



## **Sustainable Building**

## **Final Report**

**Cornell / Port Authority Project Team**

**Green Building Sustainability Assessment**

**Stewart International Airport**

**Newburgh, New York**

Amandeep Gupta

Umer Gul

Benjamin Scott Kemper

Justin Li

Rahul Margam

Jeffrey Daniel West

Yuanjie Zhou

# Executive Summary

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The Port Authority of New York and New Jersey (PANYNJ) is a bi-state agency that operates much of the regional transportation infrastructure that comprises the greater New York Harbor area - including tunnels, bridges, airports, and port facilities. Managed by a Board of Commissioners appointed jointly by the governors of New York and New Jersey, PANYNJ does not receive any state funding, but instead generates all of its operating revenues through the collection of tolls, fees, and rents.

Along with many other public and private agencies, PANYNJ has recently taken steps to reduce its infrastructure operating costs and embrace more environmentally sustainable practices. Employing its own Environmental Sustainability Guidelines, which are based on the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) building standards, PANYNJ has started focusing on the new design and rehabilitation of their facilities in an effort to reduce adverse impacts to the environment. The Engineering & Architecture Department at PANYNJ is interested in exploring new green building and sustainable design systems in their future projects as a means of reducing their environmental impact and increasing the energy/cost efficiency of their infrastructure. (Port Authority)

In particular, due to the availability of federal funding dollars for such a project, PANYNJ has presented the need for a Snow Removal Equipment (SRE) building at Stewart International Airport as an experimental platform for the application of green building techniques and methods. After refining and focusing the scope of work for this project, the team conducted a site visit with key stakeholders at Stewart International Airport and used this time to gather important information about the existing Snow Removal Equipment facility and personnel. This data and that gathered subsequent to the visit proved critical to understanding the habits and needs of the intended users of a future SRE building. The team also consulted with other airport facilities that had recently constructed sustainably outfitted SRE buildings to learn from their experiences and varied successes with implementing green features. Through life cycle analysis and feasibility assessment, this multi-disciplinary engineering graduate student team researched several sustainable design elements for an SRE facility and modeled the impact of these components on energy efficiency and cost-effectiveness.

From the element analysis contained within this report, the team developed a three-tier approach to examine the outfitting a future SRE with sustainable features. Based upon the

green elements and systems that will be examined in depth in the following sections, the team developed a three-tiered stratification of recommends based upon the cost and return from implementing these components into a snow removal equipment building at Stewart International Airport. With the exception of the initial building cost, all monetary values listed below are in terms of Net Present Value (NPV).

### **Tier One: Baseline Energy Efficient Components**

Tier One is composed of those essential elements that no new construction would go without. This includes an efficiently insulated building envelope, an ASHRAE 90.1 compliant HVAC system, and all other components associated with the basic cost of the building – such as a basic lighting systems, standard roof systems, and standard low flow water fixtures. These baseline costs were based on an assumed 64,000 SQFT snow removal equipment building with a base cost of \$100.00 per SQFT.

Basic Building Costs =  $\$100/\text{SQFT} \times 64,000 \text{ SQFT} = \$6,400,000.00$

ASHRAE 90.1 Compliant HVAC System Cost = \$945,644.00 (NPV)

**Tier One Implementation Cost = \$7,345,644.00**

### **Tier Two: Tier One + Cost Effective Sustainable Features**

The Tier Two package would consist of the baseline energy efficient building described above, in addition to the most cost-effective sustainable features as determine by our analysis. These are the green roof and skylights. Note that the NPV after the skylight cost indicates that this cost is the net present value after adding the upfront cost of the skylights and subtracting the present worth of their lifetime energy savings over 50 years.

Tier One Implementation Cost = \$7,345,644.00

Conventional Roof Cost = -1,267,169.00 (subtracted from Tier One to accommodate Green Roof)

Green Roof Cost = \$1,256,012.00 (NPV)

Skylight Cost = -\$4,595.00 (NPV)

**Tier Two Implementation Cost = \$7,329,892.00**

### **Tier Three: Tier One + Tier Two + Non-Cost Effective Sustainable Features**

The Tier Three package consists of the baseline building outlined in Tier One, the cost effective sustainable features described in Tier Two, plus the other non-cost effective green features that were explored as part of this analysis – including geothermal heating/cooling for the building office area, a photovoltaic system, ultra high efficiency water fixtures, and a storm watering harvesting system.

Tier Two Cost = \$7,329,892.00

Geothermal System Cost = \$67,946.00 (NPV)

Photovoltaic System Cost = \$2,789,602.00 (NPV)

Ultra High Efficiency Fixtures Cost = \$15,535.00 (NPV)

Storm water Harvesting System Cost = \$78,215.00 (NPV)

Reduction of HVAC system for office area = -\$47,281.00 (NPV)

**Tier Three Implementation Cost = \$10,233,909.00**

### **Other Considerations and Justifications beyond the Price Tag**

We should note that this determination of “cost effective” is solely based upon the value of the dollar as we see it today – in other words, there are other factors that one may want to consider when deciding to implement or not implement these features. This is especially true of the Tier Three products and systems, which while not cost effective right now, may pay for themselves or come closer to paying for themselves as environmental and sustainability regulations develop in the future. For example, future regulatory measures such as a Carbon Tax, used in many European countries and being preliminarily experimented with in parts of the United States, would quickly see many of these Tier Three products move toward cost effectiveness as it would inflate the relative cost of employing fossil fuels. Similar regulatory taxation and fee measures with storm water runoff are also being implemented around the world and could make Green Roofs and Storm Water Harvesting a valuable building feature in the not too distance future. Moreover, there are less tangible but equally important factors such as environmental stewardship, as well as internal directives and goals such as those set by the Port Authority Sustainable Design Guidelines. And, finally, specifically with Stewart, there is the rationale of implementing these measures as a test-bed in a smaller scale facility to determine if the Port Authority would want to scale-up their

implementation at larger facilities, where the economy of scale may make these components more worthwhile economically.

# Team Background

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## Umer Gul

Umer graduated in 2006 with a Bachelor's of Science in Computer Engineering. He has worked with Ericsson Pakistan as a team lead/ network design engineer. During his four years with Ericsson, Umer has worked in different market units and represented Ericsson Pakistan on many international forums. Currently, Umer is pursuing a degree in Masters of Engineering Management. He did not have prior experience in sustainable development field but has been excited to be part of this team.

## Amandeep Gupta

Aman graduated as a Civil Engineer last May from India and is currently studying Environmental and Water Resources Systems Engineering at Cornell. He has worked as a research associate at IIT in Kanpur, India. He has prior internship experience as well. Aman has an interest in the field of sustainable development and working on this project has helped him expand his vision and understanding regarding problems of sustainable development.

## Ben Kemper

Ben is a Master of Engineering Management student from Central New Jersey. He obtained his undergraduate degree in Operations Research and Information Engineering last May from Cornell. Ben has taken previous courses in sustainable development, and has had an interest in this subject area. Additionally, Ben brought internship experience from an engineering planning office.

## Justin Li

Having completed his undergraduate major in Operations Research in 2010, Justin is currently studying Engineering Management at Cornell. He was born in New York City but raised in Brooklyn

throughout his life. Through this project, he has learned the essential techniques required to conduct a successful feasibility study. He has also gained greater knowledge about sustainability and building management. Justin's areas of interest include the analysis and modeling of large sets of data and trade-off scenarios.

## **Rahul Margam**

Graduated in 2009 with a Bachelor's in Computer Science from JNTU, Hyderabad in India. He is currently a Master's student in Engineering Management at Cornell University. He has worked as a research assistant at IIT-Hyderabad. Rahul enjoys applying his skills as a programmer to come up with unconventional solutions to problems. This was Rahul's first time working on a project in the field of sustainability, and he has been excited about the learning opportunity that it has held.

## **Jeffrey West**

Jeff graduated from the U.S. Coast Guard Academy in 2006, where he earned his Bachelor of Science in Civil & Environmental Engineering. For the last four years, Jeff has been serving on Active Duty as a Coast Guard Officer station in Honolulu, Hawaii, and more recently in Fort Myers Beach, Florida. Although primarily responsible for Search & Rescue and Law Enforcement operations during this time, Jeff was also involved in several Civil Engineering projects. He supervised the replacement of a 150-foot reinforced concrete pier in Florida and also assisted the U.S. Geologic Survey with the construction of two tsunami detection stations on remote islands in the Central Pacific Ocean.

Currently, Jeff is at Cornell University on sabbatical to pursue a dual Master of Engineering and Master of Business Administration curriculum. Upon graduating in Spring 2012, he will return to Active Duty and serve at one of the Coast Guard's Civil Engineering Units.

## **Yuanjie Zhou**

Yuanjie graduated in 2006 with a Bachelor's degree in Environmental Science and Engineering from Tsinghua University in China. Her undergraduate researches were focused on water management. Currently, she is a master student of Engineering Management at Cornell with the specification in

energy and environment. Yuanjie has participated in some projects considering both environmental benefits and cost effectiveness. In this project, Yuanjie has the interest in the green construction, especially concerning the environmental impact and energy efficiency of projects elements, such as that for green roof infrastructures.

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# 1. Project Objective and Scope

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## 1.1 Background on PANYNJ

### 1.1.1 The Port Authority of New York and New Jersey (PANYNJ)

PANYNJ was established in 1921, as the first-ever bi-state agency in the United States. Its jurisdiction includes tunnels, bridges, trade and transportation within a 25 mile radius of the Statue of Liberty. The only exception to this is Stewart International Airport, the entity for which this team investigated the feasibility of implementing a new SRE building. The facilities currently operated by PANYNJ include: "...America's busiest airport system, marine terminals and ports, the PATH rail transit system, six tunnels and bridges between New York and New Jersey, the Port Authority Bus Terminal in Manhattan, and the World Trade Center." (Port Authority)

### 1.1.2 Stewart International Airport (SWF)

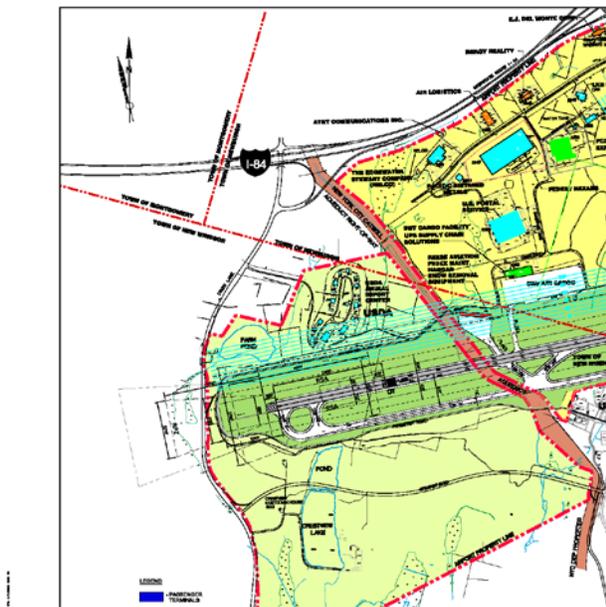
Stewart Airport is located in the southern Hudson Valley region of New York state; in the towns of Newburgh, NY and New Windsor, NY; just over 60 miles from New York City. Stewart has been operated by PANYNJ since November of 2007, at which point PANYNJ purchased the remaining 93 years of a lease for the facilities at Stewart. PANYNJ has committed \$500 million as part of a ten-year capital improvement plan to expand and improve Stewart. (Port Authority)

Stewart is considered a regional airport facility, having serviced 395,000 passengers in 2010. The current facilities consist of a single terminal with seven passenger gates and concession space. Several large cargo carriers and private aviation companies also operate hangars on Stewart's grounds. Additionally, the Stewart Air National Guard Base maintains a significant presence at Stewart. Despite its regional size, Stewart has exceptionally long runways: the main runway is 11,818 feet long; and the secondary runway is 9,818 feet long. The runways were proportioned in order to be capable of accommodating the large military aircrafts which utilize the Air National Guard Base. (Port Authority)

PANYNJ views Stewart as a strategic investment with tremendous growth potential. The Hudson Valley population is currently over 2.4 million people, and is growing at an approximate rate of ten percent every decade. (Fiscal Policy) PANYNJ also views Stewart as a potential outlet to relieve congestion of its New York City metropolitan area airport facilities, which are rapidly

approaching their capacities. Further, a rail connection from New York City to Stewart has been discussed in the New York State Legislature. PANYNJ believes that Stewart is capable of handling up to five times its current passenger flow. Moreover, PANYNJ is currently in the process of planning a terminal expansion, and is in discussions with airlines to provide service to European destinations. (Mid-Hudson)

Figure 1 below is the Stewart Airport Layout Plan. Note that all of the light yellow colored area is undeveloped land that is owned by Stewart, and represents potential area to expand Stewart’s facilities.



**Figure 1- Existing Airport Layout**

During the team’s Site Visit to Stewart Airport on February 11, 2011; the team was able to tour the airport grounds, including its current SRE storage building. The team also met with

various members of the administration and staff at Stewart to gather information. The following paragraphs describe the information gathered from the Site Visit.

Currently, Stewart houses its SRE equipment in a World War II-era warehouse style building. The building is at or beyond its useful life, and is not at all energy efficient. Insulation is sparse, and energy systems lack basic efficiencies. Furthermore, the building is too small for Stewart's SRE fleet. Some pieces of equipment are stored outside due to a lack of indoor space. Despite this, Stewart has more SRE on order so that it will be able to better meet the snow removal needs of the airport.

Thus, the need for a new SRE building at Stewart is immediate. PANYNJ views this as an especially feasible and attractive undertaking because of the fact that the Federal Aviation Administration (FAA) significantly subsidizes the construction of new SRE buildings to encourage protection of investments in high-quality SRE. Additionally, PANYNJ would eventually like to use design elements and concepts from the development of a new SRE at Stewart to assist in designing new, sustainable SRE facilities at other PANYNJ-operated airports in the New York City metropolitan area.

## 1.2 Project Objectives

The objectives of the Port Authority Sustainability Assessment were:

- (1) To identify and research green and sustainable design building features.
- (2) To evaluate the applicability of sustainable features to a Snow Removal Equipment building at Stewart International Airport.
- (3) To conduct a lifecycle cost analysis associated with the implementation of each sustainable feature at Stewart International Airport.
- (4) To make preliminary recommendations to the Port Authority's Engineering Division regarding the implementation and effectiveness of each sustainable building feature at Stewart International Airport.

## 1.3 Scope of the Project

### 1.3.1 Within the Scope

There are many green features that enhance the quality of a green structure for Stewart International Airport in Orange County. Based on the ASHRAE standards, the team considered that

promoting green design elements such as the following in new building developments will have a positive impact on the environment:

- Indoor lighting
- HVAC
- Renewable energy
- Green building materials
- Green roof system
- Stormwater & Greywater management

#### 1.3.1.1 *Indoor lighting*

Exploration of different indoor lighting technologies for artificial lighting options such as fluorescent lamps, T5 lamps, compact fluorescent lamps and solid state lighting, and natural lighting options such as skylights, clerestories and light tubes and daylight harvesting

- Usage feasibility assessment
- Cost benefit analysis
- Environmental impacts

#### 1.3.1.2 *Heating, Ventilation and Air-conditioning*

ASHRAE standard 90.1- 2010 was consulted for regulations and recommendations regarding HVAC. The general aim will be to contrast a baseline economical model of the building, incorporating no or modest green designs, with subsequent additions of green designs according to ASHRAE standards. Recommendations were then made accordingly.

#### 1.3.1.3 *Renewable Energy*

- Solar Energy was regarded as the major source of renewable energy.
- Detailed study and analysis of the potential applications of the both Active and Passive Solar energy especially photovoltaic systems
- Application of geothermal energy

#### 1.3.1.4 *Green building materials*

- Basic green building materials for the construction of the building
- New technologies for the incorporation which were feasible and appropriate for the project

- Individual or collective design and construction initiatives which could contribute to more efficient and less costly acquisition of ASHRAE standards

#### 1.3.1.5 *Green roof system*

- Incentives for inclusion of this system
- Basic structure and material
- Initial site analysis including wind, solar, vegetation view and circulation
- Cost estimate for probable construction
- Cost benefit analysis and Life cycle analysis measured against time frame and rate of return
- Environmental and social benefit

#### 1.3.1.6 *Stormwater & Greywater Management*

- Feasibility assessment of stormwater management considering factors such as runoff coefficients, materials to be used, size and location of cistern, and possible uses of the collected water
- Exploration of collection procedures, treatment processes and possible reuses of the greywater
- Recommendations regarding use of low water use fixtures

### 1.3.2 *Outside the Scope*

While this project is focused on the green design of a new storage of Port Authority, analysis of the following aspects will not be included:

#### 1.3.2.1 *Simulations*

The feasibility study was carried out to test the likelihood of success and whether project's financial, aesthetic, environmental, construction and logistical goals determined in the planning phase could be met. However, the simulations of the construction design were not included in this project.

#### 1.3.2.2 *Actual design or construction of the physical building*

The overall design and construction approach was not carried out. Thus there are limitations to further identify the opportunities and constraints that may be encountered throughout the project.

#### 1.3.2.3 *Details of the design and construction of each green element*

As some details of the design and construction of each green element were neglected, it has led to corresponding impact on cost analysis.

#### 1.3.2.4 *LEED standards*

LEED standards were not taken into consideration; only AHRAE standards and the Port Authority Sustainable Guidelines were followed.

#### 1.3.2.5 *Some of the ASHRAE regulations*

ASHRAE standard 90.1 is a very comprehensive standard, most of the regulations proved to be beyond the scope of the project.

#### 1.3.2.6 *Study of other renewable energies*

Study of wind power, biomass and hydropower energy was not carried out.

#### 1.3.2.7 *Deicing Chemicals*

Processing of the deicing chemicals was not in the scope of the project.

#### 1.3.2.8 *Site plan*

The exact position of the building within Stewart Airport was not be defined by the team.

## 2. Literature Review

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### 2.1 Introduction

This document is a review of recent literature which will serve as references for this team as it designs a new snow removal equipment storage facility for Stewart International Airport in Newburgh, New York. This airport is operated by the Port Authority of New York and New Jersey. The following literature review encompasses various sustainable development methods which the team will implement into its design, as well as a case study of a recently-constructed, sustainably designed snow removal equipment storage facility in Green Bay, Wisconsin.

### 2.2 Renewable Energy

Renewable energy is any technology that exclusively relies on an energy source that is naturally regenerated over a short time and derived directly from the sun, indirectly from the sun, or from moving water or other natural movements and mechanisms of the environment. Renewable energy technologies include those that rely on energy derived directly from the sun, wind, geothermal, hydroelectric, wave or tidal energy, or on biomass or biomass based waste products, including landfill gas. (Waltonselectric.com)

### 2.3 Solar Energy

Solar energy is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaics or heat engines. Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy.

### 2.4 Active Solar

Active solar techniques include the use of photovoltaic panels to harness the energy.

## 2.5 Photovoltaic

Photovoltaic (PV) systems use solar electric panels to directly convert the sun's energy into electricity. This conversion of sunlight to electricity occurs without moving parts, is silent and pollution free in its operation. The solar electricity fed through electronic equipment is converted to utility grade electricity for use directly in the home. The solar electricity can be used to offset the need for purchased utility electricity or, if the PV electricity exceeds the home's requirements, the excess electricity can be sent back to the utility, typically for credit. (toolbase.org)

Different types of photovoltaic products are available today from numerous manufacturers. The supply of PV collectors worldwide has increased from 20 to 30 percent annually to keep up with the demand for this renewable energy technology. PV modules (or solar electric collectors) are different from solar thermal collectors (that convert the sun's energy into thermal (typically hot water) energy). Photovoltaic modules are usually rigid, rectangular devices ranging in size from 2' by 4' to as large as 4' by 8'. Some PV module technologies are flexible and as large as 2' by about 20' or even larger. Rigid PV modules typically have a glass cover while the flexible modules have a very durable film cover. Both types of PV module construction have been rigorously tested to survive storm and hail damage and are resistant to degradation from ultra-violet rays. (toolbase.org)

Most residential PV systems are used in conjunction with utility supplied power. Excess power produced during daylight hours can be fed back into the utility's lines, while utility electricity is used in the home when the house demand is greater than can be supplied by the PV roofing. Typical residential PV systems commonly have a peak power production of between 1,200 and 5,000 watts, AC requiring from between 150 to over 1,000 square feet of installed area depending on the efficiency of the PV technology used. (toolbase.org)

Most often, PV panels are installed on roofs, but they can also be installed as free standing units, on a pole on the ground, or even on complex tracking structures that change with the sun's angle during the day. (toolbase.org).

The current levels of dependence on fossil fuels, the need of reducing the carbon emissions associated with energy use and the prospects of developing a new and extremely innovative technology sector, make photovoltaics increasingly attractive. Competition is increasing. New technologies such as ‘thin film’ are being developed. In the thin-film approach, a thin layer of the photovoltaically active material is deposited onto a supporting substrate or superstrate. This not only greatly reduces the semiconductor material content of the finished product (over 100 times less material), it also allows for higher throughput commercial production since the module, instead of the individual cell, becomes the standard unit of production (a unit some 100 times larger unit). In 1995, a new Australian company, Pacific Solar, was established to commercialize an approach to thin-film cells, based on combining the UNSW’s group now successfully commercialized buried contact work with a new approach to the design of thin-film cells. Pacific Solar is a joint venture between leading utility, Pacific Power, and Unisearch Ltd., the commercial arm of UNSW. (Green)

## 2.6 Passive Solar

Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air. Effective lighting solutions must be addressed in a holistic fashion. When it comes to proper illumination, one size does not fit all. Specific lighting needs must be addressed throughout the facility to minimize problems that arise with over-lighting or under-lighting an area. In an existing building there are certain confines one needs to work within, including the placement of fixtures, office layout and adjacencies. Although complete standardization may make some decisions easier, a smart selection of lighting alternatives, including lamps and ballasts, will provide the optimum benefits to the facility.

## 2.7 Indoor Lighting

### 2.7.1 Artificial Lights

*The following are some of the artificial lights that can be used for indoor purposes:*

### 2.7.1.1 *Fluorescent Lamps*

Developments in lighting technologies over the last 10 years have created the possibilities of reducing lighting costs by as much as 30 to 50 percent and total facility energy consumption and costs by up to 20 to 25 percent. New T8 fluorescent bulbs, when used with high efficiency electronic ballasts, can reduce total system wattage by 45 percent, compared to T12 bulbs with magnetic ballasts, and by as much as 20 to 30 percent, relative to the use of older T8 lamps and electronic ballasts. (Conley)

### 2.7.1.2 *T5 Lamps*

T5 lamps are being installed in many facilities as they offer various opportunities for lighting designers and manufacturers. T5 lamps measure 5/8 inch in diameter (16 mm). The smaller diameter lamp allows for smaller luminaires, including surface mounted, cove lighting and cabinetry applications. (Conley)

Some care must be taken in the application of T5 lamps. T5s are designed mainly for new construction and not intended for retrofit applications. Optimum use of T5 lamps are in high bay ceilings, such as outdoor overheads and warehouses. When T5 lamps are installed, fewer fixtures are needed, resulting in cost savings because fewer parts are needed, resulting in lower installation and energy costs. (Conley)

### 2.7.1.3 *Compact Fluorescent Lamps*

A compact fluorescent lamp (CFL) is a type of fluorescent lamp. Many CFLs are designed to replace incandescent lamps and can fit into most existing fixtures that use incandescent lamps. CFLs are more energy efficient than incandescent lamps, typically using 75 percent less energy and generating less heat, and can last 10 times as long. (Conley)

Compared to general service incandescent lamps producing the same amount of visible light, CFLs generally use less power and have a longer rated life, but a higher purchase price. In the United States, a CFL can save over \$30 (US dollars) in electricity over the lamp life compared to an incandescent lamp and can reduce greenhouse gas emissions by 2,000 times the weight of the lamp. Like all fluorescent lamps, CFLs contain mercury, complicating their disposal. (Conley)

CFLs radiate a different light spectrum than incandescent lamps. Improved phosphor formulations have improved the subjective color of the light emitted by CFLs such that some sources rate the best soft white CFLs as subjectively similar in color to standard incandescent lamps. (Conley)

#### 2.7.1.4 *Solid State Lighting*

Solid state lighting (SSL) is a type of lighting that uses light emitting diodes (LEDs), organic light emitting diodes (OLED) or polymer light emitting diodes (PLED) as illumination sources, as opposed to electrical filaments, gas or plasma (used in arc lamps such as fluorescent lamps). Solid state refers to the fact that light in an LED is emitted from a solid object, a block of semiconductor, rather than from a vacuum or gas tube, as is the case in traditional incandescent and fluorescent lamps. Compared to incandescent lighting, SSL creates visible light with reduced heat generation or parasitic energy dissipation, similar to that of fluorescent lighting. (Conley)

Solid-state lighting has the potential to revolutionize the lighting industry. Light-emitting diodes (LEDs)—traditionally used in signs, signals and displays—are rapidly evolving to provide light sources for general illumination. This technology holds promise for lower energy consumption and reduced maintenance. Research is being done to enhance this technology, overcome barriers, and help it to gain acceptance for general illumination purposes.

Successful solid state lighting depends not only on the performance of individual components, but also on the integration of those components and how the entire system performs. Poor integration can lead to poor light quality and premature failure of LED-based lighting systems. Interaction between LED chips, phosphors, encapsulation materials, optics, heat sinks, drivers and luminaire housing is being analyzed. The work on new ways to design LED systems for better light output and color, high luminous efficacy and longer life is also underway. The goal is to optimize integrated systems performance so that solid-state lighting systems ultimately live up to their promises. (Narendran)

#### 2.7.2 *Natural Lighting*

Greater reliance on natural light reduces energy consumption, favorably impacts human health and improves workplace and academic performance. Based on research at Carnegie Mellon University and others, daylighting appears to improve productivity and reduce absenteeism by at least 20 percent. A 20 percent increase in productivity by an employee making \$50,000 (US dollars) annually yields \$10,000 (US dollars) to the company. (Conley)

The following are some of the natural lighting techniques:

### 2.7.2.1 Skylights

Skylights are horizontal windows or domes placed at the roof of buildings, often used for daylighting. Skylights admit more light per unit area than windows, and distribute the light more evenly over the space. The optimum material to use for skylights is a white translucent acrylic. This material is a Lambertian diffuser, meaning that the light transmitted through the skylight is perfectly diffused and distributed evenly over the area the light hits. The optimum number of skylights, usually quantified as effective aperture, varies based on climate, latitude and characteristics of the skylight. However, 4 to 8 percent of the floor area is a good rule of thumb to determine the optimum number of skylights for a space. When selecting skylights, it is important to select models with at least two panes of glass and a heat reflecting coating. The heat reflecting coating will help to reduce the heat gain transmitted through the skylight to the space. Single pane skylights may weep or leak when condensation builds up around the skylight. (Conley)

### 2.7.2.2 Clerestories and Light Tubes

A clerestory is a row of windows above eye level to allow light into a space. In modern architecture, clerestories provide light without distractions of a view or compromising privacy. Often, clerestory windows provide light into interior wall surfaces painted white or another light color. The walls are placed to reflect indirect light to interior areas where it is needed. By redirecting the light, the light can be softer and more diffuse, reducing shadows. Another type of device used to redirect light is the light tube, also called a solar tube or the tubular skylight. Light tubes can be placed into a roof and admit light to a focused area within the interior of a building. Light tubes passively collect light using a rooftop dome and transmit the light into a space through a highly reflective rigid or flexible tube to a ceiling diffuser that looks very much like a recessed light fixture (Gordon 2003). An advantage of light tubes, compared to skylights, is that they allow less heat to be transferred to the space, as light tubes have less exposed surface area. (Conley)

### 2.7.2.3 Daylight Harvesting

The process of using light level detectors to augment natural light with artificial light to maintain a constant lighting level within a space, while reducing energy consumption. This technique is similar to a heating control with a thermostat. [5]

Daylight harvesting assumes an area in a building, such as an office, will have a natural source of light available during the daylight hours. A processing device monitors the natural light level and continuously adjusts the artificial light level using dimming to maintain the required light level. (Conley)

Daylight harvesting can reduce the energy consumption from artificial lighting 35 to 60 percent. Daylight harvesting can also provide significant opportunities to reduce peak demand charges, as peak demand typically occurs when the most natural light is available. (Conley)

### 2.7.2.4 Vendors

Below is the list of some of the PV vendors:

- Astronergy
- BP Solar
- Canadian Solar
- Conergy
- EcoSolargy, Inc.
- Evergreen Solar
- GE Electric
- Hyundai
- Mitsubishi Electric
- Kyocera
- NB Solar
- PowerUp
- REC Solar
- Ritek
- Samsung
- Sanyo
- Sharp SolarWorld
- Solon

- SunTech
- SunWize
- Trina Solar
- Uni-Solar
- UPG
- Yingli Solar

Of these Sharp, SolarWorld, 1Soltech and Solon panels are American made. (wholesaler.com)

## 2.8 Green Building Materials

### 2.8.1 Overview

Green building materials are a rapidly developing and expanding sector of the construction materials market. What constitutes a “green” material varies widely depending on the source. While no official government standard exists to provide definable guidelines, the Federal Trade Commission is working on such a plan. Meanwhile, the certification of green and/or sustainable building materials has been left to professional trade organizations. While each sector of the construction materials industry has its own or multiple sets of criteria, the common bond tends to be the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED) guidelines and standards. However, regardless of the source, the common elements that bind green material evaluation are very similar and include– production energy usage and waste, low toxicity/minimal emissions, recycled content/recyclability, locality of production, impact on indoor air quality, and affordability.

### 2.8.2 Dimension Stone

Dimension stone is the name given to natural quarried stones that are cut to required dimensions and finished – such as granite, slate, limestone, sandstone, and marble. Used in building facades, indoor flooring, and outdoor walkways, it is widely noted as one of the most durable and green types of building materials. Of special note is the ease with which dimension stone can be recycled during old building demolition and used either in whole form or crushed into aggregates for use in concrete mixtures. To be certified as “green” building material by the USGBC or other organization, this stone usually needs to have been quarried locally, usually within about 500 miles

of the building site. The Natural Stone Council has information available about the energy usage and green characteristics of most all commercially available dimension stone products.

### 2.8.3 Concrete

As a general building material, concrete is considered “green” by most standards, although issues do arise concerning the amount of CO<sub>2</sub> emissions released during cement its production. One remedy to that concern has been the addition of supplemental cementitious materials to replace some of the portland cement needed in the mix – to date this is generally accomplished with the use of fly ash, which is obtained and recycled from coal burning power plants. Moreover, adding to its value is that fact that concrete can be harvested during building demolition and recycled as filler or aggregate in future concrete products. In addition, the structural reinforcing steel using to support concrete can also be harvested and recycled. When used for paved surfaces or roofing, especially when compared to asphalt materials, cement has been shown to greatly aide in reducing the Heat Island Effect by reflecting a higher significance of light. Additionally, another green aspect of concrete is a special form known as pervious concrete. It is primarily used in pavement surfaces, such as parking lots, to help reduce storm water runoff concerns. It is produced by adjusting the aggregate proportions in ready mix concrete – by reducing the amount of sand and fine aggregates in the mix, voids are created that allow for water to penetrate down through the pavement.

### 2.8.4 Wood/Engineering Wood Products

The sustainable aspects of wood as a green building material are complex. At the origin of the product is the Forest Stewardship Council (FSC), which is a certification industry that works with and monitors wood harvesters to ensure that sustainable growth and harvesting practices are been used. The actual uses of wood in green construction can vary from fine finished flooring to rough framing. Technological advances/automation of sawmill facilities has resulted in the increased efficiency of output compared to years prior; in addition, the production of wood itself in much more energy efficient per ton than comparable construction materials such as steel, aluminum, cement, and glass. Advances in engineered wood products have also allowed for the optimized use of harvested trees by minimizing defects and maximizing structural capacities – glued laminated timber, laminated veneer lumber, and parallam are veneer based products typically used for load bearing structural elements.

## 2.8.5 Recycled Steel

While the production of steel involves high emissions releases and large quantities of energy, the use of recycled material accounts for 2/3 of new steel production by weight in the United States. Additionally, the use of recycled materials reduces the necessary amount of energy needed to produce steel product compared to that needed when using virgin ore.

## 2.8.6 Insulated Concrete Forms

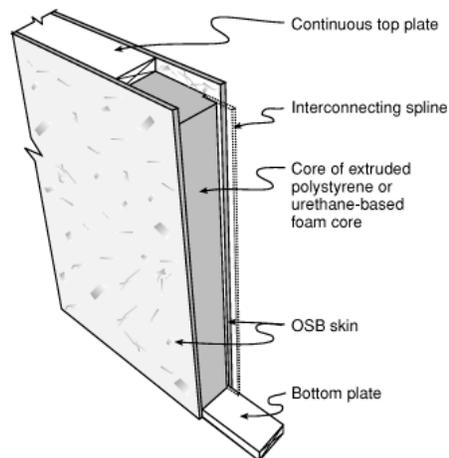
Insulated Concrete Forms (ICFs) are interconnect expanded polystyrene blocks that are stacked in place, supported with reinforcing steel bars as needed, and filled with concrete to form the walls of a structure. The end result is a composite unit with high insulation properties. This is a relatively new innovation, so one disadvantage is that construction crews often need to be trained how to use the technology; however, its use is quickly become more widespread. It also helps reduce waste on construction sites, as the units act as formwork for the concrete pour, thus eliminating the need for disposable plywood forms. These modules are produced by a number of companies, which are governed by a common trade organization, the Insulating Concrete Forms Association. Manufacturers include LOGIX, ECO-Block, Reward Wall Systems, and PolySteel – each producing similar products with slightly varying designs and features depending upon its primary targeted audience.



**Figure 2: Insulated Concrete Forms**

## 2.8.7 Structural Insulated Panels

Structural Insulated Panels (ISPs) are composite wall units composed of a core of polystyrene foam sandwiched between layers of an engineered wood produced known as oriented strand board (OSB). These boards come in varying standard sizes and are glued together with thin plywood splices and secured as the top and bottom by running lumber plates. Uses of ISPs include walls, ceilings, roofs, and flooring. Major North American manufacturers, most of who are member to the Structural Insulated Panel Association (SIPA), include sPanels, R-Control, and Intelli Structures.



**Figure 3: Structural Insulated Panels**

## 2.9 Green Roofs and Reflective Roofs

### 2.9.1 Urban Heat Island Effect

As urban areas develop, changes occur in their landscape. Buildings, roads, and other infrastructure replace open land and vegetation. Surfaces that were once permeable and moist become impermeable and dry. These changes cause urban regions to become warmer than their rural surroundings, forming an "island" of higher temperatures in the landscape. Heat islands occur

on the surface and in the atmosphere. Surface urban heat islands are typically present day and night, but tend to be strongest during the day when the sun is shining.

In contrast, atmospheric urban heat islands are often weak during the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban infrastructure. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. On a clear, calm night, however, the temperature difference can be as much as 22°F (12°C).

Several factors are known to influence the formation of the heat islands within urban areas. The most influential being the transformation of the natural land cover from permeable soil and vegetation into relatively impermeable roadways and buildings. Natural landscapes of vegetation and soil have the ability through evapotranspiration (the loss of water from the soil both by evaporation and transpiration from the plants growing thereon) to reduce the heating potential of incoming solar radiation.

## 2.9.2 Heat Island Impacts

On a hot, sunny summer day, roof and pavement surface temperatures can be 50–90°F (27–50°C) hotter than the air, while shaded or moist surfaces—often in more rural surroundings—remain close to air temperatures. These surface urban heat islands, particularly during the summer, have multiple impacts and contribute to atmospheric urban heat islands. Air temperatures in cities, particularly after sunset, can be as much as 22°F (12°C) warmer than the air in neighboring, less developed regions.

Most negative impacts of urban heat islands include :

- *Increased energy consumption:* Higher temperatures in summer increase energy demand for cooling and add pressure to the electricity grid during peak periods of demand. One study estimates that the heat island effect is responsible for 5–10% of peak electricity demand for cooling buildings in cities. <sup>[8]</sup>
- *Elevated emissions of air pollutants and greenhouse gases:* Increasing energy demand generally results in greater emissions of air pollutants and greenhouse gas emissions from power plants. Higher air temperatures also promote the formation of ground-level ozone.

- *Compromised human health and comfort:* Warmer days and nights, along with higher air pollution levels, can contribute to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.
- *Impaired water quality:* Hot pavement and rooftop surfaces transfer their excess heat to stormwater, which then drains into storm sewers and raises water temperatures as it is released into streams, rivers, ponds, and lakes. Rapid temperature changes can be stressful to aquatic ecosystems.

### 2.9.3 Methods to Reduce Heat Island Impacts

Communities can take a number of steps to reduce the heat island effect, using four main strategies :

- *increasing tree and vegetative cover;*
- *creating green roofs;*
- *installing cool—mainly reflective—roofs;*
- *using cool pavements.*

### 2.9.4 Reducing Urban Heat Islands with Green Roofs

A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. On hot summer days, the surface temperature of a green roof can be cooler than the air temperature, whereas the surface of a conventional rooftop can be up to 90°F (50°C) warmer.

Green roofs can be installed on a wide range of buildings, from industrial facilities to private residences. They can be as simple as a 2-inch covering of hardy groundcover or as complex as a fully accessible park complete with trees. Green roofs are becoming popular in the United States, with roughly 8.5 million square feet installed or in progress as of June 2008. Because the green roof infrastructure humidifies the surrounding air creating a microclimate which has beneficial effects within the immediate area, green roofs could reduce the urban heat island effect.

With regard to urban heat islands, green roofs work by shading roof surfaces and through evapotranspiration. Using green roofs throughout a city can help reduce surface urban heat islands and cool the air.

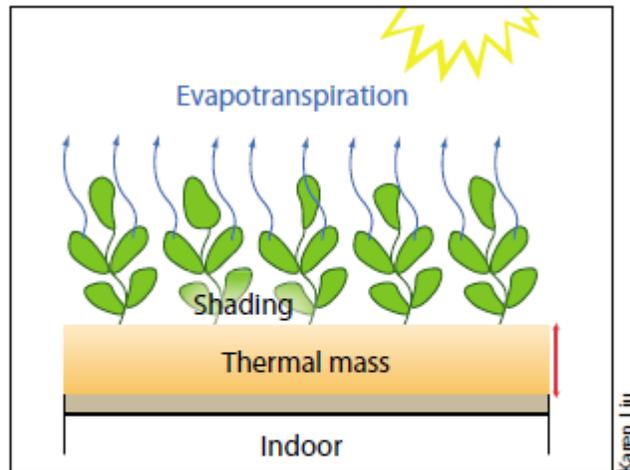
- *Shading*

The plants of a green roof and the associated growing medium, a specially engineered soil, block sunlight from reaching the underlying roof membrane. Though trees and vines may not be common on green roofs, they indicate how other vegetation on green roofs shade surfaces below them. For example, the amount of sunlight transmitted through the canopy of a tree will vary by species. In the summertime, generally only 10 to 30 percent of the sun's energy reaches the area below a tree, with the remainder being absorbed by leaves and used for photosynthesis and some being reflected back into the atmosphere. In winter, the range of sunlight transmitted through a tree is much wider—10 to 80 percent—because evergreen and deciduous trees have different wintertime foliage, with deciduous trees losing the leaves and allowing more sunlight through.<sup>[13]</sup>

Shading reduces surface temperatures below the plants. These cooler surfaces, in turn, reduce the heat transmitted into buildings or re-emitted into the atmosphere. For example, a multi-month study measured maximum surface temperature reductions due to shade trees ranging from 20 to 45°F (11-25° C) for walls and roofs at two buildings.<sup>[14]</sup> Another study examined the effects of vines on wall temperatures, and found reductions of up to 36°F (20°C).<sup>[15]</sup> Furthermore, the growing medium of a green roof itself protects the underlying layers from exposure to wind and ultraviolet radiation.

- *Evapotranspiration.*

Plants absorb water through their roots and emit it through their leaves—this movement of water is called transpiration. Evaporation, the conversion of water from a liquid to a gas, also occurs from the surfaces of vegetation and the surrounding growing medium. Together, the processes of evaporation and transpiration are referred to as evapotranspiration. Evapotranspiration cools the air by using heat from the air to evaporate water.



Plant shade reduces the sunlight that reaches the roof. Evapotranspiration further cools a green roof by using heat to evaporate water from the growing medium and plant surfaces

**Figure 4: Evapotranspiration and Shading on a Green Roof**

Green roof temperatures depend on the roof's composition, moisture content of the growing medium, geographic location, solar exposure, and other site-specific factors. Through shading and evapotranspiration, most green roof surfaces stay cooler than conventional rooftops under summertime conditions. Numerous communities and research centers have compared surface temperatures between green and conventional roofs.

Reduced surface temperatures help buildings stay cooler because less heat flows through the roof and into the building. In addition, lower green roof temperatures result in less heat transfer to the air above the roof, which can help keep urban air temperatures lower as well. Some analyses have attempted to quantify the potential temperature reductions over a broad area from widespread adoption of green roof technology. A modeling study for Toronto, Canada, for example, predicted that adding green roofs to 50 percent of the available surfaces downtown would cool the entire city by 0.2 to 1.4°F (0.1 to 0.8°C). Irrigating these roofs could further reduce temperatures by about 3.5°F (2°C) and extend a 1 to 2°F (0.5-1°C) cooled area over a larger geographic region. The simulation showed that, especially with sufficient moisture for evaporative cooling, green roofs could play a role in reducing atmospheric urban heat islands.<sup>[16]</sup>



On a typical day, the Chicago City Hall green roof measures almost 80°F (40°C) cooler than the neighboring conventional roof.

**Figure 5: Temperature Differences between a Green and Conventional Roof**

### 2.9.5 Cost of Green Roofs

Estimated costs of installing a green roof start at \$10 per square foot for simpler extensive roofing, and \$25 per square foot for intensive roofs. Annual maintenance costs for either type of roof may range from \$0.75–\$1.50 per square foot.

While the initial costs of green roofs are higher than those of conventional materials, building owners can help offset the difference through reduced energy and stormwater management costs, and potentially by the longer lifespan of green roofs compared with conventional roofing materials.

Researchers and communities are beginning to perform detailed, full life-cycle analyses to determine the net benefits of green roofs. A University of Michigan study compared the expected costs of conventional roofs with the cost of a 21,000-square-foot (1,950 m<sup>2</sup>) green roof and all its benefits, such as stormwater management and improved public health from the absorption of nitrogen oxides. The green roof would cost \$464,000 to install versus \$335,000 for a conventional roof in 2006 dollars. However, over its lifetime, the green roof would save about \$200,000. Nearly two-thirds of these savings would come from reduced energy needs for the building with the green roof.

## 2.9.6 Reducing Heat Islands with Reflective Roofs

A dark roof can get up to 180°F on a sunny, windless day. Reflectance tests show that some roof coatings, including so-called ceramic coatings and elastomeric coatings, provide a solar reflectance of over 80%.

A high Solar reflectance—or albedo—is the most important characteristic of a cool roof as it helps to reflect sunlight and heat away from a building, reducing roof temperatures. Solar reflectance isn't the only property to look for in a roofing material. It should also have a high infrared emittance to help the roof shed heat by re-radiation. Most materials do with the notable exception of aluminum roof coatings (Aluminum will stay warmer at night, while a white roof coating will radiate more of its stored heat back to the sky.). Together, these properties help roofs to absorb less heat and stay up to 50–60°F (28–33°C) cooler than conventional materials during peak summer weather

## 2.9.7 Benefits of Reflective Roofs

Cool roofs provide a number of benefits beyond urban heat island mitigation, including:

- *Reduced energy use:* A cool roof transfers less heat to the building below, so the building stays cooler and uses less energy for air conditioning.
- *Reduced air pollution and greenhouse gas emissions:* By lowering energy use, cool roofs decrease the production of associated air pollution and greenhouse gas emissions.
- *Improved human health and comfort:* Cool roofs can reduce air temperatures inside buildings with and without air conditioning, helping to prevent heat-related illnesses and deaths.
- *Cool roofs deflect some desired heat gain during the winter:* In general, though, cool roofs result in net energy savings, especially in areas where electricity prices are high.

## 2.9.8 Cost of Reflective Roofs

Although costs will vary greatly depending on location and local circumstances, cool roof coatings on a low-slope roof might cost \$0.75–\$1.50 per square foot, while single-ply cool roof membrane costs vary from \$1.50–\$3.00 per square foot. The cost premium for cool roofs versus conventional roofing materials ranges from zero to 5 or 10 cents per square foot for most products,

or from 10–20 cents for a built-up roof with a cool coating used in place of smooth asphalt or aluminum coating.

### 2.9.9 Savings of Reflective Roofs

A California study found that cool roofs provide an average yearly net savings of almost 50 cents per square foot. This number includes the price premium for cool roofing products and increased heating costs in the winter as well as summertime energy savings, savings from downsizing cooling equipment, and reduced labor and material costs over time due to the longer life of cool roofs compared with conventional roofs.

Federal tax credits are available for ENERGY STAR qualified metal roofs and reflective asphalt shingles that are installed on existing homes.

<b>Material</b>	<b>Solar Reflectance (%)</b>	<b>Temperature of Roof over Air Temperature (°F)</b>
Bright white coating (ceramic, elastomeric) on smooth surface	80%	15°
White membrane	70%-80%	15°-25°
White metal	60%-70%	25°-36°
Bright white coating (ceramic, elastomeric) on rough surface	60%	36°

Bright aluminum coating	55%	51°
Premium white shingle	35%	60°
Generic white shingle	25%	70°
Light brown/gray shingle	20%	75°
Dark red tile	18%-33%	62°-77°
Dark shingle	8%-19%	76°-87°
Black shingle or materials	5%	90°

**Table 1: Reflectance of Roof Materials**

## 2.10 Stormwater/Greywater Management

Stormwater harvesting is the process of capturing water from rain and snow, and storing it for future use. This process presents a large advantage for a snow removal equipment facility, where all the pieces of equipment need to be washed for proper maintenance. However, water is used for other purposes. So for systems that require certain levels of water quality, it is important to have a filtering system since most of the captured water is runoff from a roof surface that may contain many particles and pollutants. Common filtering systems involve the use of gravel, sand, soil or compost to separate the particles and pollutants. (Claytor and Schueler) After the filtering process is completed, the water is then collected and stored in cisterns with thousands of gallons of capacity. Once the water is filtered and stored, it can be used as drinking water, toilet water, and other indoor purposes. As a result, the drawing of water from the municipal supply is drastically minimized. In addition, capturing and properly managing stormwater has environmental benefits since it reduces the amount of runoff into water bodies, which can ultimately lead to events such as property damage and loss of animal life. (Visitacion, et al. 157)

Harvesting stormwater is simple when one receives the right amount of rain and snow. The city of Newburgh, New York is in a region that experiences harsher than average weather

conditions. In such conditions, the challenge in capturing water from snow is to melt the snow quicker than it accumulates. This can be done using deicing chemicals; but the chemicals stay in the water and might require filtration. One recent snow harvesting technology, called the IceBreaker gutter guard, eliminates this scenario. The gutter guard uses a single heat cable to quickly melt the snow and ice. (ENN) While this product is intended mainly for home-owners, it can be scalable to larger buildings.

In one successful implementation of stormwater management, the Alberici Corporate Headquarters in overland, Missouri manages to decrease demand for potable water by 70%. The headquarters has a 38,000 gallon cistern that stores water composed of 60% roof runoff.

Greywater management is an important complement to stormwater management. Greywater is defined as the water, excluding sewage or black water, produced by domestic activities. One of its most important uses is irrigation. So having an infrastructure to capture water after it is used in a facility allows further conservation of potable water. (Stockholm Environmental Institute)

## 2.11 Deicing Chemicals

In order for airports to run smoothly in the winters, large amounts of deicing chemicals must be used to deice aircrafts as well as runways. Two of the most common deicing chemicals are ethylene glycol and propylene glycol. Both of these chemicals pose health risks. They both can cause irritation in the eyes, nose, throat and skin. It can also lead to respiratory system problems.(OSHA) Therefore, it is crucial to have methods of containing deicing chemicals.

There are a few documented methods for collection of deicing chemicals. At Westchester Counter Airport in New York, the most preferred is At-gate collection which involves the baggage personnel to deice the airplane and collect the runoff right after. Pumps may be used to help facilitate the collection process. Another collection method is the use of central pads or mats which uses a minimal area. (Switzenbaum, et al.)

## 2.12 ASHRAE

**American Society for Heating, Refrigerating and Air Conditioning Engineers** was founded in 1894 at a meeting of engineers in New York City, formerly headquartered at 345 East 47th Street, and have held an annual meeting since 1895. Until 1954 it was known as the American Society of Heating and Ventilating Engineers (ASHVE); in that year it changed its name to the American Society of Heating and Air-Conditioning Engineers (ASHAE). Its current name and organization came from the 1959 merger of ASHAE and the American Society of Refrigerating Engineers (ASRE). The result, ASHRAE, despite having 'American' in its name, is an influential international organization. Amongst other international activities, it helps organize international events.

## 2.13 ASHRAE Research: Improving the Quality of Life

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is the world's foremost technical society in the fields of heating, ventilation, air conditioning, and refrigeration. Its members worldwide are individuals who share ideas, identify needs, support research, and write the industry's standards for testing and practice. The result is that engineers are better able to keep indoor environment safe and productive while protecting and preserving the outdoors for generations to come. One of the ways that ASHRAE supports its members' and industry's need for information is through ASHRAE Research. Thousands of individuals and companies support ASHRAE Research annually, enabling ASHRAE to report new data about material properties and building physics and to promote the application of innovative technologies. Chapters in the ASHRAE Handbook are updated through the experience of members of ASHRAE Technical Committees and through results of ASHRAE Research reported at ASHRAE meetings and published in ASHRAE special publications and in *ASHRAE Transactions*.

## 2.14 What Does ASHRAE Do?

ASHRAE develops standards for both its members and others professionally concerned with refrigeration processes and the design and maintenance of indoor environments. ASHRAE writes standards for the purpose of establishing consensus for:

- 1) Methods of test for use in commerce
- 2) Performance criteria for use as facilitators with which to guide the industry.

ASHRAE publishes the following three types of voluntary consensus standards: 1) Method of Measurement or Test, 2) Standard Design, and 3) Standard Practice. ASHRAE does not write “rating standards” unless a suitable rating standard will not otherwise be available i.e. to say that ASHRAE provides standard methods and procedures but does not provide comparing ratings for different performances. Consensus standards are developed and published to define minimum values or acceptable performance, whereas other documents, such as design guides, may be developed and published to encourage enhanced performance. ASHRAE is accredited by the American National Standards Institute (ANSI) and follows ANSI's requirements for due process and standards development.

## 2.15 Examples of ASHRAE Standards

- Standard 34 – Designation and Safety Classification of Refrigerants
- Standard 55 – Thermal Environmental Conditions for Human Occupancy
- Standard 62.1 – Ventilation for Acceptable Indoor Air Quality (versions: 2001 and earlier as "62", 2004 and beyond as "62.1")
- Standard 62.2 – Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings
- Standard 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings – The IESNA is a joint sponsor of this standard.
- Standard 90.2 - Energy- Efficient Design of Low rise Residential Buildings
- Standard 135 – BACnet - A Data Communication Protocol for Building Automation and Control Networks
- Standard 189.1 – Standard for the Design of High Performance, Green Buildings except Low-Rise Residential Buildings

These, and many other ASHRAE Standards, are periodically reviewed, revised and published, so the year of publication of a particular standard is important for code compliance.

The ASHRAE Journal is a monthly magazine published by ASHRAE. It includes peer-reviewed articles on the practical application of HVAC&R technology, information on upcoming meetings and product shows, classified and display advertising, and editorials. Members of ASHRAE receive the magazine and the current year's volume of the ASHRAE Handbook as membership benefits. ASHRAE also publishes many books, ASHRAE Transactions, and the International Journal of HVAC&R Research.

As of now Port Authority is interested in complying with **Standard 90.1**.

## 2.16 Purpose of Standard 90.1

To establish minimum energy efficiency requirements of buildings other than low rise residential buildings for:

- 1) Design, Construction and Plan for operation and maintenance.
- 2) Utilization of onsite renewable energy resources.

## 2.17 Scope

This standard provides:

- a) minimum energy efficiency requirement for Design, Construction and Plan for operation and maintenance of:
  - 1) New buildings and their systems.
  - 2) New portions of buildings and their systems.
  - 3) New systems and equipment in existing buildings.
  - 4) New equipment or building system specifically identified in the standard that are part of industrial and manufacturing process.
- b) Criteria for compliance with these requirements

The provisions of this standard does not apply to:

- a) Single family houses, multi-family structures of three stories or fewer above grade, manufactures houses (mobile homes), and manufactured houses (modular) or
- b) Buildings that use neither electricity nor fossil fuel.

## 2.18 Areas of Concentration

- a) Building Envelope
- b) Heating, Ventilating and Air Conditioning
- c) Service Water Heating

d) Lighting

e) Other Equipment

f) Energy Cost Budget Method

### 2.18.1 Building Envelope

There are three types of conditioned spaces per Section 5 of the ASHRAE Standard 90.1-2010: (a) nonresidential conditioned space, (b) residential conditioned space, and (c) semi-heated space. The mandatory provisions of the building envelope section address three criteria as they relate to the differing conditioned space categories. These critical areas are (1) insulation, (2) fenestration/doors, and (3) air leakage. For example, the provisions of the insulation section require that the different components of the building envelope and structure, depending upon their conditioned category, meet specific material properties, such as minimum thermal efficiency *r*-values. Moreover, much of the building envelope guidelines explore the concept of fenestration, which is all the areas of a building envelope that let in light, including windows, plastic panels, clerestories, skylights, doors that are more than one-half glass, and glass block walls. There are two sub-categories of fenestration, which are skylights and vertical fenestration. The term fenestration area accounts for the total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. There are several specifications and sizing guidelines provided in Section 5 of the ASHRAE Standard that govern and/or provide guidance in specifying the types and dimensions of these building envelope features. Finally, the air leakage section is extensive and involves the design and installation of air barriers, also taking into account loading dock weather seals, vestibules, and other unique interaction areas in the building.

### 2.18.2 Heating, Ventilating and Air Conditioning

The HVAC systems in new buildings shall meet compliance by satisfying Mandatory Provisions under Section 6.4, the Prescriptive Path under Section 6.5, and the product requirements specified in Table 6.8. Mandatory Provisions include the load calculations in accordance with ANSI/ASHRAE/ACCA Standard 183-2007, performing checks and tests for various controls of the system namely: Zone Thermostatic Controls, Ventilation System Controls, off hour controls, and HVAC system's construction and insulation. The prescriptive path details about the design and controls of Economizers(both Air and water), Air systems and Heat Rejection Systems. Prescriptive path also deals in Limitations of simultaneous heating and cooling, details for energy recovery, Exhaust systems and Radiant heating systems. Table 6.8 explains (a) different size categories and

rating conditions for different components of the system. Minimum efficiency standards and the required tests for the determination of the same has been mentioned regarding every component. (b) Minimum duct insulation for different climate zones and minimum pipe insulation according to different fluid temperature ranges.

### 2.18.3 Service Water Heating

The service water heating systems and equipment shall meet compliance by satisfying Mandatory Provisions under Section 7.4, the Prescriptive Path under Section 7.5, the Submittals listed under Section 7.7, and the product requirements specified in Table 7.8. Under Mandatory Provisions, the load calculations will following manufacturers' published sizing guidelines or generally accepted engineering standards. All water heating equipment must meet the criteria that are listed in Table 7.8, which specifies the input and conditional thresholds, as well as required performance. These are test under specific procedures, also listed in the table. In regards to piping insulation, recirculating system piping, initial outlet piping, inlet piping, and heated piping all must be insulated to levels specified by Table 6.8.3. The service water heating systems must comply with the temperature, maintenance, and pump controls specified in Section 7.4.4.1. Pipe risers serving storage water heaters and storage tanks must have heat traps on inlet and outlet piping as close to the storage tank as possible. A space-heating boiler system is allowed if it does not exceed a maximum loss determined in accordance with accepted engineering standards and handbooks, or satisfies the authority having jurisdiction that one heat source will consume less energy than separate units, or the energy input of the boiler and heater is no more than 150,000 Btu/h. For submittals, the authority with jurisdiction may require the submittal of compliance documents and other relevant information to ensure this standard is met.

### 2.18.4 Lighting

Lighting systems and equipment shall comply with Section 9.1, General; Section 9.4, Mandatory Provisions; and the prescriptive requirements of either: a. Section 9.5, Building Area Method; or b. Section 9.6, Space-by-Space Method. The mandatory provisions explain the requirements regarding the automatic lighting shutoff controls, the spatial distribution of the controls, Automatic Daylighting controls and exit signs. There are also details pertaining to lighting power allowance for building's exterior appliances and functional testing of lighting control devices. Interior lighting power allowance can be determined by using either Building Area Method or Space-by-Space Method which basically depends upon the building area type and the lighting

power density. The Building Area Method for determining the interior lighting power allowance, described in Section 9.5, is a simplified approach for demonstrating compliance while The Space-by-Space Method, described in Section 9.6, is an alternative approach that allows greater flexibility which factors in potential increase of the internal lighting power allowance allowed for specific lighting functions. The Space-by-Space method takes into account Room geometry adjustment according to the Room Cavity Ratio. For submittals, the authority with jurisdiction may require the submittal of compliance documents and other relevant information to ensure this standard is met.

### 2.18.5 Other Equipment

Compliance with Section 10 shall be achieved by meeting all requirements of Section 10.1, General; Section 10.4, Mandatory Provisions; and Section 10.8, Product Information. Mandatory provisions involve regulations for Electric Motors, Service Water Pressure Booster Systems and Elevators.

### 2.18.6 Energy Cost Budget Method

ASHRAE in this chapter differentiates between two methods, namely, the Design Energy Cost Method which involves the annual energy calculation for a proposed design and the Energy Cost Budget Method which includes simulations of a hypothetical design model based on actual proposed building design in order to determine the minimum compliance with the standard.

## 2.19 A Green Airport Case Study: Austin Straubel International

On November 11, 2010, Austin Straubel International Airport; which serves the greater Green Bay, Wisconsin area; unveiled its new, state of the art snow removal equipment facility. (Daily Reporter) The 64,000 square foot building received a Leadership in Energy and Environmental Design (LEED) Silver certification from the U.S. Green Building Council. The \$7.99 million project, which was largely funded by an FAA grant, created significant efficiency improvements from the 30 year old facilities which formerly served the same purpose for the airport. (WFRV News) Previously, snow removal equipment was scattered in a variety of buildings throughout the airfield. Some equipment was stored in front of other equipment, making certain pieces of equipment difficult to access. The new design consolidates all of the airport's snow removal equipment into one centralized building and provides ample spaces for both storage and

maintenance, as well as for the expansion of the fleet in the future. The location of the new building is closer to the airfield, allowing quicker and more efficient access. In addition to incorporating room for parking, maintenance, and washing, the new site also provides office space for some administration. (Kaiser)

Construction commenced in September of 2009 and concluded just over one year later. The new edifice, designed by Mead & Hunt, a Madison-based architectural and engineering firm, incorporates features such as low flow plumbing fixtures throughout, a 20,000 gallon cistern for recycled rainwater, an oil inceptor, a geothermal heat pump system, and a multitude of skylights. (Mead) Additionally, 84% of construction materials for the new structure were recycled. (Y100 Country) In addition to the myriad of environmental benefits the new structure provides, the associated cost savings are also expected to be quite impressive. The new building is projected to cost roughly 40% less to operate per square foot compared to more traditional alternatives. (Kaiser)

The new facility is separated into two sections: one for storage and one for maintenance and administrative activities. This layout is one of the many efficiency improvements which were suggested by the facilities' employees, who were consulted extensively for feedback while the facility was being designed. The storage and maintenance areas have separate entrances and plenty of room for maneuvering equipment. This has eliminated the clutter which exasperated daily operations in the old facility. Additionally, garage doors divide the two areas, so the maintenance bays can be heated for mechanics working on the equipment without having to heat the storage areas as well. Meanwhile, the old snow removal storage site has been refashioned as a storage location for building and ground maintenance equipment. The old site allows the airport to store this equipment all in one location; a more efficient storage system than had previously been employed. (Kaiser)

One of the main energy-saving aspects of Austin Straubel's new facility is the use of geothermal technology to heat and cool the building; the first geothermal project in Brown County, Wisconsin. (Kinney) A number of wells are drilled surrounding the building site that penetrate the earth approximately 300 feet. Further, the building uses innovative heating methods that are different from traditional heating systems. The heating system has been inserted into the building's floor slab to prevent heat from entering and remaining near the ceiling of the warehouse. However, the building does employ 25-foot wide ceiling fans, which are utilized to minimize temperature differences between the ceiling and the floor. (Kaiser)

Additional features also contribute to the building's minimal environmental impact and its LEED certification status. The new facility has 76 skylights, providing substantial passive solar energy and enough light to almost eliminate the need for indoor lighting on sunny days. The building has a white roof to reflect the heat of the sun, and the pavement surrounding the building is a light-colored concrete for the same purpose. (Kaiser)

The airport has also incorporated green concepts into the functionality of the snow removal equipment. Maintenance crews at the new site use rainwater collected in a 20,000 gallon cistern located on the roof to wash the equipment. Previously, the airport used large quantities of municipal potable water to clean the equipment. Should the cistern run empty, the new facility has the capability to switch over to the potable water source. However, the cistern had to be drained twice during the summer of its construction because it filled up so quickly, so it is expected to meet the needs of the maintenance crews. (Kaiser)

Austin Straubel International Airport has created a new snow removal equipment storage facility which should serve as a blueprint for cold weather airports throughout the country. The new facility provides significant cost savings and an environmentally sustainable model at an affordable initial cost with available grant monies. The airport has significantly improved its operational efficiency while expanding its capabilities in an environmentally-conscious manner.

# 3. Element Analysis

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## 3.1 Analysis Assumptions

The following assumptions were used consistently throughout this analysis. These assumptions were all based upon either direct guidelines from the Port Authority or utilities usage information provided by Stewart International Airport.

Metric	Assumed Value
Life Cycle	50 years
Discount Rate	7.50%
Inflation Rate	3%
Cost of Electricity	\$0.07 / kWh
Cost of Gas	\$0.808 / therm
Growth of Energy Cost	3% / year
Cost of Water	\$0.01 / gallon
Growth of Water Cost	5% / year
ASHRAE Standard	90.1

Table 2: Assumptions

## 3.2 Building Envelope Analysis

### 3.2.1 Siting & Location Factors

The primary guidelines offered by the Federal Aviation Administration’s (FAA) Advisory Circular regarding the selection of a proper location for Snow Removal Equipment (SRE) buildings include:

- (a) Provide unencumbered egress/ingress to facility by employees and delivery vehicles.
- (b) Does not interfere with fire rescue response or hamper taxing aircraft.
- (c) Provide snow removal equipment direct access to runway and taxiways.

(d) Avoid existing or potential revenue-producing locations.

With these factors in mind, as well as the general layout of the airport and areas open to development, we had identified the two most probable locations for a future SRE building. The primary location would be in the area of the current SRE building. There is flat/open space in this area which would not require significant topographic prep work to begin construction, although there are existing derelict buildings that would likely need to be removed to provide the necessary space and apron around the building. We believe this is the ideal location because it provides for all of the above criteria and avoids the area in the vicinity to the existing terminal, which has great potential for future expansion and revenue-generating activities for the Port Authority.

The secondary location we identified is located adjacent to the U.S. Military Academy's aviation hangar. Although it meets nearly all the criteria identified as critical by the FAA Circular, it would occupy land close to the existing passenger and hanger facilities which could be better used for other revenue generation, should Stewart continue to expand into the future as planned.

### 3.2.2 Building Footprint & Layout

Based on the SRE fleet size required at Stewart and the FAA Circular, we strongly recommend consideration of a Center-Aisle Design for the storage bay within the proposed SRE building. It is the most efficient design for medium/large size fleets, as it allows central access to all parking stalls and most importantly limits the number of garage/bay doors needed for the building, which is a major source of heat loss in the winter months and additional expense in terms of initial construction and recurring maintenance costs.

Because of the complexity of sizing a snow removal equipment building and the anticipated fleet equipment changes at Stewart as large multi-purpose machines are brought online and new equipment mothballed, we defaulted our analysis to a 64,000 SQFT building, which was based upon comparables at other airport facilities in the United States and can be used as a basis of scaling our sustainability components in the following sections.

### 3.2.3 Envelope Materials

There are as many options in building envelope design for box-type buildings as there are projects that need construction. In choosing paths to research, we first took a holistic look at our material options – examining issues such as required labor, timeliness/rapidity of construction,

system constructability, material durability, and recent SRE building projects, as well as obvious components such as basic cost of materials and their energy efficiency rating. Because of the interwoven nature of building construction and so as not to get bogged down in the details, we choose to make several simplifying assumptions in regards to the building envelope analysis.

To begin with, regardless of the type of materials used for roofing or the wall systems, almost every building of this nature is going to be built around a poured reinforced concrete slab foundation. For the purposes of our energy efficient calculations, we assumed this would be the same poured concrete slab in all analysis cases, with 2-inches of foam perimeter insulation at R-65.

Since the energy efficient of a Green Roof as examined as a separate component from Building Envelope, we decided to default to a standard sheet metal insulated roof for all analysis cases. Characteristics of this component were metal sheathing with 6-inches of fiberglass insulation, which produced a thermal resistance of R-19.

Thus, the determinate of building envelope really came down to the framing and wall system used. In looking at existing snow removal equipment buildings and other similar structures common to airport facilities, we developed three cases for analysis:

- (a) Concrete Masonry Units (CMU) Wall System, R-1.28
- (b) Steel Framing and Aluminum Sheathing w/ 6-inches Fiberglass Insulation, R-19
- (c) Concrete Structurally Insulated Panels w/ 6-inches Polyurethane Insulation, R-45

Through our research, it quickly became apparent that insulation is the main component of thermal resistance for all of these systems. While concrete layers from the structurally insulated panels provides more thermal resistance than the thin aluminum sheathing of a metal frame type structure, both get that vast majority of their thermal properties from the type and thickness of their insulation. The industry standard in most cases is roller fiberglass type insulation for metal clad buildings and polyurethane for concrete sandwich panels. Thus, we used these types respectively for our design. We choose 6-inches of insulation in each case for simplification and to keep the envelope about the same dimensions in each scenario. In reality, there are innumerable combinations of structural material to insulation that could be considered for further analysis. As most of these systems, especially the insulated panels, are proprietary and unique of each manufacturer, their data and its reliability can vary and should be scrutinized before taken at face

value. The way in which manufacturers test their products and calculate these advertised R-values varies considerably.

In reading recent data published from the Portland Concrete Association, a concrete industry professional and trade organization, we discovered that the R-value of concrete does not accurately account for the energy saving properties it exhibits in terms of its thermal mass. The only way that this can be accounted for is through more sophisticated simulation, such as can be achieved with DOE and/or commercially produced lifecycle analysis software.

### 3.2.4 Materials Energy Efficiency Calculations

For our energy efficiency calculations, we made the simplifying assumptions that the building was square dimensions and there were no window/door openings. These calculations only accounted for changes in thermal resistance produced by difference between the wall system, roofing system, and slab system.

#### **Equation**

Energy Savings = Building Area x  $(1/Rvalue_1 - 1/Rvalue_2)$  x 24 x HDDZ x Cost Per Unit Heating Fuel / BTU Per Unit Fuel / Heating System Efficiency

#### **Inputs:**

Energy Savings = USD

Building Area = SQFT

R-Value = SQFT x Deg F x h / BTU

HDDZ = Heating Degree Days

Cost Per Unit Heating Fuel = USD/Therm

BTU Per Unit Fuel = BTU/Therm

Heating System Efficiency = 1.0 (simplifying assumption)

	<b><u>Area</u></b>	<b><u>Percent Area</u></b>	<b><u>Material Type</u></b>	<b><u>R-Values</u></b>
<b>Walls</b>	30360	19.17%	CMU 12" Block	1.28
<b>Ceiling</b>	64009	40.42%	6" Fiberglass/Alum Shell	19
<b>Floor</b>	64009	40.42%	2" Foam Perimeter Insulation	65
	158378	100.00%		34.19

**Table 3: Sample Calculation for Determine Equivalent R-Value of Structure**

The results of this analysis, based on thermal resistance alone, indicated that the concrete insulated panels would be the most economical option, saving \$1320.00 annually over a masonry unit structure and about \$720.00 annually over a steel structure. Note that roof and floor systems account for about 80% of this dimensioned structure, meaning that the relative impact in wall material is low compared to those components.

Based upon other factors such as the industry/trade standard, durability against machinery, ease of cleaning and resilience against snow removal chemicals and materials, and other factors, we believe that precast concrete structurally insulated panels are the clear choice. Research also indicates additionally savings to be gained in terms of construction labor and productivity, although these were not quantified for this project.

### 3.2.5 Cost Calculations

Accurately estimating the construction costs of a building is a complex measure that goes well beyond the materials used, as factors such as labor and the constructability of components plays a major role. One way of simplifying this process is to examine comparable projects and correct for time and geographical cost differences. To simplify our analysis, we examined comparables and determined that a figure of about \$100/SQFT was a conservative and scaled estimate of the cost to construct a basic SRE building to include a concrete structurally insulated panel envelope, a basic lighting and water fixture package, and general outfitting.

## 3.3 HVAC System Analysis

### 3.3.1 Background

HVAC (Heating, Ventilating, and Air Conditioning) refers to technology of indoor or automotive environmental comfort. The three central functions of heating, ventilating, and air-conditioning are interrelated, providing thermal comfort, acceptable indoor air quality, within reasonable installation, operation, and maintenance costs. HVAC systems can provide ventilation, reduce air infiltration, and maintain pressure relationships between spaces.

In modern buildings the design, installation, and control systems of these functions are integrated into one or more HVAC systems. In addition, as no two buildings are same, the HVAC systems installed in those will be different as well. For large buildings, especially buildings that

more than one purpose, it is paramount to have separate HVAC system for each part of the building calibrated to function according to the heating, ventilating and air conditioning requirements of the area.

The whole building is provided with Thermostatic Controls according to the zones, while some are mutually independent, some are dependent on others. Off Hour controls are provided to monitor and regulate the functioning of the HVAC systems when the building is not being used. Careful measures are taken to ensure proper designing and installation of the duct work.

### 3.3.2 Building Layout

The building was considered to be comprised of three zones

- a) Storage Area (30,000 sq ft)
- b) Maintenance Area (30,000 sq ft)
- c) Office Area (4,000 sq ft)

### 3.3.3 Utilities Usage

#### 3.3.3.1 *As per Current SRE and Administrative building*

At first, Electricity and Gas Consumption was calculated assuming that the present scenario is continued i.e. create a hypothetical building of the same size as the proposed building, but with electricity and gas usage values per SF the same as the current building. The 2010 utilities data from Administrative Building (138) was scaled to a 4,000 square foot area while the data from Mechanical/ Storage Building (2290) was scaled for the 60,000 square foot area. It was assumed that the usage pattern in the new SRE building will be same as that of Building no. 138 in the office area and Building no. 2290 in the Storage and Maintenance area respectively.

The usage computed for HVAC applications only is estimated as

**Electrical Usage: 5.975 kwh/sq ft/year or 382,400 kwh/year**

**Gas Usage: 1.15 CCF/sq ft/year or 74,000 CCF/year**

Note: The electricity usage value is smaller than the value used in the photovoltaic analysis (627,200 kWh/year) because the above value includes electricity consumption only for HVAC (no lighting, other loads, etc.)

### 3.3.3.2 Building with Conventional HVAC system

Since the current SRE building used by Port Authority is old, the energy consumption from that building would not be credible for use as baseline consumption. To provide this baseline consumption the first step was to calculate the usage for a present age building with a conventional, Non-ASHRAE compliant Heating, Ventilating and Air-Conditioning system. The pertinent data regarding Electricity and gas consumption was acquired from the U.S. Department of Energy Building Energy Use Survey for Non- Mall buildings.

<b>Principal Building Activity</b>	<b>Electricity Energy Intensity (kWh/square foot/year)</b>
Office	4.7
Service	3.3
Warehouse and Storage	1.2
Total Consumption	2.40

**Table 4: Electricity Consumption By HVAC system in the building**

**Total Electricity Usage: 153,800 kwh/year**

<b>Principal Building Activity</b>	<b>Natural Gas Intensity (CCF/square foot/year)</b>
Office	0.28
Service	0.47
Warehouse and Storage	0.20
Total Consumption	0.33

**Table 5: Gas Consumption By HVAC system in the building**

**Total Gas Consumption: 21,101 CCF/year**

### 3.3.3.3 *Building with Highly Efficient HVAC system*

By highly efficient HVAC system we basically mean an ASHRAE compliant system. Careful study of the **ASHRAE Standard 90.1 -- Energy Standard for Buildings except Low-Rise Residential Buildings** was undertaken. In an ASHRAE compliant HVAC system all the utilities and equipment will be expected to follow various ASHRAE guidelines. All the systems and controls like Zone thermostatic controls, Off- Hour Controls, Ventilation System etc. will work according to the prescriptive paths mentioned in the standard. A SEER rating of >13 for the Air conditioning system is expected.

The following calculations were made according to the data provided by various HVAC system contractors. The systems cost and energy usage varies according to the building's location, usage of the different zones with in the building etc. This is our best estimate for a building of this size on the basis of the limited time, to conduct the analysis, and information that we had. The true cost, however, would need to be adjusted for the actual building. It must be noted that the analysis method and figures used provide only a rough idea regarding the cost and energy consumption of the HVAC system, a more detailed analysis will have to be conducted to get more exact figures.

#### 3.3.3.3.1 System Size and Installation

From research and our talks with the contactors of HVAC systems, we concluded that three separate systems will be installed in each zone. Each system (except for office zone) will comprise of two principal units:

- a) Roof Top Unit: Will provide Air conditioning and Ventilation and in case of office area will provide space heating as well.
- b) Radiant Heating Unit: A radiant gas floor heating unit will be installed in the storage and maintenance zones.

#### 3.3.3.3.2 Upfront Cost

Cost	Purchase	Installation
Storage	\$75,000.00	\$150,000.00
Maintenance	\$75,000.00	\$150,000.00
Office	\$10,000.00	\$30,000.00
Individual Total	\$160,000.00	\$330,000.00
Total Upfront Cost	\$490,000.00	

**Table 6: Upfront Cost of Highly Efficient HVAC system (rough estimates provided by the Vendor according to the different zones)**

3.3.3.3 Replacement and Maintenance Cost

After every 15 years the ductwork in the system needs replacement while the rest of the system needs extensive maintenance. The cost of all this work can be roughly considered as 1/3<sup>rd</sup> of the installation cost i.e. \$110,000.<sup>1</sup> (Carrier Corp.)

3.3.3.4 Energy Consumption

The equipment with a SEER rating of 21 was considered to be the part of the system. The power consumption of the unit was calculated using the following equation:

$$\frac{BTU}{hour} * SEER Rating = Average Power Consumption(\frac{Watts}{hour})$$

The Number of Usage hours per year were than factored in according to the data provided by Port Authority. The final energy usage for the highly efficient HVAC system turned out to be

<b>Electricity</b>				
	Storage	Maintenance	Office	Total
Usage (Kwh/sq ft/yr)	2.06	2.67	0.4	2.23
Total Usage(kwh/yr)	61714	80000	1600	143314

<b>Gas</b>				
	Storage	Maintenance	Office	Total
Usage (CCF/sq ft/yr)	0.12	0.25	0.0 <sup>2</sup>	0.18
Total Usage(kwh/yr)	3764.7	7529.4	0.0	11294.12

**Table 7: Energy Consumption for Highly Efficient HVAC system**

<sup>1</sup> Carrier Corporation.

<sup>2</sup> As the Roof Top Unit alone caters for both Conditioning and heating demands of the office area the gas consumption of the area will be zero.

### 3.3.4 Present Worth of Highly Efficient HVAC System

Present worth analysis of the HVAC system for a life cycle of 50 years was performed. It was assumed that both the costs of electricity and of natural gas would grow by an annual rate of 3%. The upfront cost of installation, as well as the replacement cost in 15 years, was incorporated.

This analysis shows that the Present Worth of the HVAC system, incorporating all of the features described in the previous paragraph, is **\$945,644.00** i.e. the system will cost Port Authority approximately the above mentioned value in 50 years. Since, enough data was not available regarding the cost of baseline system a Net Present Value of the system could not be performed, hence, we can't comment on the cost effectiveness of the system. Nonetheless, significant emissions savings are associated with the implementation of this system as will be shown in the later sections.

### 3.3.5 Comparison of the Utility Usages

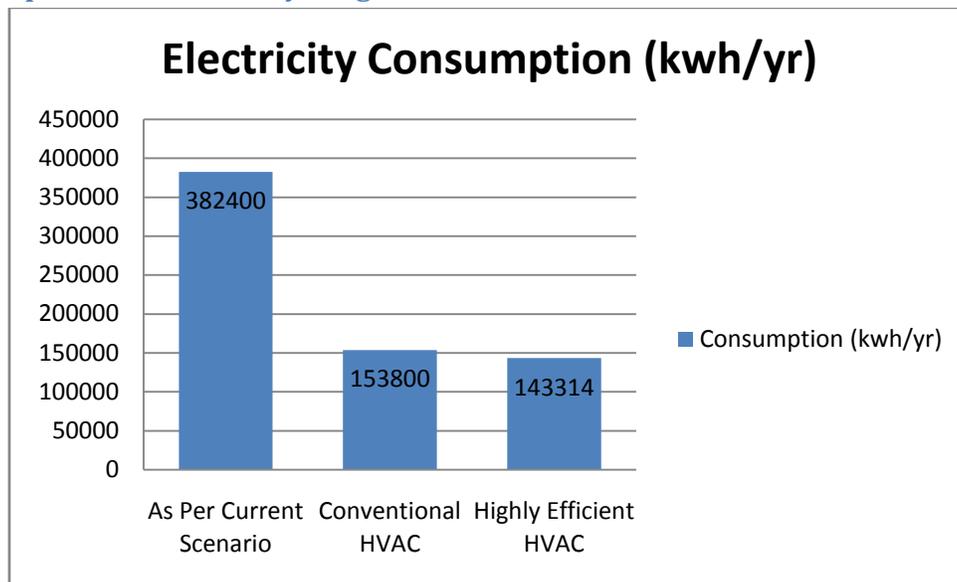


Figure 6: Comparison of Electricity Consumption for the three HVAC systems<sup>3</sup>

<sup>3</sup> Cornell 2011

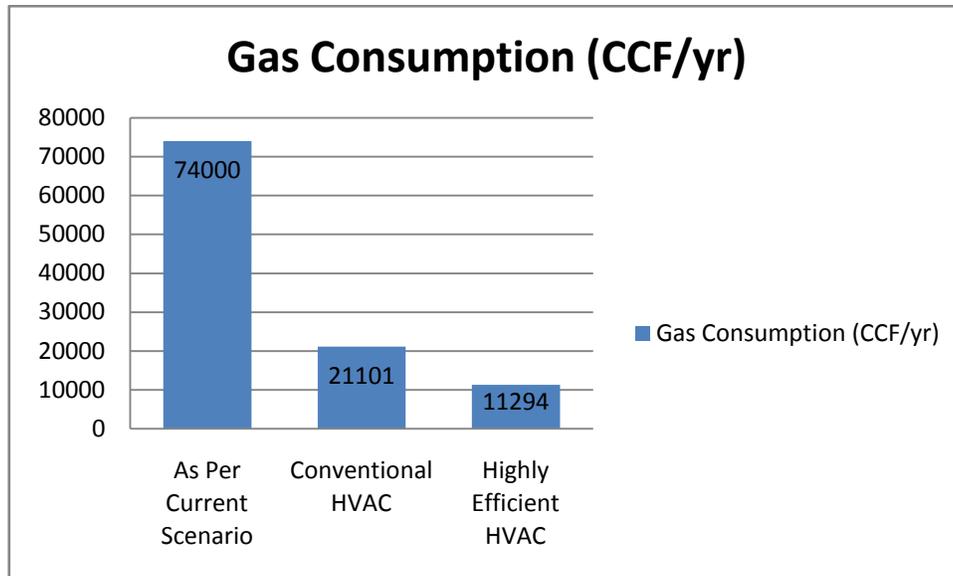


Figure 7: Comparison of Gas Consumption for the three HVAC systems<sup>4</sup>

### 3.3.6 Cost Comparisons

Costs of energy used were the costs assumed throughout this analysis: \$0.07/kWh for electricity and \$0.795/CCF for natural gas as per the data provided by Port Authority.

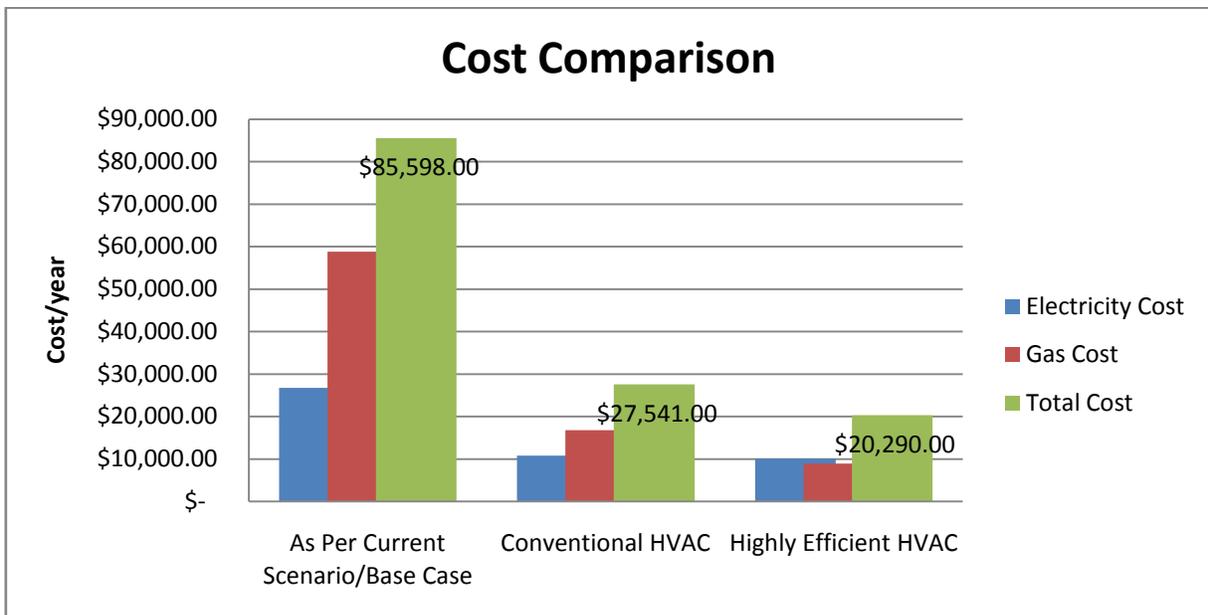


Figure 8: Cost Comparison for the three HVAC systems<sup>5</sup>

<sup>4</sup> Cornell 2011

<sup>5</sup> Cornell 2011

### 3.3.7 Emissions Reductions

Using the EPA's estimate of emissions for natural gas consumption, 5.3 kg/therm, it was determined that total CO<sub>2</sub> emissions reductions associated with the highly efficient HVAC system would be 6,044,432 pounds of CO<sub>2</sub> over the lifetime of the building. This calculation is demonstrated in Equation below.

Equation:

$$EPA\ Emissions\ Estimate * Natural\ Gas\ Savings = CO2\ Savings$$

$$\frac{5.3\ kg\ CO2}{therm} * 2.20462 \frac{lbs}{kg} * \frac{therm}{0.967\ CCF} * 500,200\ CCF = 6,044,032\ lbs\ of\ CO2$$

Similarly, using NYSEDA's 2008 annual report, *Patterns and Trends*, the electricity mix for the region was determined, including the CO<sub>2</sub> output weighted by source type. The total electricity savings over the 50 year lifetime of the HVAC system was determined to be 534,771 kWh. Using the electricity mix in Table 1 below and weighting accordingly, the total CO<sub>2</sub> emissions savings due to reduced electricity consumption from implementation of the HVAC system was estimated to be 314,490 pounds of CO<sub>2</sub>.

#### NYS Electricity

Mix			Electricity Savings		
Source	lbsCO <sub>2</sub> /MWh	TWh	Weight	kWh/source	lbs CO <sub>2</sub> /source
Natural gas	714.4	43.9	26.49%	141680.54	101216.58
Nuclear	0	43.2	26.07%	139421.40	0.00
Hydro	0	27.5	16.60%	88752.05	0.00
Imported	1038.4	23.9	14.42%	77133.60	80095.53
Coal	1869.1	19.2	11.59%	61965.07	115818.90
Petroleum	1453.7	3.7	2.23%	11941.18	17358.90
Wind	0	1.3	0.78%	4195.55	0.00
Other	0	3	1.81%	9682.04	0.00
<b>Total</b>	<b>5075.6</b>	<b>165.7</b>			<b>314489.91</b>

**Table 8: NYS Electricity Mix and Electricity savings by highly Efficient HVAC system**

Combining the CO<sub>2</sub> emissions reductions estimates from savings in natural gas usage and electricity usage gives total CO<sub>2</sub> emissions reductions (Equation).

Equation:

*CO<sub>2</sub> Savings from Natural Gas + CO<sub>2</sub> Savings from Electricity = Total CO<sub>2</sub> Savings*

*6,044,032 lbs + 314,490 lbs = **6,358,522 lbs or 2889 metric tons***

## 3.4 Geothermal System Analysis

### 3.4.1 Background

Ground source heat pumps, or geothermal energy systems, are electrically powered systems that tap the Earth's stored energy to heat and cool buildings. Geothermal systems consist of a system of pipes and pumps which add heat to a building in the winter and removes heat from the building in the summer. A system can be categorized as closed or open loops in a horizontal or vertical orientation. (International Ground) The loop type and orientation is chosen on a site by site basis, depending on the available land, soil, and rock type at the installation site. In a closed loop system, water or antifreeze solution is circulated through plastic pipes buried within the Earth's surface. This is possible due to the fact that 46 percent of the sun's energy is absorbed by the Earth, making the temperature under the surface of the Earth is a constant 50-55 degrees Fahrenheit in most locations throughout the year. (NYSERDA, CANMET 5) The low thermal conductivity of soil allows the fluid to collect heat from the Earth during the winter months, and carries it into the building. (CANMET 6) In the summer, the system reverses itself to cool the building carrying the heat from the building into the ground, which serves as a sink. An open loop system operates similarly, in environments where sources of water are readily available and open discharge is feasible. (International Ground) The system of pumps and pipes is linked to the building's HVAC system to heat or cool the facility as necessary. The system allows energy to be efficiently recovered and reused in buildings with simultaneous heating and cooling needs. (NYSERDA) Geothermal systems are considered to be an exceptionally efficient energy system due to the renewable nature of the Earth's natural thermal energy. (AMI Contracting)

### 3.4.2 System Size and Installation Costs

A geothermal system was investigated to satisfy the heating and cooling needs of the 4,000 square foot office area of the new SRE building. Initially, an analysis was started to examine the use of a large geothermal system to meet the heating and cooling needs of the entire 64,000 square foot facility. However, it was immediately evident that the system would not be financially feasible for the entire facility due to the large upfront costs for drilling and installation. Thus, only the office area was considered for a geothermal system.

The first task was to determine the number of tons of capacity needed for the 4,000 square foot area. During a March 11, 2011 phone conversation with Mr. Scott Volberding, the Facilities Director for the new SRE facility at Austin Straubel International Airport in Green Bay, Wisconsin, data was provided about that building's geothermal system, which services the office space in building. Using a combination of case studies and data provided by both geothermal contractors and Mr. Scott Volberding, it was estimated that the 4,000 square foot office space would require a capacity of between five and six tons. (Bloomfield 1-5, CANMET 20) Conservatively, a capacity of six tons was used to price this system. The average initial cost per ton of capacity was also estimated using a combination of case studies and data provided by geothermal contractors. The average initial cost per ton for this system was determined to be \$5,000. Thus, the upfront cost of installing six tons of capacity was determined to be \$30,000 (Equation 1).

Equation 1:

$$\textit{Tons Of Capacity} * \textit{Cost Per Ton} = \textit{Cost Of Installation}$$

$$6 \textit{ tons} * \$5,000/\textit{ton} = \$30,000$$

The upfront cost of drilling is another significant cost. Mr. Scott Volberding further explained that geothermal system implemented at Austin Straubel required 4,800 feet of wells. Using this figure, at a cost of \$14 per foot of drilling, a figure derived from relevant case studies, the approximate cost of drilling is estimated to be \$67,200 (Equation 2). (Bloomfield 1-8)

Equation 2:

*Feet of Drilling \* Cost Per Foot of Drilling = Cost of Drilling*

$$4,800 \text{ feet} * \frac{\$14}{\text{foot}} = \$67,200$$

Combining the upfront cost of installation with the upfront cost of drilling gives a total upfront cost of \$97,200, a significant investment (Equation 3).

Equation 3:

*Cost of Installation + Cost of Drilling = Total Upfront Cost*

$$\$30,000 + \$67,200 = \$97,200$$

### 3.4.3 Maintenance and Replacement

Further, case studies showed that the annual maintenance cost of a geothermal system is relatively cheap: approximately \$0.05 per square foot per year. (Crane 3) However, a significant replacement cost exists in Year 26, due to the need to replace all of the pumps and pipes for the system. (EnergyHomes.org) To estimate this cost, the \$30,000 cost of installation was grown at the given 3% annual rate of inflation until Year 26, giving a replacement cost of \$64,698 (Equation 4).

Equation 4:

*(Installation Cost) \* (1.03)<sup>26</sup> = Replacement Cost*

$$(\$30,000) * (1.03)^{26} = \$64,698$$

### 3.4.4 Utilities Savings

To determine the utilities usage savings with a geothermal system, current utilities usage for Admin. Building 138 at Stewart Airport was used. First, the 2010 utilities usage data for Building 138 was scaled to a 4,000 square foot area. It was assumed that the 4,000 square foot office space in the new SRE would require the same amount of gas per square foot as Building 138. The total annual gas usage for heating the 4,000 square foot office area would then be approximately 2,045 CCF.

Since a geothermal system cools as well as heats, electricity savings exist from the elimination of an air conditioning system. To estimate these savings, the 2010 electricity usage for Building 138 was used. First, average electricity usage from the winter months, November through May, was averaged. This average was determined to be 2,249 kWh. Next, the electricity usage for the summer months, June through October, was averaged, and determined to be 3,636 kWh. The so-called “summer months” were selected based on their observably higher levels of electricity usage when compared with the so-called “winter months.” It was assumed that these differences in electricity usage were attributable to air conditioning use during these warmer months. Taking the average difference in electricity usage between summer months and winter months, and multiplying it by the five summer months, gives an approximation of annual energy use due air conditioning for 4,000 square feet of 6,938 kWh. This calculation is shown in Equation 5 below.

Equation 5:

$$\begin{aligned} & (\text{Average Summer Month Electricity Use} - \text{Average Winter Month Electricity Use}) \\ & \quad * \text{Number of Summer Months} = \text{Electricity Use Due to Air Conditioning} \\ & (3,636 \text{ kWh/month} - 2,249 \text{ kWh/month}) * 5 \text{ months} = 6,938 \text{ kWh} \end{aligned}$$

Costs of energy used were the costs assumed throughout this analysis: \$0.07/kWh for electricity and \$0.795/CCF for natural gas. With these costs, the 2010 cost savings potential for the new SRE building office space was calculated as follows:

Equation 6:

$$(Electricity\ Savings * Cost\ of\ Electricity) + (Gas\ Savings * Cost\ of\ Gas) \\ = Total\ Potential\ Cost\ Savings$$

$$\left(6,938\ kWh * \frac{\$0.07}{kWh}\right) + \left(2,045\ CCF * \frac{\$0.795}{CCF}\right) = \$2,104.05$$

### 3.4.5 Net Present Value Analysis

This procedure was repeated for every year in a 50-year net present value analysis for the geothermal system. The first year of this analysis was 2012, so the 50<sup>th</sup> year was 2061. It was assumed that both the costs of electricity and of natural gas would grow by an annual rate of 3%. Additionally, maintenance costs were incorporated in this analysis. As mentioned, maintenance was assumed to be \$0.05 / square foot per year, and was assumed to grow at an annual 3% rate of inflation. Further, capital costs were included in this analysis. The upfront cost of installation, as well as the replacement cost for the pipes and pumps in Year 26, were incorporated, grown at the 3% annual rate of inflation.

From a financial perspective, this analysis shows that the net present value of the geothermal system, incorporating all of the features described in the previous paragraph, is - **\$67,945.59**. Thus, the system is not cost effective as is. Nonetheless, significant emissions savings are associated with the implementation of a geothermal system. Such a system would save 102,236 CCF of natural gas and 346,898 kWh of electricity over the building's 50 year lifetime.

### 3.4.6 Emissions Reductions

Using the EPA's estimate of emissions for natural gas consumption, 5.3 kg/therm, it was determined that total CO<sub>2</sub> emissions reductions associated with this geothermal system would be 1,235,338 pounds of CO<sub>2</sub> over the lifetime of the building. (United States Environmental Protection Agency) This calculation is demonstrated in Equation 7 below.

Equation 7:

*EPA Emissions Estimate \* Natural Gas Savings = CO2 Savings*

$$\frac{5.3 \text{ kg CO}_2}{\text{therm}} * 2.20462 \frac{\text{lbs}}{\text{kg}} * \frac{\text{therm}}{0.967 \text{ CCF}} * 102,236 \text{ CCF} = 1,235,338 \text{ lbs CO}_2$$

Similarly, using NYSERDA’s 2008 annual report, *Patterns and Trends*, the electricity mix for the region was determined, including the CO<sub>2</sub> output weighted by source type. The total electricity savings over the 50 year lifetime of the geothermal system was determined to be 346,898 kWh. Using the electricity mix in Table 1 below and weighting accordingly, the total CO<sub>2</sub> emissions savings due to reduced electricity consumption from implementation of the geothermal system was estimated to be 204,005 pounds of CO<sub>2</sub>. (NYSERDA)

NYS Electricity Mix

(Electricity Savings for new SRE Office Space)

Source	lbsCO2/MWh	TWh	Weight	kWh/source	lbs/CO2/source
Natural gas	714.4	43.9	26.49%	91,905.87	65,657.55
Nuclear	0	43.2	26.07%	90,440.40	0.00
Hydro	0	27.5	16.60%	57,572.01	0.00
Imported	1038.4	23.9	14.42%	50,035.31	51,956.67
Coal	1869.1	19.2	11.59%	40,195.73	75,129.84
Petroleum	1453.7	3.7	2.23%	7,746.05	11,260.44
Wind	0	1.3	0.78%	2,721.59	0.00
Other	0	3	1.81%	6,280.58	0.00
<b>Total</b>	<b>5075.6</b>	<b>165.7</b>			<b>204,004.50</b>

**Table 9: NYS Electricity Mix and Electricity Savings from the Geothermal System**

Combining the CO<sub>2</sub> emissions reductions estimates from savings in natural gas usage and electricity usage gives total CO<sub>2</sub> emissions reductions (Equation 8).

Equation 8:

*CO2 Savings from Natural Gas + CO2 Savings from Electricity = Total CO2 Savings*

$$1,235,338 \text{ lbs} + 204,005 \text{ lbs} = \mathbf{1,439,343 \text{ lbs}}$$

As a point of reference, according to EPA estimates, this amount of CO<sub>2</sub> emissions reductions would be the equivalent of taking 2.82 average vehicles (by 2011 emissions standards) off the road for the next 50 years. (United States Environmental Protection Agency)

## 3.5 PV System Analysis

### 3.5.1 Background

Photovoltaic energy is energy obtained from any visible light and is used for generating electricity. In contrary to solar energy, which uses only energy radiated from the Sun, photovoltaic cells (commonly referred to as just photovoltaics) capture any visible light and convert it into energy. Thus photovoltaics are able to produce energy even during the night from moonlight. (renewableenergy101.info)

Photovoltaic energy is used for generating electricity, while the device necessary for exploiting photovoltaic energy is the photovoltaic module which consists of photovoltaic cells. Photovoltaic modules are in turn linked into a photovoltaic array because the energy generated by one photovoltaic module is not enough to satisfy the needs of a household. Photovoltaic energy systems are relatively new but have become very popular in recently, mostly because they don't only use sunlight to generate energy like the solar cells but it can also produce electricity on a cloudy day or at night. (<http://www.renewableenergy101.info/photovoltaic-energy/>)

Each type of system requires specific components besides the PV modules. The final cost of any PV system ultimately depends on the PV array size, the battery bank size, and on the other components required for the specific application. (Seco)

### 3.5.2 Determine Energy Consumption

To calculate the lighting need of the PA building we used the electricity energy intensity data from United States Department of Energy (DOE). Since our PA building comprised of 3 main areas namely warehouse and storage, service and office we used weighted average to calculate the average electricity energy intensity (kWh/square foot) expended. Below is the table for the electricity energy intensity for lighting. These figures cover electricity for lighting and HVAC (explained in detail below) plus a nominal amount for all other electrical applications.

<b>Principal Building Activity</b>	<b>Electricity Energy Intensity (kWh/square foot)</b>
Office	17.3
Service	11
Warehouse and Storage	7.6
Weighted Average for PA building	9.8

**Table 10: Building Type Electrical Energy Intensity II**

To calculate the total lighting energy consumed annually by the PA building, the total square footage of the building was multiplied with weighted average electricity energy intensity. Once we had the total energy consumption it was multiplied with the electricity rate PA is getting to get the total annual cost that would be incurred by PA.

$$\begin{aligned} \text{Weighted Average for PA building} &= (30000/64000) \times 7.6 + (30000/64000) \times 11 + (4000/64000) \times \\ &17.3 \\ &= 9.8 \text{ Kwh/SF} \end{aligned}$$

At an average of 9.8 kWh/SF/yr, the facility would consume 627,200 kWh/year, which at a cost of \$0.07/kWh has a value of \$43,904 per year.

### 3.5.3 Determine PV system output

There are known 'productivity rating' values for certain areas. For example:

Tucson, Arizona: 1700 kWh/kW. (DOE)

Newark, Delaware: 1350 kWh/kW. (UD)

Ithaca: 1100 kWh/kW. (CU)

As an approximation, Newburgh falls somewhere between Ithaca and Newark, DE. So we can approximate the productivity equal to 1200 kWh/kW.

To calculate the array size of the PV system we can simply divide the energy expended calculated above with the productivity of 1200 kWh/kW., in this case giving  $627,200/1200 = 523$  kW system size.

### 3.5.4 Estimate Balance of System Cost

Besides PV modules and inverters, complete PV systems also use wire, switches, fuses, connectors and other miscellaneous parts. We use a factor of 20% to cover balance of system costs. Thus the total cost of the system is  $(\$1 + \$5) \times 1.2 = \$7.20/\text{watt}$ , or \$3.76 million for the entire system. (Seco)

### 3.5.5 Net Savings

The life of PV system is taken to be 25 years and cost on it is incurred in year 0 and 25. Next the saving from the use of PV system is calculated for each year. Finally the NPV of the savings for 50 year is calculated.

Year	Cost without	Cost of PV	Savings
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	PV	System	
0		3,136,000.00	(3,136,000.00)
1	43,904.00	0.00	43,904.00
2	45,221.12	0.00	45,221.12
3	46,577.75	0.00	46,577.75
4	47,975.09	0.00	47,975.09
5	49,414.34	0.00	49,414.34
6	50,896.77	0.00	50,896.77
.	.	.	.
.	.	.	.
.	.	.	.
38	131,063.39	0.00	131,063.39
39	134,995.29	0.00	134,995.29
40	139,045.15	0.00	139,045.15
41	143,216.51	0.00	143,216.51
42	147,513.00	0.00	147,513.00
43	151,938.39	0.00	151,938.39
44	156,496.54	0.00	156,496.54
45	161,191.44	0.00	161,191.44
46	166,027.18	0.00	166,027.18
47	171,008.00	0.00	171,008.00
48	176,138.24	0.00	176,138.24
49	181,422.39	0.00	181,422.39
50	186,865.06	0.00	186,865.06
NPV	860,636.03	3,650,238.33	(2,789,602.30)

**Table 11: Net Present Value for the PV system**

## 3.6 Lighting System Analysis

### 3.6.1 Background

For lighting system we will be using skylights. Skylights have been around for a long time and have recently begun to witness resurgence in popularity as design elements in homes. Skylights are a great way to light the interior part of a given room or structure using natural light. This has the dual benefit of being environmentally friendly as well as aesthetically pleasing. Skylights are simple to install and can go a long way in helping you cut down on your electricity bills. Skylights are also easy to uphold and do not need to be maintained on a regular basis. (Claws)

Besides using Skylights for natural lighting we will be using T5 lamps as artificial lights. The T5 lamp is an increasingly popular development in fluorescent lighting. In 1995, T5 fluorescent lamps entered the market in the United States. Today, the three major lamps manufacturers aggressively market T5 lamps. Luminaire manufacturers create innovatively designed compact luminaires using up-to-date optical materials. Recently, lighting designers have begun to specify such T5 luminaires for high-end new construction. The marketing and innovative design of T5 systems have left many end users wondering whether they should consider T5 luminaires instead of T8 luminaires, especially in new construction and retrofitting of T12 magnetic systems. End users are confused by the 10°C (18°F) difference in optimal temperature and the small difference in system efficacy between T5 and T8 systems. (Akashi)

### 3.6.2 Cost of Baseline Lighting

To calculate the lighting need of the PA building we used the electricity energy intensity data from United States Department of Energy (DOE). Since our PA building comprised of 3 main areas namely warehouse and storage, service and office we used weighted average to calculate the average electricity energy intensity (kWh/square foot) of lighting expended. Table 1: Building Type Electrical Energy Intensity

<b>Principal Building Activity</b>	<b>Electricity Energy Intensity (kWh/square foot)</b>
Office	6.8
Service	4.6
Warehouse and Storage	4.1
Weighted Average for PA building	4.5

**Table 12: Electricity Consumption for Lighting**

Weighted Average of Lighting for PA building =  $(30000/64000) \times 4.1 + (30000/64000) \times 4.6 + (4000/64000) \times 6.8 = 4.5 \text{ kWh/SF}$

To calculate the total lighting energy consumed annually by the PA building, the total square footage of the building was multiplied with weighted average electricity energy intensity of lighting. Once we had the total energy consumption it was multiplied with the electricity rate PA is getting to get the total annual cost that would be incurred by PA. The average electricity energy intensity value of 4.5kWh/SF/year gives a total consumption of 288,000 kWh/year of lighting, which at \$0.07/kWh amounts to a cost of \$20,160 per year. Note that this calculation is conservative: for example, a web-based calculator from GE calculates that using high-efficiency T-5 lighting for the service and warehouse/storage areas might reduce the consumption per SF to 1.7 kWh per year, which would significantly reduce the load.

### 3.6.3 Cost of Skylights

Skylights are horizontal windows or domes placed at the roof of buildings, often used for daylighting. Skylights admit more light per unit area than windows, and distribute the light more evenly over the space. The optimum number of skylights, usually quantified as effective aperture, varies based on climate, latitude and characteristics of the skylight. However, 4 to 8 percent of the floor area is a good rule of thumb to determine the optimum number of skylights for a space.

In order to calculate the reduction in energy consumption with skylights installed we used different web and excel based tools. One such too was SkyCalc developed by Heschong Mahone group. Based on the data provided by the PA building such as the lighting and occupancy schedule amongst other recommendations we concluded that skylights help reduce the energy consumption by 25%. So the annual cost of lighting is \$15,131. Though the cost of electricity offset as a result of the skylights is 25% but we need to incorporate the cost of skylights for a 50 year life cycle to gauge the utility of skylights.

In the process of optimizing the number of skylights different contractor were consulted. Wasco skylights and United Skys are few to be named. We provided them with info such as location of the building, area, height of the ceiling and type of the building. Based on one such quote from Wasco Skylights we opted for 'Clear over diffusing acrylic' skylights as the cost of skylights is same and this one requires the minimum number of 120 skylights for the required lighting.

The cost of a unit skylight is \$615 with curbs. Hence the cost of all skylights is \$73,800 for the first time installation. The industry standard on these skylights is anticipated 20 year life span. The skylights have very negligible maintenance cost hence we can assume them to have zero maintenance cost in the life span.

### 3.6.4 Life Cycle Analysis

For the life cycle analysis of the utility of skylights we calculated the NPV for lighting costs without skylights and NPV for lighting cost with skylights. The lighting cost with skylight incorporates the cost of skylights in it. We used an inflation rate of 3% which was provided by PA to calculate the cost of subsequent 50 years. To calculate the NPV value for the project life cycle discount rate of 7.5% was used which was also provided by PA. The same was done for the cost of electricity incurred on lighting with skylights.

In order to find the net saving as a result of the skylights we needed incorporate the capital cost of skylights. The lifecycle of a skylight is 20 years and hence need to be replaced every 20 years. We assumed the skylights to be installed first time in 0<sup>th</sup> year and then in year 20 and year 40. The cost of each year was calculated by summing up the cost of electricity incurred on lighting with skylights and the actual cost of skylights. In the year 50 we calculate the residual value of the skylights we can get back as we have used the skylights for only half of it life cycle.

Then the net saving for each year was calculated by subtracting the cost of electricity incurred on lighting with skylights and cost of skylights from the cost of electricity incurred on lighting without skylights. To calculate the net savings for the 50 year lifecycle of the project the NPV of savings in each year is calculated.

## 3.7 Low Flow Fixtures

### 3.7.1 Background

Plumbing fixtures that significantly reduce the amount of water released per use are labeled “low-flow” or “low-flush.” These fixtures use just enough water to be effective, saving excess, clean, drinking water that usually goes down the drain. Toilets are one of the main sources of wasted water, with older models using up to six gallons per flush. Faucets and showerheads are also water-wasting culprits.

Installing low-flush or dual-flush toilets and flow-reducing faucets and showerheads can significantly decrease water use. Low-flush toilets use 1.6 gallons per flush or less and are just as effective as older models that use more than twice that amount. Another option is dual-flush toilets, which offer an ultra-low flush of 0.8 to 1.1 gallons for liquid waste and 1.6 gallons for solid waste. Flow reducers for faucets and showerheads and pedal-controlled faucets can also significantly reduce a home's water use, and its monthly water bill.

The benefits of using Low Flow fixtures include,

1. Environmental Benefits

- Protects the natural water cycle and saves water for the future generations.
- Reduces the energy use and associated greenhouse emissions from treatment and distribution.

2. Economic Benefits

- Lessens capital investment needed for water supply and waste water treatment infrastructure, leading to more stable taxes and water rates.
- Decreases building operating costs, by decreasing the amount of water used.
- Decreases building operating costs, by decreasing the amount of water that must be treated, heated cooled and distributed – all of which require energy.

Two types of Low flow fixtures were analyzed for Indoor Potable water conservation, Low Flow fixtures and Ultra Low Flow Fixtures. The cost benefits, reflected by reduced water usage and savings in heating costs by using ultra low flow fixtures over low flow fixtures were calculated. The number of bathroom fixtures were taken as the same as that used in the current maintenance building.

### 3.7.2 Installation Costs

The installation costs of the fixtures were obtained from vendors. The costs are shown in the table below,

One Time Cost

	Low Flow	Ultra-High Efficiency
Toilets	\$132.00	\$2,529.00
Lavatory Faucet	\$44.74	\$49.24
Shower Head	\$16.25	\$13.50
Kitchen Faucets	\$48.77	\$53.27
Urinals	\$85.00	\$244.00

**Table 13: Installation Cost of Fixtures provided by Vendors**

Since the number fixtures wanted is kept the same as those in the current maintenance building. The total installation costs of the fixtures are estimated as shown below,

	Number Wanted	Low-Flow	Ultra-High Efficiency
Toilets	5	\$660	\$12,645
Lavatory Faucet	5	\$224	\$246
Shower Head	1	\$16	\$14
Kichen Faucets	1	\$49	\$53
Urinals	2	\$170	\$488
<b>Total</b>		<b>\$1,119</b>	<b>\$13,446</b>

**Table 14: Total Installation Cost of Fixtures**

### 3.7.3 Estimation of Usage

The fixture water consumption rates were obtained from the vendors. The flow rates in Gallons pre Minute (GPM) for Faucets and Shower heads, gallons of water used per flush (GPF) for Urinals and Toilets. The appropriate rate of use for each fixture is tabulated below.

	Low Flow	Ultra High Efficiency
Fixture	Flow Rates	Flow Rates

Toilet	1.6	Gpf	0	Gpf
Lavatory Faucet	2.2	Gpm	0.5	Gpm
Shower Head	2.2	Gpm	1.25	Gpm
Urinals	1	Gpf	0	Gpf
Kitchen Faucet	2.2	Gpm	0.5	Gpm

**Table 15: Usage Estimate**

It can be seen that the Ultra High efficiency fixtures involve the usage of waterless urinals and waterless toilets which have a water usage of 0 Gallons per flush, as well as faucets and showerheads with very low flow rates.

The average usage of the fixtures by the occupants during the course of the day was taken from the LEED hand book. The average usage of fixtures is assumed to be,

Fixture Usage		
Fixture	Use/Day	Duration of Use(Seconds)
Toilet	1	N/A
Lavatory Faucet	3	15
Shower Head	1	480
Urinals	2	N/A

**Table 16: Fixture Usage**

On average an employee will use the toilet once a day, the urinal twice a day, the lavatory faucet 3 times for 15 seconds at a time and the shower once for 480 seconds or 8 minutes per use.

### 3.7.4 Estimation of Yearly Savings

The yearly savings are estimated for using Ultra High Efficiency fixtures over Regular low flow fixtures which are the current standard. To make these calculations, we must know the number of people that will occupy the building. We have considered that there will be, 10 workers from the months of December to March and 6 Workers for the rest of the months. Considering that there are 260 working days in a year, this makes about 1960 employee days.

Since:

$$10 * 100 + 6 * 160 = 1960$$

There are 100 working days for the months from December to March and 160 working days from April to November.

Using the number of employee days and the fixture consumption and usage rates, the calculations are made for the amount of water saved per year when ultra high efficiency fixtures are used over low flow fixtures. About 24451 Gallons of water is saved when ultra high efficiency fixtures are used.

The amount of gallons of water used per year for each option are shown below,

SRE Building			
Low Flow Costs			
No. Of Employee days	Fixture	No. of Gallons used / Year	Costs
1960	Toilet	3136	31.36
	Lavatory Faucet	3234	32.34
	Shower Head	34496	344.96
	Urinals	3920	39.2
	<b>Total</b>	<b>44786</b>	

**Table 17: Low Flow Costs**

SRE Building			
Ultra High Efficiency			
No. Of Employee days	Fixture	No. of Gallons used / Year	Costs
1960	Toilet	0	0
	Lavatory Faucet	735	7.35
	Shower Head	19600	196
	Urinals	0	0

Total	20335
-------	-------

**Table 18: Ultra High Efficiency Costs**

The difference of these 2 usages is 24450 Gallons. Considering the cost of water to be \$ 0.01 / Gallon, the total cost savings per year are \$244.51.

Considering that one fourth of this water is heated, we can say that the amount of heated water saved is about 4349 Gallons. If this is the amount of water that is not heated every year then there are heating costs that are saved as well. The savings for the heating costs are determined using the formula,

$$Q = m * c * \Delta t$$

Where,

Q = heat energy

m = mass

c = specific heat

$\Delta t$  = change in temperature (= final - initial temp)

The heat energy is calculated in Joules and then converted into BTUs. The efficiency of the heater is taken as 85% and the actual amount of energy saved is estimated.

Cost savings on heat/Yr					
	kg of Water Saved	Initial Temp of Water	Final Tamp of Water	C	Btu Saved
Maintenance Shed	16505.48295	50	140	4190	5601795.86
Efficiency of Heater	85%				
Total	6590348.071				

Energy(BTU)saved/yr					
Total					
Energy(CCF) saved/yr	64.61125559				
Cost	51.1398088				

**Table 19: Cost Savings on Heat per Year**

The efficiency of the heater is also taken into account and the Total Energy saved per year in BTUs is calculated. The cost savings in heating form using the ultra high efficiency fixtures is about \$ 51 per year.

### 3.7.5 Net Present Value Analysis

The net present values of the following are computed over a 50 year lifecycle considering that the price of water will grow at 5%, energy will grow at 3% and the inflation rate will be 3%. It is also considered that the lifecycle of the fixtures is 10 years, i.e. the fixtures are replaced every 10 years.

*Net Present Value of the Low Flow fixtures = \$2,114.66*

*Net Present Value of the Ultra High Efficiency fixtures = \$25,416.21*

*Net Present Value of the Energy and Water Savings = \$7,767.11*

*Net Present Value of Total Savings = (\$15,534.45)*

It can be seen that the NPV of the Total Savings is negative. The savings of water and heat do not fully offset the costs involved in using ultra high efficiency fixtures.

## 3.8 Green Roof System Analysis

Green (vegetated) roofs have gained global acceptance as a technology that has the potential to help mitigate the multifaceted, complex environmental problems of urban centers. While policies that encourage green roofs exist at the local and regional level, installation costs remain at a premium and deter investment in this technology. The objective of this project is to quantitatively integrate the range of stormwater, energy, and air pollution benefits of green roofs into an economic model that captures the building-specific scale. Currently, green roofs are

primarily valued on increased roof longevity, reduced stormwater runoff, and decreased building energy consumption. Proper valuation of these benefits can reduce the present value of a green roof if investors look beyond the upfront capital costs.

### 3.8.1 Background

A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. On hot summer days, the surface temperature of a green roof can be cooler than the air temperature, whereas the surface of a conventional rooftop can be up to 90°F (50°C) warmer (Liu, K. and B. Baskaran).

Green roofs can be installed on a wide range of buildings, from industrial facilities to private residences. They can be as simple as a 2-inch covering of hardy groundcover or as complex as a fully accessible park complete with trees. Green roofs are becoming popular in the United States, with roughly 8.5 million square feet installed or in progress as of June 2008 (International Greenroof & Greenwall Projects Database).

The benefits of green roofs include:

- a) **Reduced energy use:** Green roofs absorb heat and act as insulators for buildings (Sandifer, S.), reducing energy needed to provide cooling and heating (Akbari, Huang).
- b) **Reduced air pollution and greenhouse gas emissions:** By lowering air conditioning demand, green roofs can decrease the production of associated air pollution and greenhouse gas emissions. Vegetation can also remove air pollutants and greenhouse gas emissions through dry deposition and carbon sequestration and storage.
- c) **Improved human health and comfort:** Green roofs, by reducing heat transfer through the building roof, can improve indoor comfort and lower heat stress associated with heat waves (Center for Disease Control and Prevention).
- d) **Enhanced stormwater management and water quality:** Green roofs can reduce and slow stormwater runoff in the urban environment; they also filter pollutants from rainfall.
- e) **Improved quality of life:** Green roofs can attenuate noise in the airport and provide aesthetic value and habitat for many species.

Estimated costs of installing a green roof start at \$10 per square foot for simpler extensive roofing, and \$25 per square foot for intensive roofs. Annual maintenance costs for either type of roof may range from \$0.75–\$1.50 per square foot (Peck, S. and M. Kuhn).

While the initial costs of green roofs are higher than those of conventional materials, building owners can help offset the difference through reduced energy and stormwater management costs, and potentially by the longer lifespan of green roofs compared with conventional roofing materials.

Researchers and communities are beginning to perform detailed, full life-cycle analyses to determine the net benefits of green roofs. A University of Michigan study (Clark, C., P. Adriaens) compared the expected costs of conventional roofs with the cost of a 21,000-square-foot (1,950 m<sup>2</sup>) green roof and all its benefits, such as stormwater management and improved public health from the absorption of nitrogen oxides. The green roof would cost \$464,000 to install versus \$335,000 for a conventional roof in 2006 dollars. However, over its lifetime, the green roof would save about \$200,000. Nearly two-thirds of these savings would come from reduced energy needs for the building with the green roof (Clark, C., P. Adriaens).

### 3.8.2 Installation Costs for Conventional and Green Roofs

To determine how the environmental benefits reduce the installation cost gap between green and conventional roofs, the magnitude of the gap was first determined. Cost and size data were mainly obtained from roofing cost and time estimates provided by plant operations for seventy-five sample roofs from the research of the University of Michigan (Clark, C., P. Adriaens) and experts' advice of Mother Plants, a local business that supplies green roof plantings in Ithaca.

	<b>Green Roofs</b>	<b>Conventional Flat Roofs</b>
Life time (yr)	40	20
Square Footage	64,000	64,000
Initial cost per square foot	\$20.00	\$15.50
Installation cost	\$1,280,000	\$992,000

**Table 20: Cost Comparison between Green and Conventional Roofs**

### 3.8.3 Stormwater Fees and Reductions

The reduction of stormwater volume by green roofs benefits municipalities; however, not all local water authorities pass the economic savings on to the owner of the green roof. Traditionally, the budget for stormwater management is provided through property taxes or potable water use fees. In recent years, municipalities have been moving toward stormwater fees based upon total impervious surface on a property, creating an opportunity to “credit” green roofs for stormwater reduction. The commercial stormwater fee is \$0.28 per square meter per year. It was assumed that the reduction in stormwater fees due to a green roof is normally distributed at fifty percent of the stormwater fee for the building footprint according to data on fee reduction policies in Portland, Oregon; Minneapolis, Minnesota; and Ann Arbor, Michigan.

	Green Roofs	Conventional Flat Roofs
Stormwater fee(/m <sup>2</sup> *yr)	0.14	0.28
Square footage	64,000	64,000
Stormwater fee (/yr)	\$833	\$1666
Stormwater fee saving(/yr)	\$833	0

**Table 21: Comparison between Green and Conventional Roofs**

### 3.8.4 Energy Savings Determination and Valuation

There are 3 different energy models to estimate Roof Conductance According.

Roof Type	Roof Conductance (W/m <sup>2</sup> /K)		
	R-value Model	EnergyPlus Model	ESP-r Model
Conventional Roof	0.5	0.38	0.59
Green Roof	0.24	0.36	0.42

**Table 22: Roof Conductance**

In this project we will use EnergyPlus Model because the estimation lies between the other two. Thus the green roof has a relative Energy Saving of nearly \$0.5 per square meter per yr compared with the conventional roof.

### 3.8.5 Economic Analysis

Once the costs and benefits were determined on a per unit area basis, the results were integrated into an economic model to determine the length of time required for a return on

investment in a 64000 square feet green roof using a net present value (NPV) analysis with an interest rate of 7.3% and inflation rate of 3%. It was assumed that on the 50-yr basis of the project, the conventional roof would be replaced every 20 years and the green roof would be replaced after 40 years. However maintenance costs have not been included in this analysis.

	<b>Green Roofs</b>	<b>Conventional Flat Roofs</b>
NPV	(\$1,256,012)	(\$1,267,169)

### 3.9 Stormwater Harvesting Analysis

#### 3.9.1 Background

The conservation of water is a challenging task. Aside from the continual consumption from a local supply, there are two alternate sources of water: greywater and stormwater. Greywater refers to waste water that has been used by applications such as sinks and washing machines. This excludes dirtier water such as kitchen sink and flushed toilet water. Nonetheless, greywater still contains bacteria and other pathogens (Waskom and Kallenberger), which make it a potential public health issue if it were to be reused in commercial buildings. Stormwater, which refers to the water from rain and snowmelt, is perceived as a clean, fresh source of water that would require much less treatment than greywater. In general, due to lower contamination than with greywater, stormwater harvesting is regarded as a much more acceptable alternative than greywater reuse. (Maunsell)

One method for stormwater harvesting is the implementation of a storage system that will collect, store, and reuse stormwater. By collecting the precipitation, the quantity of runoff is reduced; and after being used, the same water can then be properly disposed. A large application of stormwater harvesting is to harness natural precipitation, thus reducing dependence on the municipal supply and lowering water costs. (Hicks 1)

A stormwater harvesting system for a commercial facility, such as a snow removal equipment building, is based on a simple process. Precipitation falls onto the rooftop of the building where it then flows into receptors, usually gutters, which lead into pipes connected to a large underground storage tank. The water is filtered in the system and collected in the tank for later use.

When water is demanded by the building, whether for washing or toilet flushing, the pump system will pump the water into the building. (Jay R. Smith Mfg. Co.)

### 3.9.2 Assumptions

In order to analyze the implementation of a harvesting system at Stewart Airport’s snow removal equipment building, a few assumptions must be pointed out. First, it will be assumed that the construction of the rooftop is optimized for water capture, meaning the use of slopes or other simple techniques will efficiently flow the water into the pipes. However, if a green roof is adopted, the roof can tolerate a modest degree of slope without affecting the plants’ ability to grow. Second, since precipitation can take on the form of snow, which may accumulate in the winter, it is assumed that all of the snow on the roof will naturally melt into water. Third, the estimate water demand will be based on water usage in the maintenance and administrative buildings. For the cost analysis, the inflation of the cost of water will be an annual growth of 3%.

The cost of the system will be based on Table below.

<b><u>Item</u></b>	<b><u>Cost</u></b>
<b>Flush filters</b>	<b>\$120.00</b>
10,000 gallon tank	\$17,372.50
Excavation (per tank)	\$6,750.00
<b>Underground Tank</b>	<b>\$24,122.50</b>
Overflow valve	\$107.00
Overflow PVC pipe	\$195.00
Overflow cleanout tee	\$33.60
Potable supply valve	\$330.00
Potable supply tubing	\$1,280.00
Potable supply backflow preventer	\$287.00
Potable supply actuated valve	\$309.00
<b>Plumb Tank</b>	<b>\$2,541.60</b>
Pump	\$533.00
Level control	\$166.00
Pump panel	\$1,734.00

Pump installation	\$945.00
<b>Tank Pump</b>	<b>\$3,378.00</b>
<b>Floating Intake</b>	<b>\$256.00</b>
<b>Distribution Piping</b>	<b>\$12.80</b>
<b>Booster Pump</b>	<b>\$1,478.00</b>

**Table 23: (Hicks 22-23)**

### 3.9.3 System Size and Installation Costs

It is important to first look at the most recent water usage at Stewart Airport (Table 23 below). For the maintenance building, where mostly washing occurs, there are 18 active pieces of equipment. The airport is anticipating seven more pieces of equipment later this year, which brings the monthly water demand to 39722 gallons (Equation 1). This figure also assumes that water usage is based on a per vehicle basis. The administrative building, where water usage consists of toilet flushing, hand washing, and other office uses, experiences a monthly demand of 25,000 gallons. The total monthly demand is, thus, 64722 gallons, with an average cost of water at \$0.01 per gallon. The total annual water cost is \$7728, which grows annually at 5%. Using a spreadsheet, the present value of water costs over the next 50 years is \$213,791.24.

Equation 1:

$$\text{Number of Equipment} * \text{Demand Per Equipment} = \text{Monthly Water Demand for Maintenance}$$

$$25 \text{ equipment} * 1589 \frac{\text{gallons}}{\text{equipment}} = 39722 \text{ gallons}$$

<b>Current Water Usage</b>	<b>Maintenance</b>	<b>Administrative</b>
Avg Monthly Usage (gal)	28600	25000
Cost of Water (\$/gal)	\$0.0061	\$0.0144
Monthly Cost	\$174.02	\$359.28
Annual Cost	\$2,088.26	\$4,311.36

**Table 24: Current Water Usage**

To calculate the cost of a harvesting system, 70,000 gallon harvesting system is first proposed, based on the average monthly water demand. However, one caveat is that during winter seasons, certain periods will experience rare and extremely high demands for equipment washing that may not be met by the system. Since the bulk of the cost for a harvesting system is accounted for by the tanks, it is not economical to have a larger system just to meet the extreme demands. It is much cheaper to purchase the extra need (in the event that the collection system is not sufficient) from the municipal supply.

Another consideration for the sizing of this system is to ensure that there is sufficient precipitation. With over 45 inches of annual precipitation (which translates to over 100,000 gallons of water a month) in Newburgh, NY, shortage in stormwater is not a concern (Table 24). In fact, only 45% of the potential precipitation is needed to meet the annual demand. Thus 45% of the roof area could be used in the case of adopting a conventional roof. If a green roof were adopted, the percent of capture area could be increased up to 100% in order to take into account the amount of water withdrawn by the green roof.

<b>Month</b>	<b>Precipitation (inches)</b>	<b>Collection Amount (gal)</b>	<b>Water Demand (gal)</b>
January	3.48	138838	64722
February	2.90	115699	64722
March	3.49	139237	64722
April	3.95	157590	64722
May	4.50	179532	64722
June	4.11	163973	64722
July	4.65	185517	64722
August	3.92	156393	64722
September	4.11	163973	64722
October	3.70	147616	64722
November	3.60	143626	64722
December	3.29	131258	64722
Annual	45.70	1823252	776666.67

**Table 25: Water Demand**

So the actual system would have seven 10,000 gallon underground tanks. The total upfront cost is \$224,772.70, which includes costs for excavation, filters, pumps, piping, and installation. This figure is detailed in Table 25 below.

Item	Cost	Units	Total
Flush Filters	\$120.00	7	\$840.00
Underground Tank	\$24,122.50	7	\$168,857.50
Plumb Tank	\$2,541.60	7	\$17,791.20
Tank Pump	\$3,378.00	7	\$23,646.00
Floating Intake	\$256.00	7	\$1,792.00
Distribution Piping	\$1,500	1	\$1,500.00
Booster Pumps	\$1,478.00	7	\$10,346.00
<b>Capital Cost</b>			<b>\$224,772.70</b>

**Table 26: Capital Cost**

Also, the system needs to be replaced after 25 years. In addition, throughout the lifecycle, there are operating costs for the system, such as replacements of various parts (Table 26).

Maintenance	Frequency (years)	Cost
Mucking Tank replacement	5	\$1,500.00
Pump replacement	10	\$16,890.00
Minor fittings replacement	5	\$1,500.00
Booster pump replacement	10	\$1,478.00

**Table 27: Maintenance Cost**

### 3.9.4 Net Present Value Analysis

The net present value was calculated by determining the net saving of each year if the system were implemented. In the first and 25<sup>th</sup> year of the analysis, there is a capital cost of

\$224,772.70 since the system is assumed to have a lifetime of only 25 years; thus, everything needs to be replaced. Throughout the 50 year analysis, the operating costs were factored in based on their frequencies shown in Table 5. The implementation of such a large system is quite expensive. Over 50 years, the NPV of the savings after the implementation is **-\$78,215.07**, based on the assumption that the system will meet the complete water demand yearlong. As mentioned before, peak demand periods, which are unevenly distributed, may not be met so the savings is actually less and the NPV value of **-\$78,215.07** is overstated. It would be too costly to support an infrastructure that does meet all demand.

# 4. Conclusion and Recommendations

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## 4.1 HVAC

Since it was only possible to fully analyze the life cycle cost of one HVAC system (the ASHRAE 90.1 fully compliant HVAC), it was not possible to carry out an NPV analysis comparing multiple options. Instead, just the PW of the single system is provided. On the other hand, as demonstrated above, the system provides significant emission reductions. Further investigations should be made by Port Authority into HVAC systems as the figures in the above sections are rough estimates (due to lack of a detailed design of the building that would allow more accurate costing of the HVAC). Although based on the preliminary analysis, it is recommended that Port Authority should apply ASHRAE standard 90.1 compliant HVAC system to the new SRE building at Stewart International Airport to truly attain a Green and Sustainable Building.

## 4.2 Geothermal System

While this analysis has shown that the proposed geothermal system is not cost effective as is, it does offer significant emissions reductions, as demonstrated above. Thus, if the significance of this CO<sub>2</sub> offset can justify the negative net present value of the investment, a geothermal system should be considered for the office space in the new SRE building at Stewart International Airport. Further, Federal funding may be available for investment in this renewable energy system. Such monies may also offset the negative net present value of the geothermal system. Therefore, it is recommended that Stewart International Airport investigate the availability of such Federal funding before making a definitive decision regarding implementation of a geothermal system in the new SRE building.

In the case that a geothermal system is pursued for the new SRE building at Stewart, a list of local, NYSERDA-verified geothermal consultant and contractor contacts is included as an Appendix to this report. (NYSERDA)

## 4.3 PV System

The price per watt of photovoltaics is still very high. Although PV panels will provide electricity for decades without further cost, their high price still means that for most applications, traditional fossil fuels are a better investment. (Fraser) As mentioned in the table above the NPV of

cost without PV is \$ 860,636, while NPV of Cost of PV system is \$ 3,650,238 giving us a negative NPV savings of \$2,789,602. Thus the net savings do not offset the cost of the PV system, thus it is not recommended to use PV systems for financial reasons.

Japanese tragedy has underscored the need for renewable energy future. The situation is sending a clear reminder about the potential risks and danger of nuclear energy, and provides an opportunity to focus on how clean, safe, renewable energy resources could be used as an alternative electrical energy supply. (Freiburg)

Photovoltaic technology has entered a new era where the urban residential generation of electricity is becoming the dominant application area. A sympathetic environment for the introduction of grid connected residential photovoltaic systems, considered important for this continued local growth, is important.

The present health of the industry, although based on a relatively fragile system of government subsidy, is helping to stimulate the introduction of improved manufacturing techniques and technology. This should see the successful introduction of a second generation thin-film technology over the coming decade. Although earlier thin-film technologies have had problems with cost, stability, manufacturability, durability and/or toxicity, the thin-film polycrystalline-silicon-on-glass technology developed should offer new prospects in this area. (Green) So in future the use of thin film technologies should be explored to see if the costs could be reduced to low enough to be used at Port Authority premises.

## 4.4 Lighting System

Although the net savings as a result of usage of skylights is only \$4,595 but it reduces energy consumption by 25%. It also favorably impacts human health and improves workplace performance. Based on research at Carnegie Mellon University and others, daylighting appears to improve productivity and reduce absenteeism by at least 20 percent. Hence our recommendation is to install skylights.

In future the recommendation is to explore the use of light tubes, also called a solar tube or the tubular skylight. Light tubes can be placed into a roof and admit light to a focused area within the interior of a building. Light tubes passively collect light using a rooftop dome and transmit the light into a space through a highly reflective rigid or flexible tube to a ceiling diffuser that looks very much like a recessed light fixture (Gordon 2003). An advantage of light tubes, compared to skylights, is that they

allow less heat to be transferred to the space, as light tubes have less exposed surface area.

Another recommendation would be to explore using different lightings such as xenon light solutions and LED solutions. Along with it the usage of light level detectors should be explored. There are many low level lighting detection solutions as Avalanche Photodiodes (APDs), Channel Photomultipliers (CPMs), Single Photon Counting Modules (SPCMs) and Silicon Photomultipliers (SiPMs). (Excelitas.com)

## 4.5 Green Roof

The environmental benefit results were integrated into an economic model to determine the length of time required for a return on investment (ROI) for an individual building's green roof system. The green roof upfront cost is 39% higher than the conventional roof at installation (\$1,280,000 versus \$992,000). The NPV was calculated using energy estimates, stormwater estimates and the air pollution estimate. The NPV of the total cost for the green roof and the conventional roof on a 50-year basis are nearly the same (-\$1,256,012 versus -\$1,267,169). However considering the capacity for the green roof to reduce energy use and attenuate noise, reduce air pollution such as NO<sub>x</sub> and greenhouse gas emissions, enhance stormwater management and water quality considering, it has more environmental benefits.

Although the analysis gives a slight environmental advantage to the green roof, the following caveats apply:

- a) The financial up-charge for additional structural engineering needed to support the green roof is difficult to quantify and outside the scope of this project. If there are significant additional costs for supporting the extra weight of the green roof, these may negate the savings.
- b) As mentioned above, the NPV analysis includes a savings of \$833/year for stormwater management. If these charges are not assessed, then the revenue stream would change.
- c) The NPV analysis assumes that maintenance costs are negligible for the green roof, beyond costs that would be incurred for an ordinary roof. This finding is confirmed anecdotally by conversations with the building manager of Weill Hall at Cornell University, which has a green roof. Plants are chosen to be very hardy (regardless of high or low rainfall) and to need maintenance just one time per year. If, however, a green roof was found to need more maintenance, the NPV advantage might decline significantly.

## 4.6 Stormwater Harvesting

While the harvesting system is not economically beneficial, there are upsides to having such a component. Firstly, it conserves potable water that is usually drawn from the local supply. Such a system would capture much of the water that can potentially be harmful runoff that travels into streams and other parts of the environment. Being able to properly manage the quantity and quality of stormwater runoff is not only environmentally beneficial, but reducing the quantity can reduce the risk of flooding around the facility's perimeter. (Agua Solutions) These advantages apply to stormwater harvesting systems generally; since SWF is located on a large, flat parcel of land, hazardous runoff or potential for flooding may not pose significant risks, so the financial advantage may not exist.

It is recommended for Stewart International Airport to consciously weigh the costs and benefits presented in a way that considers beyond the economic feasibility. Also, this analysis determined the size of the system based on monthly demand. In reality, precipitation and water usage is spread across the month. A more accurate sizing of the system can be determined by keeping track of the frequency and usage, especially equipment washings, on a daily basis. Intuitively, this implies that the actual size of the system may not need to meet 70,000 gallons. For example, if the collection size is only 40,000 gallons, the net present value of this element is actually \$37,111.47, which is a favorable investment. Again, this 40,000 gallon system assumes that it will meet the entire need of the new snow removal equipment building. On the other hand, if reducing the size of the system also reduces the amount of water made available, the positive NPV may not materialize.

Another important step would be to observe the accumulation of snow on the roof during the winter months. While the analysis assumes that all snow will melt, there may be rare instances when snow accumulates to an extreme amount that may actually hinder the productivity of the harvesting system. In this event, heated gutters should be installed to facilitate the melting of the snow or ice. (ENN)

# 5. Future Prospects

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The start-up nature of this project combined with the short timeframe of a single semester project did not allow sufficient time to explore all desired aspects of designing, building, and operating a sustainable SRE building. Based on the research and findings over the length of this project, this team has identified several areas that it would recommend to be explored by future student teams and/or by Port Authority Engineering and Sustainability personnel.

## 5.1 Energy Analysis Software Modeling

While calculating the thermal efficiency of a building can be simplified with the use of thermal resistance R-values, to truly explore the energy efficiency of a potential SRE building, the next logical step would be modeling with commercially available software. One such recommended software would be DOE2, a free program published by the U.S. Department of Energy and developed by the efforts of James J. Hirsch & Associates (JJH) and the Lawrence Berkeley National Laboratory (LBNL).

Programs like DOE2, and its enhanced versions packaged under the names eQuest and PowerDOE, can be used to run full building simulations and therefore allow for a more comprehensive picture of how the SRE will operate as a whole unit. Compared to our analysis which primarily explored sustainable elements on individual components, using a software package is the best and, really only, way to fully understand the interconnected nature of all these systems and how they impact the overall energy efficiency of the structure.

## 5.2 Availability of Federal Funding

While the team's analysis has shown that not all of the green elements investigated are financially viable, there is considerable federal funding available both for investment in new SRE facilities and sustainable and green design at airport facilities. Although outside the scope of this project, the Port Authority is highly encouraged to investigate the availability of such funding for the design elements discussed in this paper. With the promise of government subsidies, some of the green features of the proposed SRE that were not found to be cost effective could become more

financially attractive options. Such information will also help the Port Authority glean a more accurate estimate of what the total cost costs for which they would be responsible would be.

### **5.3 Information from Local Vendors**

Another logical next step for a future student team or for the Port Authority Engineering and Sustainability personnel is to initiate communication with local vendors for the systems presented in this paper. This will enable a more accurate estimate of system and construction costs, as well as enable the Port Authority to gather more information about its options in planning and implementing the new SRE facility.

### **5.4 Detailed Study of HVAC systems**

Since the design and installation of HVAC system is significantly subjective to climate of the area, architectural design of the building, and the purpose of the building. It would be useful for the future teams to have the detailed design of the building in hand as it would help them to get a more accurate estimate of the costs of the system.

A deeper study of the ASHRAE standard 90.1 looking into Zone Thermostatic Controls, Off Hour Controls, Ventilation System Controls, Energy Cost Budget Method etc. will be of great help.

Wisconsin Airport has used Large fans (a.k.a Big Ass Fans) in their facility for Air control inside the building, due to lack of information on the conditioning unit, and Exhaust System used sufficient study could not be done on this front. This system, apparently, can be very cost effective and is a potential area of study.

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## APPENDIX 1- Geothermal Vendors List

States	Designer	Installer	Mechanical	Company Name	Mailing Address	City	State	Zip	Office Phone	Website	Email
Yes	Yes	Yes	Yes	AirMasters Environmental Services, Inc.	20 Newhard Place	Hopewell Junction	NY	12555	845-226-1695		<a href="mailto:Airmasters@aol.com">Airmasters@aol.com</a>
	Yes			Alfandre Architecture PC	7 Innis Ave.	New Paltz	NY	12561	845-255-4774	-	
Yes	Yes	Yes	Yes	Altren Consulting & Contracting, Inc.	P.O. Box 396	Rifton	NY	12571	845-658-7116	<a href="http://www.altren.net">www.altren.net</a>	<a href="mailto:charles@altren.net">charles@altren.net</a>
Yes	Yes		Yes	D.J. Heating & A/C	P.O. Box 700	Marlboro	NY	12542	845-236-4436		
Yes	Yes	Yes	Yes	D.Silvestri Sons Inc.	173 Old Route 9, Ste. 1	Fishkill	NY	12524	845-897-4008		
Yes		Yes	Yes	EMCO	477 Hasbrouck Ave.	Kingston	NY	12401	845-338-2290	<a href="http://www.emco477.com">www.emco477.com</a>	
	Yes	Yes	Yes	Enviro-Tech, Inc.	1800 Rt. 9G	Staatsburg	NY	12580	845-229-6855		<a href="mailto:envirotec@optonline.net">envirotec@optonline.net</a>
	Yes	Yes	Yes	Hudson Valley Clean Energy	13 Hook Rd.	Rhinebeck	NY	12572	845-876-3767	-	

		Yes		Hudson Valley Drilling	2177 Rt. 94	Salisbury Mills	NY	12377	845-496-2131		
			Yes	Jeff Lowe Plumbing Heating & Air Conditioning	101 Smith Avenue	Kingston	NY	12401	845-331-2480		
	Yes	Yes	Yes	Sigma-Tremblay	4 Delavergne Ave.	Wappingers Falls	NY	12590	845-297-4000	<a href="http://www.sigmatremblay.com">www.sigmatremblay.com</a>	
	Yes			SJM Associates	58 Brookside Dr.	West Shokan	NY	12494	845-657-2072		<a href="mailto:sjmassociates@hvc.rr.com">sjmassociates@hvc.rr.com</a>

**Table 28: NYS Geothermal Consultant and Contractor List\***

\*Source: <http://www.nyserda.org/programs/geothermal/default.asp>

# APPENDIX 2- Management Report

## Summary

Progress of the Port Authority Sustainability Team remains on track. Based on individual feedback, team processes have been working well. Given our diverse academic/personal backgrounds, team members are comfortable with the domains they have taken responsibilities for in terms of researching and modeling. Overall, everyone is gaining a wealth of knowledge about the green industry through extensive research. Weekly meetings take place in a highly collaborative environment where members exchange ideas and information, and short term and long term goals are reiterated at each meeting to ensure that everyone is on the same page.

There has been a challenge in refining the project scope since the goals and requirements are dependent on Port Authority's needs and objectives. This challenge has been addressed at our initial site visit and at monthly teleconferences, where existing and new topics are discussed. In addition, the team has also reached out to engineers at Mead & Hunt. The A/E design firm worked on a similar sustainably designed snow removal equipment (SRE) building in Austin Straubel International Airport in Wisconsin. This was a very beneficial opportunity, since the Port Authority has similar interests for their new SRE building at their Stewart International Airport. The team is currently involved in finalizing the collection of green systems and energy data, which will be used to construct a working model to analyze the energy efficiency and cost effectiveness for Port Authority to engage in green building designs.

There is a general consensus that the collaborative tools the team has used thus far have been very effective in keeping all the information organized. Dropbox has provided the whole team with one centralized location to share and to refer to documents (such as minutes and data tables) at any time. Additionally, the use of Google Documents has allowed individuals to pursue simultaneous efforts while editing group documents. The team will continue to use these technologies for the remainder of the project, as we shift toward a new team structure that will focus on the model and final presentation. This next phase of the project will require a much higher level of communication and collaboration in order to bring together the final deliverables in a way that will most benefit our client.

## Midterm Management Report

### Amandeep Gupta

While writing the midterm evaluation report I feel very good and confident about the direction of the project. Although the teams have been divided into sub-teams, due to the participation in weekly meetings everyone has a general overview of the whole project which is really essential as the teams are mutually dependent on each other's work. All team members are working effectively and professionally in their respective areas of the project. Even though everyone comes from a different educational background the team members have attained compatibility with the goals of the team and their respective functions in it.

Dropbox is being effectively used to share pertinent documents, especially the meeting minutes, among the team members. Project team liaisons are working very well in keeping the team updated on questions, messages etc. from the professor and Port Authority.

Research regarding different areas is mostly complete. In the second half of the project more concentration will be given to the spreadsheet model. We still need to work out a formal structure for the team which has been missing up to this point.

As for my personal contribution, I have been majorly working on ASHRAE standards especially HVAC system. This project has helped me realize how to effectively work in a team, what actual projects look like and what is expected from a consultancy team. Over all the project has been a very valuable experience so far and I hope we will provide some good result in the end.

### Yuanjie Zhou

This project is an interesting experience as it demonstrates the efficiency of working in a relatively small team, which is functioning well so far. Everybody is engaged and contributing with sufficient work. Responsibilities and tasks are being allocated rationally, equitably, and effectively.

The group members have made good use of site visit, teleconferences and technologies such as Google and Dropbox. The leadership structure works well on the communication with Port Authority and other

outside groups as well as within the team. The weekly meeting with advisor and the whole team always helps me come up with new ideas and push the whole project a step further. Thus every group member gets involved and contributes to various elements for this green construction project within the scopes, including literature review and basic model structure building.

My work so far focuses on the research on the green roofs for the green building. Based on the literature review, I have come up with the basic structure, cost and benefit analysis to estimate the possibility, cost efficiency and environmental benefits for the Port Authority to use this green element for the new building. The work has gone through well so far and the life cycle with cost benefit analysis for the green roofs is carried through as well. With more utility data from Port Authority we just got recently, I will try to build a more detailed model to calculate and estimate the cost benefit of the green roofs later on as the whole team will switch the focus from the basic green building structure research to the real model building.

My suggestion to improve the second half of project later on is to work more efficiently in sub-groups in order to build the models within various scopes, which ensures every group member with the right skills that are matched to the tasks so that each team member can give input on relevant decisions. Besides, it will be also helpful to have a schedule for the whole milestones for the rest of the project which can help push the team progress more rapidly and clearly, especially for the teleconferences. In this way, the team could work more effective and better communicate with the outside groups, which help to achieve the team goals and guarantee a positive team experience.

### Ben Kemper

At this juncture of our team's project, I believe that we are working together effectively to work towards creating a successful finished product. We have naturally evolved into an organizational format. The team has one liaison with its Port Authority contacts and another liaison with its faculty advisor contact. The team also has an individual designated for taking notes during meetings.

The team holds one weekly meeting with its faculty advisor to discuss its progress and to determine its weekly deliverables. Additionally, there are weekly team meetings to discuss how work will be distributed within the team and to share ideas amongst team members. Further, DropBox and an email listserv are used for communicative purposes. Thus far, work has been distributed evenly

amongst team members. Research topics are distributed based on interest levels of individual team members in a particular subject. While this has been a successful model thus far, I think that some of the topics could be better addressed by sub teams, as opposed to being addressed by individuals, due to their large scope. For this reason, I think it would be advantageous to formally organize sub teams, and to have these sub teams meet independently, and then bring their contributions to the weekly team meetings. This would help the team avoid overlaps in research areas, as well as provide a forum for discussion, collaboration, and idea generation. Further, I believe the team needs to address the work breakdown for the final report and presentation. This work can be distributed to existing sub-teams, or new sub teams can be formed for the express purpose of completing these final project deliverables.

With regard to my personal contribution to the project, I think that I am making significant progress towards achieving all of my Personal Goals. I have been an active contributor to various aspects of the project. I have taken leadership positions, as the interim liaison to the Port Authority, and as the permanent liaison with the Faculty Advisor. Further, I have learned how to function effectively within a team of our size. I believe that I am successfully applying many of the techniques which I learned in CEE 5900: Project Management, to this project. I am recognizing team dynamics and organizational features and adapting appropriately. Overall, I believe this project has been a valuable educational experience and a successful endeavor thus far. I am looking forward to the next phase of the project and the development of an impressive tool for the Port Authority by our team!

### [Justin Li](#)

It is the halfway mark of our project and I feel confident that the final product will meet the collective and individual goals set out in the beginning of the semester. This project started out with a team of seven individuals unfamiliar with one another; but it has grown to become a group of teammates that are comfortable communicating and working effectively together.

For the first half of the semester, we spent a lot of time gathering the requirements of Port Authority and collecting information that is essential to meeting these requirements. Team members have taken responsibility for different components of the project, which are then brought to the table at the weekly team meetings. The team also meets with Professor Vanek to discuss what has been done so far, what is being worked on, and what needs to be added to the agenda. Dropbox and Google Docs have been great tools for collaboration on assignments that involve multiple individuals. The Dropbox folder, in particular, has allowed everyone to stay on the same page since minutes and all other information are visible to everyone.

The success of the team, thus far, has been due to the breakdown of work based on individual interests. This, in my opinion, stimulates a high level of productivity and encourages information sharing. However, it is important to maintain a high level of communication so everyone knows who is doing what and what still needs to be assigned so that we can cover all the grounds of the project. Furthermore, in the second half of the project, it will be beneficial to reorganize the breakdown of the work since some components, such as the ASHRAE standards, turned out to require multiple individuals. Subteam meetings would be good too since there is sometimes a lot to do at the weekly meetings.

Up until this point of the project, I have had the role of keeping things organized through taking minutes and making sure the Dropbox folder is up to date. In terms of research, the topic of stormwater management has been very interesting. However, due to the limited documentation on large scale cisterns, I hope to be in direct contact with the contractors involved on the Austin Straubel building. Lastly, I have had the pleasure to lead the design of the spreadsheet in its primary stages. The second phase of our project will shift to incorporating all of our information and ideas onto this single tool that will be presented as part of the final deliverables.

### [Umer Gul](#)

Eighth Week into the project, I feel that we as a group have a very good rapport going on which is being reflected by our project progress. Project is very much on track with the milestones which we as a team had setup initially. What has helped us gel well is the fact that being from diverse background, we complement each other. Though all of us are working independently on our domains, everyone is willing to help other and share the burden.

As the project has progressed the structure of our team has evolved. We started off with one person as the liaison with port authority and our advisor but now we have different people interacting with port authority and advisor. This has helped the team to focus more on every particular detail. One member is responsible for making minutes on the meeting. This has been very useful not only in keeping track of the progress but also filling in members who are not able to attend the meetings due to conflicts. These minutes of the meeting are shared on the drop box. Besides the meetings with Project advisor every week for the feedback, the group meets every Tuesday and discusses the progress. Also the action points for the next weeks are assigned during the meeting and thus far everyone has been addressing them, contributing to the project effectively.

The research areas have been assigned based on either the background or the interest of the individual. My area of research for the project has been renewable source of energy and lighting. Thus far I have been able to develop an initial model for photovoltaic array sizing. The main input for this are the energy specifications provided to us by the Port Authority. The work on lighting model is still in progress.

Even though the project is progressing well, I feel the need for formation of sub teams due to large scope of some research areas. Besides balancing the workload it would also give opportunity to members to hone their team skills. We are currently exploring what different research areas can be combined together to synergize. All in all the project has progressed well and we all are looking forward to the second half of the project and presenting our final deliverables to Port Authority.

### Rahul Margam

At the half point of the Project, our progress as a team has been good. For the first half of the semester, we gathered the requirements of Port Authority and collected information that is essential to meeting the project goals. The team members each picked areas of focus in the project for the literature review. This was a good way get everyone familiarized with what was to be achieved. A similar approach was followed in making the model where each team member picked an area of interest and research costs associated with that area. Team meetings are held weekly to update each other on the progress made by each team member. Weekly team meetings are also held with the Faculty Advisor to review the team's progress and to set the direction of the next steps to be achieved.

The project team has not yet been broken down into sub-teams. Jeff is the liaison with port authority and Ben is the liaison with the faculty advisor. In my opinion division of the team into sub-teams will help us to focus on areas that are key to the success of the project. This also helps team members who are working on areas that have a lot of overlap in them. The team communicates through E-Mail and dropbox is used by the team to collaborate.

Thus far, I have worked on green roof technologies for the literature review and have worked on researching on the costs for the low flow fixtures for the proposed building. There is also the broader area of the efficient use of water during the cleaning of the equipment; it would be worthwhile to research the use of innovative methods to reduce the wastage of water by reusing it.

With the team's current progress I am confident that we will be able to deliver what we have promised to the Port Authority.

### Jeffrey West

Approaching the Cornell/Port Authority Project half-life, I believe our group is about where we need to be in terms of research and modeling. Given that the first few weeks of the semester were dedicated to the mini-course, group forming/norming, and our site visit to Stewart International Airport, I believe we have made significant progress. Up until this point, we have also spent a descent amount of time defining and refining the scope of our project as we learn more about the domain of sustainability and green infrastructure systems. All of these have been necessary diversions toward our ultimate objectives for this project. At this point, most of our research should be complete in the next couple weeks, at which time the entirety of our efforts can be devoted to creating the energy and costing model that will assess the green/sustainable features of our hypothetical snow removal equipment building.

With regard to group dynamics, while everyone has been and remains amicable, I believe we have some work to do to truly come together as a team and attack this problem with a united front. Up until this point, the routine as been to meet once per week as a team, in addition to our weekly progress meeting with Dr. Vanek and our monthly teleconferences with Port Authority. On Tuesday afternoons, we have been able to pull everyone together for an average of 2-3 hours to discuss our project research, brainstorm ideas, and divide up work for the coming week. While this has worked, I do not believe it

has made the best use of the team concept in problem solving. This “divide and conquer” methodology leaves much to be desired, as we are essentially just working independently and only getting one perspective attached to each component of the project. Instead, I believe we need to refocus and reorganize to stick more closely to our sub-team concepts so that we have more perspectives attacking each component of the building system. That said, it has been difficult to do this because of the sheer magnitude of what we are looking at in our research. Green building, like most all aspects of sustainable design, is very new. Literature and research is sparse and often conflicting. Additionally, most commercial products – such as green roofs and modular building systems – are developed by smaller companies with the details of their proprietary developments often difficult to uncover. Along these lines, none of us have had any significant background in sustainability or energy systems, and I have personally found this project very eye-opening. But, even with these challenges, I believe our team is doing a tremendous job and well on track. And, as we start to move toward modeling development and refinement, we are working more and more as a single force. I believe we are on track for success and can harness even more productivity and innovation by continuing to make a greater effort to pull together.

## **End-of-Semester Management Summary**

One major challenge during the second half of this semester project was to transition from research and data collection to quantitative analysis and the modeling of green and sustainable systems. Overall, this was a very smooth transition, as early on it was decided that individuals would keep working with the sustainable elements they had previously researched and would also take responsibility for those corresponding sections of the modeling tool. This personal maintenance of the basic knowledge of the systems being analyzed helped to save time and avoid confusion, as team members did not have to conduct a total handoff of information to someone unfamiliar with the characteristics of that sustainable element. The downside of this approach is that it kept information fragmented amongst group members. However, to address this issue and help maintain a cohesive analysis and report, team members adhered to a consistent schedule of weekly group meetings and maintained open lines of communication between meetings through the use of email and electronic databases such as Drop Box and Google Docs.

Another challenge that we confronted in the second half of the semester was preparing for the project oral presentation. Similar to the development of the model and green component analysis, we made the decision to have each group member prepare slides and talking points that corresponded to the green components with which they had done that majority of their work. After conducting our practice presentations, however, we decided that for the Final Presentation it would be best to limit the number of speakers to both save time and help avoid confusion for the audience. While this meant that certain group members had to conduct some cross-pollination of green component knowledge, this decision also allowed us to devote the effort of a non-presenting group member toward refining and troubleshooting our excel model. In order to address the increased demands of the project at this point, we decided to increase the frequency of our meetings and began convening on a near daily basis the week before our presentation to finalize the slideshow and practice our oratory rhetoric. In the end, we conducted our Final Presentation with five of seven members speaking before our audience.

After the Final Presentation, we began managing our final transition to address our report write-ups and deliverables. As a written deliverable to the Port Authority, we composed a comprehensive Element Analysis, which detailed the calculations and thought process behind our sustainable design recommendations. In the end, we presented the results of our findings as a three-tier measure of sustainability – first with an industry standard building, then a building that only included cost-effective green features, and finally a building that incorporated all the green features we had examined. This analysis, and the Final Report deliverable to the University, were drafted and edited by one group member who compiled input and write-ups from individual group members. By designating a specific point of contact for these write-ups, it helped us keep track of individual member deliverables and keep consistency in formatting and writing style.