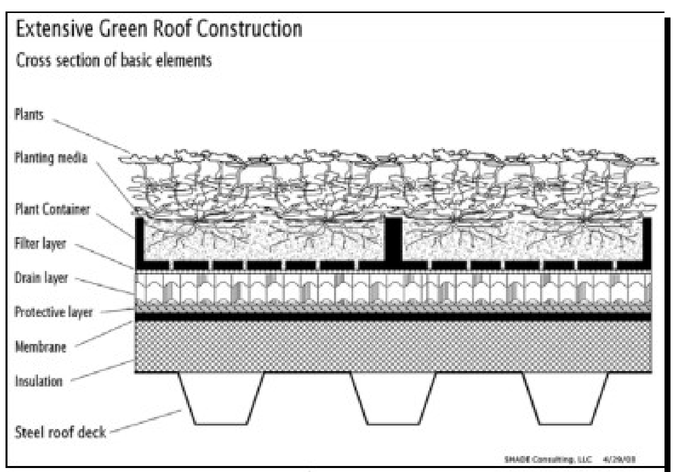

FIgure 4 - Components of extensive green roof structure **[19]**

Intensive

Also referred to as rooftop gardens, these design implementations usually contain a variety of plants and a minimum planting medium depth larger than their extensive counterparts; however, the two types of design incorporate the same construction materials and differ only in the amounts in which they are utilized. The components include: plants, planting media, plant containers, a filter layer, a drainage layer and a protective layer. The membrane is consistent with the roofs original surface material **[19]**.

Green roof technology has been proven and is utilized in countries across the world. For this reason we can estimate its readiness level as at least TRL7 or above.

Economic Analysis:

The following Economic Analysis is regarding the case study site Helen's House at 309 Henry St. New York, NY. EUI (Energy Usage Intensity) is a metric used to determine a building's overall energy impact. EUI is calculated by taking a building's annual energy consumption and dividing the value by its total building floor area **[14]**. Helen's House's current EUI without any sustainable installations was calculated as:

Helen's House EUI (electricity consumption only)= 51,084 kWh / 15,274 ft^2 = **3.34**

This number is not taking into account energy associated with heating via gas or oil; however, the annual 51,084 kWh electricity consumption is estimated to account for 67% of the total annual energy consumption and thus an approximate total consumption and EUI can be determined:

Helen's House EUI (total energy consumption) = [(51,084)x(100)] / [67] = **76,244 kWh/yr**

Using this total energy consumption Helen's House EUI is actually:

Helen's House EUI (total energy consumption) = 76,244 kWh / 15,274 ft^2 = **4.99**

Photovoltaic Installation -

The following assumptions were made while evaluating economic metrics associated with PV installation in the case study site:

- Estimated annual electricity consumption for building of 51,084 kWh **[5]**.
- Usable area for solar panel installation of 614 ft^2 **[3]**.
- $8/W install cost and system size of 4.9 kW DC **[3]**.
- Estimated total energy consumption for building of 76,244 kWh.
- EUI using total energy consumption of 4.99.

- Electricity rate of $0.21 per kWh.
- PV life expectancy of 25 years.
- Salvage Value of 10% initial cost **[16]**.

Cost and generation estimates

Given the above stated assumptions, the cost of a 4.9 kW DC system utilizing 614 square feet and with an installation cost of $8 per W, the overall system cost would be:

System Cost prior to incentives = (4.9 kW) x ($8/W) = (4,900 W) x ($8/W) = **$39,200**

NYSERDA, Federal and State tax credits, and property tax abatements reduces upfront cost by an aggregate $26,849 as illustrated in Table 2 **[15]**.

Cost Before Incentives
$39,200
Incentives
NYSERDA/LIPA Incentives - $4,419
Federal Tax Credit - $10,458
NY State Tax Credit - $5,000
NYC Property Tax Abatement - $6,972
Cost After Incentives
$15,424

Table 2 - Effect of incentives on system cost **[15]**

The system itself would generate approximately 5,347 kWh per year, as illustrated in Table 3

Month	**Approximate Energy Generated (kWh)**
January	308
February	382
March	482
April	521
May	553
June	546
July	543
August	521
September	497
October	431
November	257
December	253
Total	**5,347**

Table 3 - Monthly energy generation from Helen's House case study.

This value would account for the following percentage of the building current annual electricity demand:

Percentage of current building electricity consumption = (5,347 kWh) / (51,084 kWh) = **10.47%**

And would account for approximately **7%** of the buildings total annual energy consumption.

EUI/NPV/SPB Metrics

Taking the offset in demand produced by the PV modules into account the building's new EUI would be:

Helen's House EUI post PV installation = 70,897 kWh / 15,274 ft^2 = **4.64** (a reduction of 0.35)

A discounted cash-flow analysis to determine the discounted NPV future value can be seen below:

NPV = Initial Cost + (P/A) x Annuities + (P/F) x Salvage Value

P/F = 1 / [1.05^{25}] = 0.295

P/A = [$1.05]^{25}$ -1 / [(0.05)x$(1.05)^{25}$] = 14.09

NPV = -$15,424 + 14.09 x [(5,347 kWh) x ($0.21/kWh)] + 0.295 x ($1,542) = **$852**

A simple payback period (SPB) by which the project investment expenses would be recouped as estimated as:

SPB = Initial Cost / Net Annuity = $15,424 / $1,123 = **13.73 years**.

Green Roof Installation:

The rooftop dimensions of Helen's House are 38 feet by 43 feet yielding a total usable area of 1,634 feet. Note that this estimate is 1,000 feet larger than what was estimated for the PV system. This is due to the fact that only a portion of the roofing space was suitable for PV installation while the green roof has the capacity to encompass the whole area. Costs associated with the installation of a 1,634 foot green roof were calculated using the Green Roof Energy Calculator developed by the Green Building Research Laboratory at Portland State University **[21]**.

The tool takes into account local utility rates, roof area, building type, growing media depth, leaf area index, and percent coverage. The following assumptions were made for the calculation.

- 2 inch growth media consistent with low-profile intensive green roof installation.
- Full 1,634 square foot available for installation
- Leaf area index of 2.5

The current annual energy savings were calculated when compared to a dark roof, which is consistent with the tar covering on Helen's House, as well as compared to a white roof with albedo of 0.65. The green roof was not as successful as the cool roof design in electrical savings; however, the thermal benefits associated with the green roof are evident in the gas savings, typically associated with heating costs. The results can be viewed in Table 4.

Annual Energy Savings compared to a Dark roof (Albedo = 0.15)	
Electrical Savings	174.3 kWh
Gas Savings	16.9 Therms
Total Energy Cost Savings	$107.82
Annual Energy Savings compared to a White roof (Albedo = 0.65)	
Electrical Savings	-305.9 kWh
Gas Savings	57.6 Therms
Total Energy Cost Savings	$53.71

Table 4 - Annual Energy Savings between Cool and Green Roof **[21]**.

Implementation of such a design, using the $10 per square foot estimate from the EPA, would cost a total of :

$(\$10/ft^2) \times (1{,}634\ ft^2) = \$16{,}340$

Some installations provide credits for stormwater impact fees which help to lower initial investment cost.

Using these energy savings, we can calculate the impact this installation would have on EUI, originally 4.99.

EUI after Green Roof Installation = (75,574.7 / 15,274 ft^2 = **4.94** (a reduction of only 0.05).

Similarly cool roof designs have minimal impact on overall building EUI

EUI after Cool Roof Installation = (76,000 / 15,274 ft^2) = **4.975**

Extensive green roof designs associated with retrofit constructions currently present a net present value (NPV) ranging from 10% - 14% more costly than standard counterparts; however, a reduction of 20% in construction costs would yield cost competitiveness in the roof's value **[26]**.

It should be noted that Green and Cool roof designs provide other benefits to the system and that this section has only been interested in discussing the economic impacts of said installations. The following section will discuss the environmental implications of photovoltaic and green/cool roof implementation as a whole and in regards to Helen's House.

Environmental Assessment:

The purpose of this section is to evaluate the environmental impacts associated with the two selected Net-Zero Energy Building (NZEB) technologies. Buildings currently consume a large portion of energy and material resources during their respective life times, as well as through the embodied energies and emissions associated with their production. Buildings currently account for 41% of total energy consumption in the United States and 38% of its greenhouse gas emissions **[17]**. Considering these values, it is crucial that we begin developing new resident construction strategies to mitigate the costs associated with our aging infrastructure while also performing detailed analysis of new methodologies to ensure they do indeed provide a sustainable alternative. Figure 1 illustrates the life cycle of a standard building with operational phase impacts such as HVAC, lighting, plug loads, and water usage ignored **[18]**.

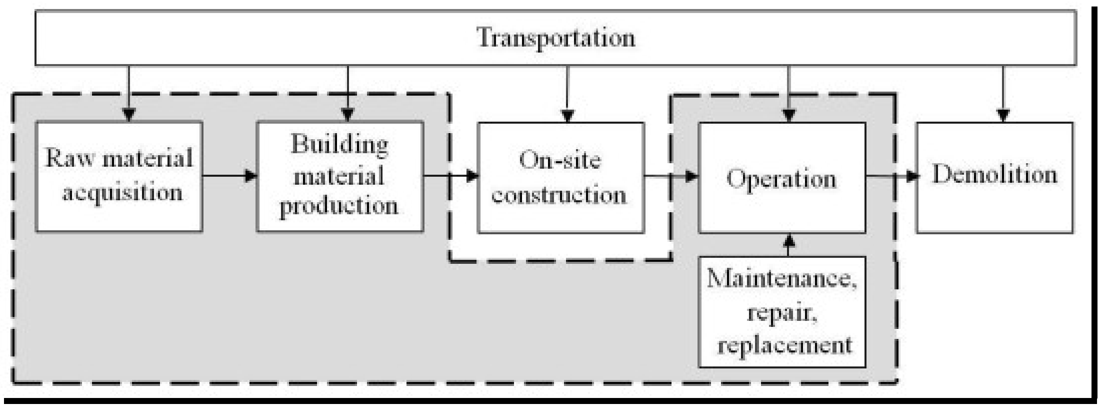

Figure 5. - Life Cycle schematic of standard building sans operational phases **[2]**

Photovoltaic Installation -

PV arrays can still contribute to greenhouse gas emissions through the embodied energy and emissions associated with their production. According to the National Renewable Energy Laboratory (NREL), rooftop PV systems currently contribute approximately 41 g of CO_2e per kWh of energy produced compared to 820 g CO_2e/kWh produced via standard coal power plants and 490 g CO_2e/kWh for combined cycle gas **[22]**. Considering the typical U.S. household consumes, on average, 900 kWh per month, a rough estimate greenhouse gas reduction of ~700 kg per household per month can be expected by investing in rooftop PV installations as depicted in Table 1 **[23]**. This is not accounting for available irradiation in the region as that will determine maximum capacity for photovoltaic electricity generation.

Considering the significance of upstream processes on photovoltaic greenhouse gas emittance it is important to have a thorough understanding of the steps making up their production. This point is illustrated in Figure 6 which is an Inventory Analysis for a simple mono-crystalline silicon panel.

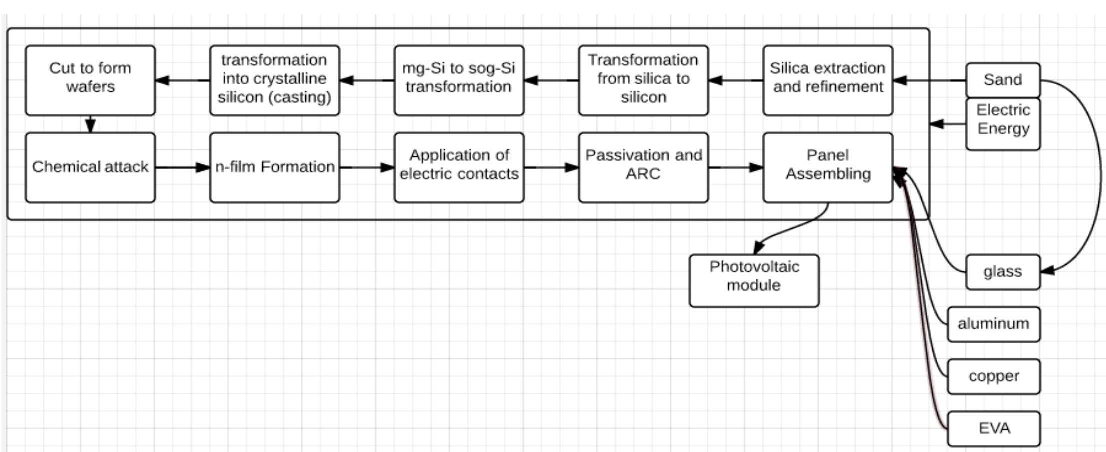

Figure 6. - Inventory Analysis for silicon module/panel production. **[24]**

Case Study: Helen's House

Embodied energy calculations were done for the case site using the statistics previously discussed from NREL. Using the previously calculated electrical consumption for the residence (51,084 kWh) and these values we can determine the hypothetical savings, in CO_2e, associated with supplementing these demands, as well as the real savings associated with what was already determined as potential yield at this location.

Hypothetical PV System Embodied Emission - (41 g CO2e/kWh) x (51,084 kWh) = 2,094,444 g or **2,094 kg of CO2e**

Standard Coal Embodied Emissions - (820 g CO2e/kWh) x (51,084 kWh) = 41,888,880 g or **41,888 kg of CO2e**

Combined cycle Embodied Emissions - (490 g CO2e/kWh) x (51,084 kWh) = 25,031,160 g or **25,031 kg of CO2e**

Real PV System Embodied Emission - (41 g CO2e/kWh) x (5,347 kWh) = 219,227 g or **219.23 kg of CO2e**

Real Standard Coal - (820 g CO2e/kWh) x (5,347 kWh) = 4,384,540 g or **4,384 kg of CO2e**

Real Combined cycle Embodied Emissions - (490 g CO2e/kWh) x (5,237 kWh) = 2,620,030 g or **2,620 kg of CO2e.**

To clarify, a hypothetical system generating the full electrical demands of our case site would save ~39,000 kgs of CO2e when compared to standard coal methods and ~23,000 kg of CO2e when compared to combined cycle embodied emissions. In reality, the system would save ~4,000 kg of CO2e when compared to standard coal practices and ~2,400 kg of CO2e when compared to combined cycle practices.

Green Roof Installations -

Green roof vegetation provides significant urban forest benefits such as carbon sequestration and the improvement of local air quality. In addition, they have the potential to serve as new habitats for wildlife, reduce urban heat island effects, and retain 70-100% of runoff in the summer and 40-50% in the winter **[25]**.

Additional environmental impacts can be determined through the careful analysis of the construction, operation, and maintenance phases for both standard and green roof implementations. Tables 5 and 6 show the environmental impacts associated with common flat roofs over a 50 year period, as well as the changes in those impacts upon the implementation of a green roof.

impact category	impact indicator	materials phase	use phase	maintenance phase	total
abiotic depletion	ton Sb equiv.	18.4	73.6	11.4	103
global warming (GWP100)	ton CO_2 equiv.	2,900	8,970	1,630	13,500
ozone layer depletion (ODP)	kg CFC-11 equiv.	0.32	0.88	0.08	1.28
human toxicity	ton 1,4-DB equiv.	950	2,180	574	3,700
photochemical oxidation	ton C_2H_2	0.72	1.71	0.49	2.92
acidification	ton SO_2 equiv.	12.4	43.7	2.57	58.6
eutrophication	ton PO_4 equiv.	0.42	2.19	0.04	2.65
freshwater aquatic ecotoxicity	ton 1,4-DB equiv.	75.4	152.5	10	238
marine aquatic ecotoxicity	10^3 ton 1,4-DB equiv.	3,630	5,190	181	9,000
terrestrial ecotoxicity	ton 1,4-DB equiv.	3.85	23.65	2.44	29.9

Table 5 - Environmental Impacts for standard flat roof over 50 yr span

impact category	impact indicator	Δ materials	Δ use	Δ maintenance	Δ total	% change total
abiotic depletion	ton Sb equiv.	0.02	−4.72	−0.50	−5.20	−5.0
global warming (GWP100)	ton CO_2 equiv.	2.0	−101	−40.0	−139	−1.0
ozone layer depletion (ODP)	kg CFC-11 equiv.	0.00	−0.02	−0.01	−0.03	−2.4
human toxicity	ton 1,4-DB equiv.	1.00	−81.0	−15.0	−95.0	−2.6
photochemical oxidation	ton C_2H_2	0.00	−0.06	−0.02	−0.08	−2.7
acidification	ton SO_2 equiv.	0.00	−0.96	−0.29	−1.25	−2.1
eutrophication	ton PO_4 equiv.	0.00	−0.13	−0.01	−0.14	−5.3
freshwater aquatic ecotoxicity	ton 1,4-DB equiv.	0.06	−6.00	−0.40	−6.34	−2.7
marine aquatic ecotoxicity	10^3 ton 1,4-DB equiv.	0.00	−211	−4.00	−215	−2.4
terrestrial ecotoxicity	ton 1,4-DB equiv.	0.00	−0.35	−0.10	−0.45	−1.5

Table 6 - Environmental Impacts with added green roof installation over 50 yr span

The addition of green roofing technology had a significant effect on the use and maintenance stages of the roofs life cycle. Not surprisingly, additional environmental impacts were associated with the materials/construction phase due to the processing and transportation of necessary supplies for development.

Case Study: Helen's House

For the purposes of evaluating environmental impacts on Helen's House an average total CO_2 layer emissions of 57.71 kg CO_2/m^2 was assumed for the processing and transportation of materials **[27]**. Total surface area of the case study roof was 15,274 ft^2 which, when converted to meters, yields a surface area of 1419 m^2. The total emissions associated with each layer covering the 1,419 meter squared available roof coverage is:

$$\text{Total Emissions} = (57.71 \text{ kg } CO_2/m^2) \times (1{,}419 \text{ } m^2) = \mathbf{81{,}890.49 \text{ kg of } CO_2.}$$

The largest contributor to CO_2 emissions were for the transportation of the materials as opposed to production and transportation of labor **[27]**. If materials were sourced locally (plants from urban parks or gardens) and certain high emitting components replaced (such as the waterproofing layer which is typically produced from fossil fuel by-products) these emission values could be significantly reduced

The area receives between 28 and 62 inches of rainfall annually **[28]**. During summer months the green roof structure would retain a range of 21-28 inches during low precipitation years and 46.5-62 inches during high precipitation years.

Additionally, these numbers drop to 11.2-14 inches and 24.8-31 inches during the winter months.

Green roofing is considered a sustainable and low environmental impact building system with the potential for improvements and design or material innovations in the future. Green roofs help eliminate the need for regular maintenance on standards roofs due to UV and wind damage and also serve as insulation materials during the winter months.

Social Sustainability Assessment:

This section of the report is geared towards evaluating the impacts of our two NZEB technologies on social well-being of either society as a whole or particular groups of stakeholders. Social metrics will be discussed on the following criteria: Quality of life, Equity, Diversity, and Social cohesion.

Quality of life -
Helen's House is a government run transitional house with services geared towards supporting people affected by homelessness and unemployment. The implementation of photovoltaic installations and green roof technologies would help to offset the costs associated with heating and generating electricity for the residents over the long run and would serve as an investment into the program as a whole to lessen the burden for future high need individuals and their children by offsetting monetary resource demands currently affiliated with heating and electricity consumption. Additionally, the installations would serve as educational models for low and underprivileged community members who generally aren't exposed to said technologies because of the high capital costs associated with their deployment.

Equity -
The target group is already faced with a significant social disadvantage through their lack of housing. The implementation of these technologies would relief stress on the government institution as a whole over the long run and would better serve both employees of the transitional house, as well as, the residents themselves. This project would be effecting the poorest and most vulnerable members of the NYC community.

Diversity -
I am of the belief that this project would significantly impact diversity in a positive light. The majority of civil strife and conflict is generated around groups of individuals who are impoverished in some shape or form, as well as neglected by their communities. A public investment initiative aimed at improving the lifestyle for homeless individuals would illustrate support from the community and, hopefully, help to promote understanding across the community's diverse cultures and backgrounds.

Social cohesion -
The very definition of social sustainability is an occurrence in which the formal and informal processes, systems, structures, and relationships support the capacity of

current and future generations to create healthy liveable communities **[29]**. As previously stated, the development of renewable projects for government assisted housing is a very visible form of supporting the most underprivileged within our community and promoting cohesion and acceptance among stakeholders, similar to the diversity aspect previously discussed.

The various environmental, economic, and social systems and affiliated factors comprising the cast study site are all part of a much larger system which will be termed the sustainability system. The economic and environmental implications discussed above illustrate the feasibility of such an undertaking while the social metrics discussed previously are illustrative of a system in need of outside support. The two technologies seem to be most appropriately utilized in commercial or multi-family settings due to the efficiencies associated with these building categories. The social benefits for the addressed underprivileged stakeholders are evident and further support the necessity for further renewable project implementation for urban low income populations.

Bibliography:

[1] UN Department of Economic and Social Affairs. *World Urbanization Prospects*. 2014. Retrieved April 20th 2015. Access

[2] U.S. Energy Information Administration. *Residential Energy Consumption Survey (RECS)*. 2009. Retrieved April 20th 2015. Access

[3] The City University of New York. *NYC Solar Map.* 2009. Retrieved April 15th 2015. Access

[4] The City University of New York. *Strategic Zones*. 2009 Retrieved April 15th 2015. Access

[5] Columbia University. *Estimated Total Annual Building Energy Consumption at the Block and Lot Level of NYC*. 2009. Retrieved April 18th Access

[6] Henry Street Settlement. *Helen's House*. Retrieved April 25th 2015. Access

[7] International Economic Development Council, *Analysis of the Net Zero Energy Home* Industry, 2013, Date visited: Mar 10th, 2015 Access

[8] Kenney, T., and J. Wiehagen. 2007. Zero Energy Homes—The Potential of large-scale implementation. *Proceedings of the Thermal Performance of the Exterior Envelopes of Whole Building X* , Florida, USA. December.

[9] Ham and Petersham Street Champions, *Solar PV Panels,* Dated visited: Mar 10th, 2015 Access

[10] Bee Solar Power, *Frequently Asked Questions* Date visited: Mar 10th 2015 Access

[11] Tester, Jefferson, Elisabeth Drake, Michael Driscoll, Michael Golay, and William Peters. "Solar Energy." *Sustainable Energy: Choosing among Options*. 2nd ed. 2012. p. 680. Print.

[12] Tester, Jefferson, Elisabeth Drake, Michael Driscoll, Michael Golay, and William Peters. "Solar Energy." *Sustainable Energy: Choosing among Options*. 2nd ed. 2012. p. 681. Print.

[13] Alternative Energy. *Common Types of Solar Cells*. Retrieved April 15th 2015. Access

[14] EnergyStar. *What is energy use intensity (EUI)?*. Retrieved April 24th 2015. Access

[15] CUNY. *NY Solar PV Incentive Guide: Residential*. November 2014. Retrieved April 25th 2015. Access

[16] ASES. *Salvage Value of Photovoltaic Systems*. Retrieved April 25th 2015. Access

[17] National Renewable Energy Laboratory. *Zero Energy Buildings: A Critical Look at the Definition*. June 2006. Retrieved April 19th 2015. Access

[18] Basbagill. J, Flager. F, Lepech. M, Fischer. M. *Application of life cycle assessment to early stage building design for reduced embodied environmental impacts*. Retrieved April 19th 2015. Access

[19] The Construction Specifier. *Green Roof Specifications and Standards.* August 2003. Retrieved April 27th 2015. Access

[20] U.S. Environmental Protection Agency. *Green Roofs*. Retrieved April 23rd 2015. Access

[21] Portland State University. *Green Roof Energy Calculator*. Retrieved April 24th 2015. Access

[22] IPCC Working Group III. Mitigation of Climate Change, Annex II I: Technology - specific cost and performance parameters. IPCC. 2014. p. 10. Retrieved April 19th 2015. Access

[23] U.S. Energy Information Administration. FAQ *How much electricity does an American home use?*. February 2015. Retrieved April 19th 2015. Access

[24] A. Stoppato, Energy, Volume 33, Issue 2, February 2008, *Life cycle assessment of photovoltaic electricity generation* Pages 224-232. Retrieved April 18th 2015.

[25] Green Roof ToolKit. *Green Roof Overview*. Retrieved April 24th 2015. Access

[26] Green Roofs Tree of Knowledge. *Economic Benefits.* January 2007. Retrieved April 23rd 2015. Access

[27] PLEA. *Carbon Dioxide emissions of green roofing - case study in southern Brazil*. Retrieved April 24th 2015. Access

[28] Northeast Regional Climate Center. *Normal Average Temperature (Deg F): Annual (1971-2000)*. 2012. Retrieved April 20th 2015. Access

[29] Adams, W.M. *The Future of Sustainability: Re-thinking Environment and Development in the Twenty-first Century*. January 2006. Retrieved April 25th 2015. Access