CEE 5910: M.Eng Sustainable Residential Development Study

Anson Lin, Enrique Martinez, Fona Osunloye,
Thomas Ruggieri, Quentin Tourancheau, Thomas Virgin

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Supervised by: Dr. Francis Vanek

Cornell University
School of Civil & Environmental
Engineering, Engineering Management
220 Hollister Hall,
Ithaca, NY 14853

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Executive Summary

This project analyzes the environmental impact and economic feasibility of a sustainable residential development through the evaluation of building improvements that utilize "green" technologies and practices. Various scenarios were developed for a model home to be replicated for 30 identical buildings within a development in the Tompkins County area. These scenarios were evaluated based on the following metrics: energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, economic feasibility, and stewardship of resources and sensitivity to their impacts. The technologies from our research used in these scenarios were specifically chosen to optimize the above metrics. Due to the flexibility of the available technologies and assumptions in this project, a lifecycle cost analysis model was created to allow us in evaluating the possible scenarios.

Recommendation and Results

Our results were divided into three scenarios that best represent our research and findings as well as present a feasible combination of green technologies to build within a sustainable home: Efficient, Efficient with PV system, and Highest Efficiency. The "Efficient" scenario is based on choosing the best green technology options with the lowest net present values from our model. The "Efficient with PV System" adds a solar photovoltaic system to the Efficient scenario as a source of electricity. And the "Highest Efficiency" scenario chooses the best available green technologies to add to a new sustainable home regardless of costs. These scenarios are compared to a baseline utilizing technologies that match building codes and standards in the Tompkins County area.

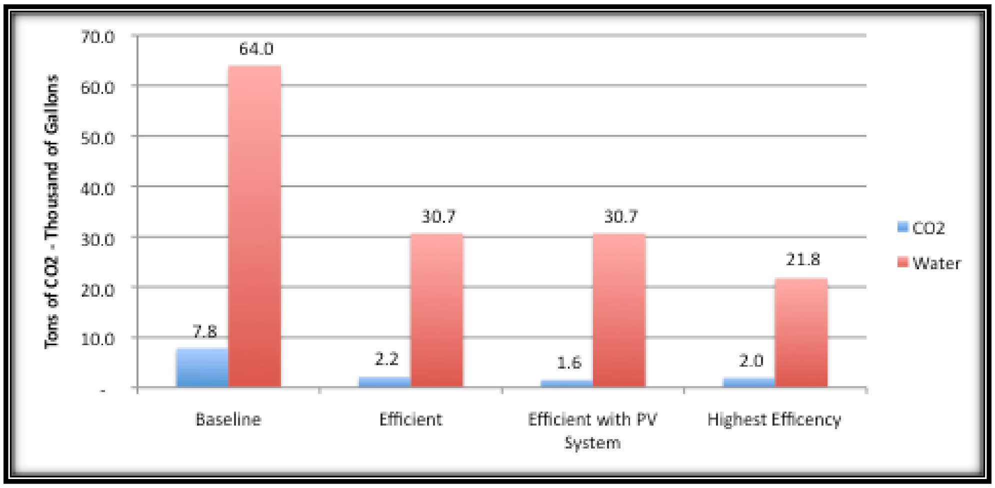

Figure 1 Comparison of Environmental Impact by Scenario (from Recommendations section)

Table 1 Scenario Comparison (from Recommendations Section)

Scenario	Incremental Cost/ sq. ft	CO2 Savings	Water Savings
Efficient	$ 9.92	5.68	33.32
Efficient with PV System	$ 12.92	6.24	33.32
Highest Efficiency	$ 17.80	5.82	42.20

The graph and table (found in our Recommendations section) show that the Efficient scenario is the most cost-effective and sustainable scenario. It saves 5.68 tons of CO_2 and 33.32 gallons of water annually at an incremental cost of $9.92 per SqFt. over the baseline. These results may vary depending on the size of the house and actual conditions of home usage; in this case, we assume a 1,805 SqFt. residential home in Tompkins County using conservative estimates. We recommend the technologies implemented in this scenario because they have the greatest impact on the environment for the estimated costs spent on such a project, but it is up to a builder to decide whether this is a worthwhile investment (refer to details in the Results sections for technologies and lifecycle cost analysis for this scenario).

1. Introduction

1.1. Context and Motivation

With recent concerns about greenhouse gases and climate change becoming an international issue, there is a growing trend in world nations supporting sustainability initiatives to preserve our environment. Globally, the buildings sector has been found to be the number one contributor of CO2 emissions[1] and it is a large consumer of energy resources and nonrenewable materials. In the US, buildings make up 40% of primary energy use, 72% of electricity consumption, and 39% of CO2 emissions[2]. The year 2011 is a critical turning point in our environmental history, and as international organizations and firms adopt these guidelines, the world will benefit in the long run from the collaborative efforts of individuals. Residential buildings and communities take a large part of this growing effort and demonstrating the possibilities of building and improving a sustainable residential development will help promote the adoption of the movement toward sustainable green buildings. As an example of the growing importance of sustainable buildings, the USGBC (U.S. Green Building Council) has developed the internationally recognized LEED green building certification program that serves as a guide for professionals to making sustainable green buildings.

Within the last few years, LEED has become very popular and widely used by professionals in the designing and construction of sustainable buildings and demand for LEED certification is expected to increase in the years to come. According to the LEED system, a building can be awarded a Certified, Silver, Gold, or Platinum rating based on the number of credits the building fulfills. This strict rating system has helped save energy costs for tenants and owners, improve the life of people using the spaces, and reduce the carbon footprint of buildings. There are even government tax incentives and evidence of increased market value of properties[3] if a building is rated as LEED Certified or higher. These benefits are just a few of the many incentives why people are starting to invest in green buildings using the LEED system.

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[1] Energy Information Administration (2006). Emissions of Greenhouse Gases in the United States.

[2] Environmental Information Administration (2008). EIA Annual Energy Outlook

[3] CoStar. Effect of LEED Rating Levels on Office Property Assessed and Market Values. http://www.costar.com/josre/JournalPdfs/02-LEED-Ratings-Levels.pdf

1.2. Project Goal

This project is intended to provide a scenario for using strategies designed at improving performance of buildings by utilizing sustainable or “green” technologies and concepts. The metrics that are evaluated in this report are energy savings, water efficiency, CO2 emissions reduction, improved indoor environmental quality, economic feasibility, and stewardship of resources and sensitivity to their impacts.

1.3. Team Structure

Our project team is divided according to the five LEED New Construction rating criteria: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality, and Materials and Resources (excluding Innovation). The team of six is sub-divided into two groups of three, with each group handling some section(s) of the LEED rating criteria.

Sub-team 1 – Fona Osunloye (Sustainable Sites), Thomas Virgin (Materials and Resources), and Anson Lin (Indoor Environmental Quality)

Sub-team 2 – Enrique Martinez (Energy and Atmosphere), Quentin Tourancheau (Energy and Atmosphere), and Thomas Ruggieri (Water Efficiency)

Thomas Virgin is a LEED accredited professional and has working experience in commercial and residential construction in Florida. He is designated as the head of overseeing the LEED roles of the team members do not overlap or are coordinated properly. He has a background in Civil and Environmental Engineering and is currently pursuing a Masters of Engineering degree in Engineering Management and a minor in the Graduate Program in Real Estate.

Fona Osunloye is the project team’s liaison to the client’s representative. She comes to this team with a background in Electrical Engineering, a minor in Mathematics, and is currently pursuing a Masters of Engineering degree in Engineering Management. She has 2years of experience working in the field of Management Consulting both in the United States and abroad. Her interests include renewable energy, volunteering and tennis.

Anson Lin takes meeting minutes and insures the documentation of the project are organized and kept up to date. He has a Bachelor’s of Science in Operations Research and Information Engineering, a minor in Real Estate, and is currently pursuing a Masters of Engineering degree in Engineering Management. Anson has experience working for a bank and retail real estate development firm. In his free time he enjoys breakdancing and golf.

Enrique Martinez shared the primary role of our model development for energy and atmosphere. He earned his Bachelor of Science in Civil and Environmental Engineering and is currently pursuing a Masters of Engineering degree in Engineering Management. He was working experience with a residential development firm in Mexico and enjoys laser tag in his spare time.

Quentin Tourancheau shares the primary role of our model development for energy and atmosphere. Quentin has obtained a Bachelor of Science in Industrial Engineering and Economics in France. He is currently pursuing a Masters of Engineering degree in Engineering Management and is interested in sustainability and innovative technologies.

Thomas Ruggieri held the primary role of our model development for water efficiency. His background is in Mechanical Engineering and is currently pursuing a Masters of Engineering degree in Engineering Management. Thomas has over three years' experience in the Army ROTC and four years working experience with an electrical contractor. In his spare time Thomas enjoys scuba diving.

1.4. Sustainable Technology Categories

Energy and Atmosphere Description

Energy and Atmosphere are linked in two primary ways. First, fossil-fuel energy contributes directly to air pollution and climate change. Second, atmospheric winds, solar radiation, and precipitation are sources of renewable wind, wave, solar, and hydroelectric power. Because atmospheric problems can be mitigated best by increasing the efficiency with which energy is used, optimizing the use of natural energy resources, and understanding the effects of energy technologies on the atmosphere, the two areas, Energy and Atmosphere, are naturally coupled together.

The very root of what makes a home green is how effectively it responds to its surrounding environment. This has defined the primary material pursuit of humankind for all time – building better shelters to keep us warmer, cooler, and drier. Many of the native building techniques employed centuries ago are still reliable in similar climates today, and used as optimal models for environmentally conscious architects.

Water Efficiency Description

Saving water has become even more important with the increasing stress that our ever growing population places on available water supplies and distribution channels. By employing water-saving technologies and activities, maximizing water efficiency within buildings and reducing the generation of wastewater, this aspect of the project aims to mitigate the threat that this presents to both human health and the environment.

Indoor Environmental Quality Description

IEQ (Indoor Environmental Quality) is important to the health and wellbeing of residents and people using these buildings. IEQ addresses such concerns as natural daylight, indoor air quality, ventilation, control systems for smoke and comfortable heating/lighting, and low-emitting materials.

These concerns are inter-connected with many of the other criteria such as presenting ways to save energy. However, these concerns also address the safety and comfort of residents so that they will live in a sustainable building that is not detrimental to their health. A residential building should not sacrifice the health of its residents for the improvement of sustainability in its other factors. Science has proven that some of these green IEQ solutions can improve productivity and the lifestyle of people living in these sustainable spaces. Altogether, IEQ improvements can then produce synergetic effects of enhancing the lives of residents, helping the environment, and saving long-term costs.

Materials and Resources

Utilizing sustainable, or “green”, building Materials & Resources can reduce the need for virgin materials, limited natural resources, and increase the use of domestic products. Sustainable products provide environmental, social and economic benefits while protecting public health, welfare, and the environment over the full commercial cycle of the products, from extraction of raw materials to the end of the useful life.

Sustainable Site Description

Sustainable site development and landscaping involves the different steps that are taken to prepare a physical site for construction and planting, and how this site is then maintained so as to ensure minimal impact on the environment. For the purpose of this project, we using this aspect of the LEED New Construction rating criteria to determine the feasibility and extent to which pollution from construction activities can be reduced through controlling factors such as soil erosion, waterway sedimentation and airborne dust generation.

1.5. Approach

Along with these metrics, this project is concerned with the financial feasibility of these designs. Through the use of life cycle costs, life cycle savings, and discounted cash flows the project is compared with a baseline model. The baseline model utilizes current municipal building code requirements for technologies and their corresponding costs to be analyzed against these projects findings.

2. Site Description

2.1. TOMPKINS COUNTY

Tompkins County is a county located in the U.S. state of New York, and comprises the whole of the Ithaca metropolitan area. As of the 2010 census, the population was 101,564. Tompkins County is in the west central part of New York State, south of Syracuse and northwest of Binghamton. Geographically, it belongs to the Central New York region, although some locals have been known to consider themselves as being part of the Southern Tier. According to the U.S. Census Bureau, the county has a total area of 492 square miles (1,273 km^2), of which 476 square miles (1,233 km^2) is land and 16 square miles (40 km^2) (3.17%) is water.

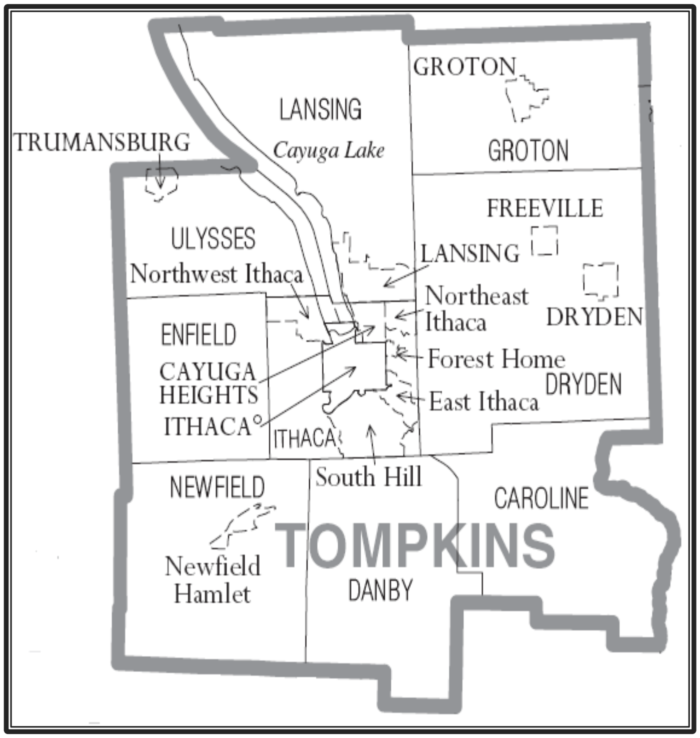

Figure 2 Map of Tompkins County

As of the census of 2000, there were 96,501 people, 36,420 households, and 19,120 families residing in the county. The population density was 203 people per square mile (78/km^2). There were 38,625 housing units at an average density of 81 per square mile (31/km^2). There were 36,420 households out of which 25.80% had children under the age of 18 living with them, 41.20% were married couples living together, 8.20% had a female householder with no husband present, and 47.50% were non-families. 32.50% of all households were made up of individuals and 8.10% had someone living alone who was 65 years of age or older. The average household size was 2.32 and the average family size was 2.93. The median income for a household in the county was $37,272, and the median income for a family was $53,041, with the per capita income for the county being $19,659. The most recent population figures are taken from the 2010 census, which puts the population of Tompkins County at about 101,564.

The county seat is Ithaca, and the county is home to Cornell University, Ithaca College and Tompkins Cortland Community College.[4]

2.2. ITHACA, NEW YORK

Named for the Greek Island of Ithaca, and sitting on the southern shore of Cayuga Lake in Central New York, the city of Ithaca is the largest community in the Ithaca-Tompkins County metropolitan area - which also contains the separate municipalities of the town of Ithaca, the village of Cayuga Heights, the village of Lansing and other towns and villages in Tompkins County. Being home to Cornell University with its population of over 20,000 students, as well as Ithaca College which is located just south of the city in the town of Ithaca, it is most popularly known for being a college town. These two colleges, and the nearby Tompkins Cortland Community College, influence Ithaca's seasonal population. In 2010, the city's population was 30,014, and the metropolitan area had a population of 101,564.

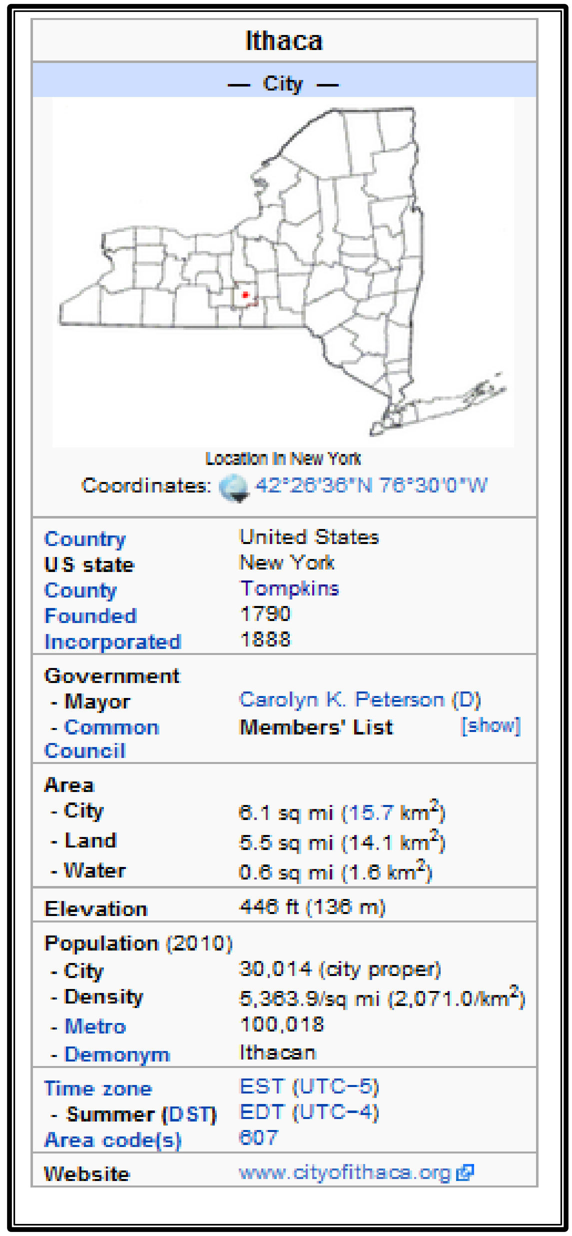

Figure 3 Demographics of Ithaca

The economy of Ithaca is based on education and manufacturing with high tech and tourism in strong supporting roles. As of 2006, Ithaca remains one of the few expanding economies in economically troubled New York State outside of New York City, and draws commuters from the neighboring rural counties of Cortland, Tioga, and Schuyler, as well as from the more urbanized Chemung County.

With some level of success, Ithaca has tried to maintain a traditional downtown shopping area that includes the Ithaca Commons pedestrian mall and Center Ithaca, a small mixed-use complex built at the end of the urban renewal era. Some in the community regret that downtown has lost vitality to two expanding commercial zones to the northeast and southwest of the old city. These areas

[4] Information about Tompkins County culled from http://en.wikipedia.org/wiki/Tompkins_County,_New_York

contain an increasing number of large retail stores and restaurants run by national chains. Others say the chain stores boost local shopping options for residents considerably, many of whom would have previously shopped elsewhere, while increasing sales tax revenue for the city and county. Still others note that the stores, restaurants, and businesses that remain in downtown are not necessarily in direct competition with the larger chain stores. The tradeoff between sprawl and economic development continues to be debated throughout the city and the surrounding area. Another commercial center, Collegetown, is located next to the Cornell campus. It features a number of restaurants, shops, and bars, and an increasing number of high rise apartments and is primarily frequented by Cornell University students.

Ithaca was founded on flat land just south of the lake — land that formed in fairly recent geological times when silt filled the southern end of the lake. The city ultimately spread to the adjacent hillsides, which rise several hundred feet above the central flats: East Hill, West Hill, and South Hill. Its sides are fairly steep, and a number of the streams that flow into the valley from east or west have cut deep canyons, usually with several waterfalls. Ithaca experiences a moderate continental climate, with cold, snowy winters and sometimes hot and humid summers. The valley flatland has slightly milder weather in winter, and occasionally Ithacans experience simultaneous snow on the hills and rain in the valley. The natural vegetation of the Ithaca area, seen in areas unbuilt and unfarmed, is northern temperate broadleaf forest, dominated by deciduous trees. Due to the microclimates created by the impact of the lakes, the region surrounding Ithaca (Finger Lakes American Viticultural Area) experiences a short but adequate growing season for winemaking, and is thus home to a number of wineries.[5]

Climate data for Ithaca, New York (Cornell University, 1971–2000) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °F (°C)	68 (20)	67 (19.4)	85 (29.4)	89 (31.7)	93 (33.9)	102 (38.9)	103 (39.4)	98 (36.7)	100 (37.8)	91 (32.8)	81 (27.2)	69 (20.6)	103 (39.4)
Average high °F (°C)	31.2 (-0.44)	33.2 (0.67)	42.3 (5.72)	54.5 (12.5)	67.3 (19.61)	75.7 (24.28)	80.1 (26.72)	78.7 (25.94)	70.9 (21.61)	59.4 (15.22)	47.2 (8.44)	36.1 (2.28)	56.4 (13.56)
Average low °F (°C)	13.9 (-10.06)	13.7 (-10.17)	22.4 (-5.33)	33.1 (0.61)	43.4 (6.33)	53.1 (11.72)	57.2 (14)	55.9 (13.28)	47.9 (8.83)	37.3 (2.94)	30.6 (-0.78)	20.3 (-6.5)	35.7 (2.06)
Record low °F (°C)	−25 (-31.7)	−25 (-31.7)	−17 (-27.2)	11 (-11.7)	22 (-5.6)	31 (-0.6)	38 (3.3)	32 (0)	24 (-4.4)	15 (-9.4)	−4 (-20)	−19 (-28.3)	−25 (-31.7)
Precipitation inches (mm)	2.12 (53.8)	2.06 (52.3)	2.56 (65)	3.29 (83.6)	3.22 (81.8)	3.87 (98.3)	3.54 (89.9)	3.39 (86.1)	3.84 (97.5)	3.23 (82)	3.10 (78.7)	2.49 (63.2)	36.71 (932.4)
Snowfall inches (cm)	18.8 (47.8)	14.1 (35.8)	11.7 (29.7)	3.7 (9.4)	0.1 (0.3)	0 (0)	0 (0)	0 (0)	0 (0)	0.5 (1.3)	6.1 (15.5)	13.0 (33)	68.0 (172.7)
Avg. precipitation days	15.8	13.0	13.6	13.6	13.3	12.5	11.7	11.0	12.8	13.2	13.9	14.8	159.2
Avg. snowy days	12.2	9.5	6.9	2.2	0.1	0	0	0	0	0.3	4.2	9.1	44.5

Source: NOAA [12]

Figure 4 Climate Data for Ithaca, NY

[5] Information about Ithaca, NY culled from http://en.wikipedia.org/wiki/Ithaca,_New_York

2.3. ECOVILLAGE ITHACA (EVI)

An ecovillage is an intentional community with the goal of becoming more socially, economically and ecologically sustainable. In 1991, while participating in the Global Walk for a Liveable World environmental walk across the United States, Joan Bokaer, together with Liz Walker; developed the vision for such a village within Ithaca, NY. By September 1991, plans were already underway, but it wasn't until 1995 that the Final Site Plan for the first EcoVillage neighborhood was approved, and ground broken on the project.

EcoVillage currently includes two 30-home cohousing neighborhoods, FRoG (First Resident's Group) and SONG (Second Neighborhood Group), and a third neighborhood TREE, which is still in the planning/construction stage and should be ready for habitation by 2012. There is also an organic CSA vegetable farm, an organic CSA/U-Pick berry farm, office spaces for cottage industry, a neighborhood root cellar, community gardens and varied natural areas. Over 80% of the 175 acre site is planned to remain green space, including 55 acres in a conservation easement held by the Finger Lakes Land Trust.

The First Resident's Group, or FroG, as it is fondly called by the residents, was completed in August 1997, and it was the first completed cohousing project in the state of New York. Occupying 3 acres of the village land, the neighborhood is comprised of 30 homes (15 duplexes), with homes ranging in size from 922 sf. for a one-bedroom home, to 1642sf. for a four-bedroom home, with most of the homes being three-bedroom houses of 1350sf. A variety of strategies were employed to achieve high energy efficiency and improve overall sustainability in the Frog neighborhood. All homes employ passive solar design, and are insulated with 6-7 inches of dense-pack cellulose (recycled newspaper), in an innovative double-wall design which allows the plumbing and wiring to run completely inside the insulating barrier. Triple-paned fiberglass windows keep out the cold while welcoming winter solar gains. South-facing arbors with deciduous vines minimize overheating in warmer months. Heat is provided by an innovative shared hot-water system, with one gas boiler per cluster of six to eight homes. These centralized "energy centers" can thus facilitate integration of future renewable energy inputs, such as solar collectors or fuel cells. To help with waste and stormwater management, homes were designed with dual drain piping, so as to enable a future greywater re-use system. Interior lighting is compact fluorescent, with generous natural daylighting, that includes the use of solar light tubes in bathrooms. Laundry facilities are centralized in the Common House, enabling the use of high-end resource efficient machines. In terms of materials and resources, some homes have interior insulated shades and/or added thermal mass such as tile floors, and other green features, such as marmoleum or bamboo flooring, which were added on an individual basis.

The second cohousing neighborhood known as SONG (Second Neighborhood Group) was completed in 2004, and an interesting fact about this neighborhood is that all its homes have achieved EnergyStar certification. SONG used a self-development model in its construction phase, and its construction included a significant amount of participation on the part of the residents. The homes in this neighborhood were customized to the individual families' interests and budgets, and so it utilized a greater variety of green building approaches than those that were employed in the construction of FRoG. These include passive solar design, photovoltaics, solar hot water, high-efficiency condensing gas boilers, Eco-Block foundations, Durisol foundations, Structural Insulated Panels, super-insulated roofs, several types of high-performance windows, straw bale insulation, rainwater collection, composting toilets, drain heat recovery, salvaged materials, and more.

Village residents have the opportunity to share common dinners several times per week in the two Common Houses, and volunteer about 2-3 hours per week on various work teams to keep things running smoothly: outdoor maintenance, finances, governance, future projects, and more. The evolving village culture includes plenty of neighborly support for families in need, various annual celebrations to mark the seasons, and lots of ad hoc parties, music jams and concerts, and talent shows[6].

[6] Information about EcoVillage Ithaca (EVI) culled from http://ecovillageithaca.org/evi/

3. Project Assumptions

3.1. Development Size

For the purpose of this project the development size was chosen to be a total 30 identical buildings. The layout of the buildings is an important feature to be scrutinized carefully to maximize sustainability benefits. However, for this project the selection of the site plan and general layout will be outside the scope of work. The development size is chosen to resemble an Ecovillage at Ithaca neighborhood, as discussed in the previous chapter.

3.2. Floor Plan

To properly evaluate the benefits and features of a sustainable development and individual buildings, a standard floor plan was developed. Based on the statistics of Tompkins County the size and general features of each building was determined. As seen in the figures below, each building contains the following features:

- Approximately 1800 square feet (900 square feet per floor)
- Three bedrooms
- Two bathrooms
- Full kitchen
- Clothes washer and dryer closet
- Attic
- Balcony
- Dining Room
- Gathering Room
- Lounge
- Deck
- Baseline Cost of Construction of $100 per square foot

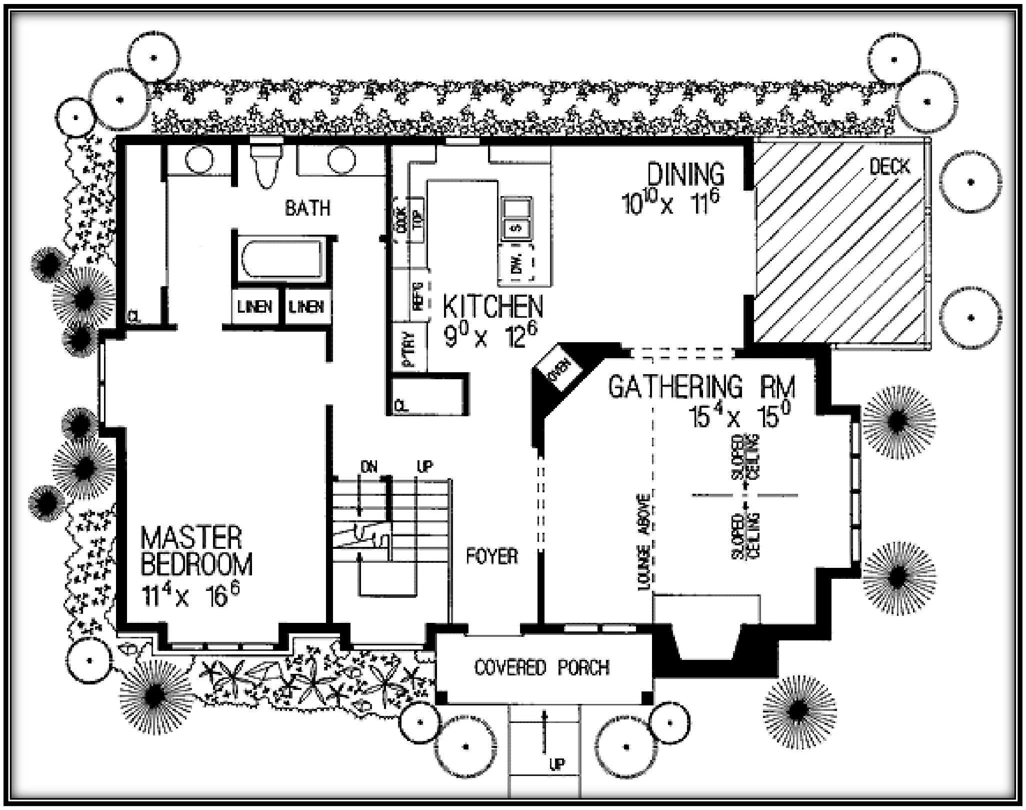

Figure 6 First Floor

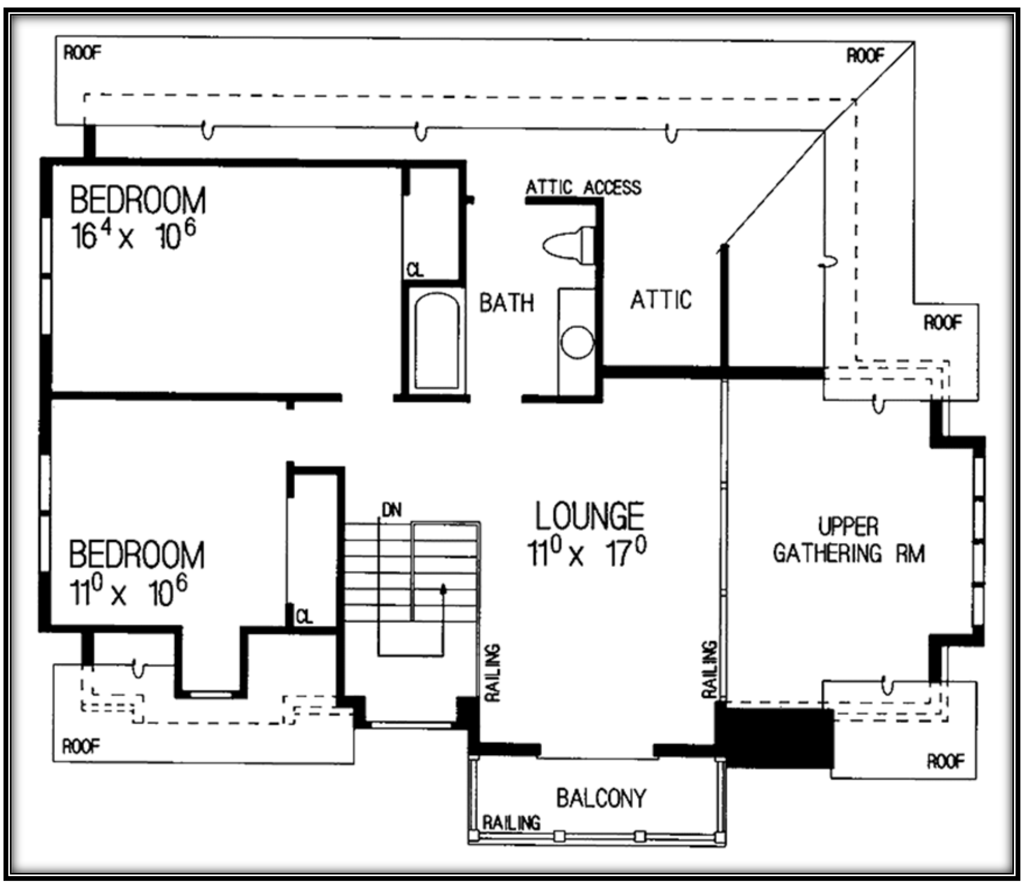

Figure 5 Second Floor

3.3. Elevations

Design of the elevations is also outside the scope of work, but the elevations should blend in with the surrounding areas. Below are a couple of examples.

Figure 7 Elevation Option 1

Figure 8 Elevation Option 2

3.4. Utility Costs

This project utilized the assumption that the entire development would have access to municipal water and sewer. The development is also assumed to have access to local gas and electricity. Locating these items prior to selection of a development site is important and these assumptions are not trivial. Below are the values that were utilized for utility costs.

- Water - $0.0045 per gallon
- Gas - $1.33 per Therm
- Electricity - $0.185 per kWh

3.5. Finance Values

The life cycle cost analysis portion of the model needs to incorporates a few financial assumptions. In the model presented in this report the following were used:

- Discount Rate – 7%
- General Inflation Rate – 3%

4. Sustainable Technologies

4.1. Energy and Atmosphere

Building Envelope

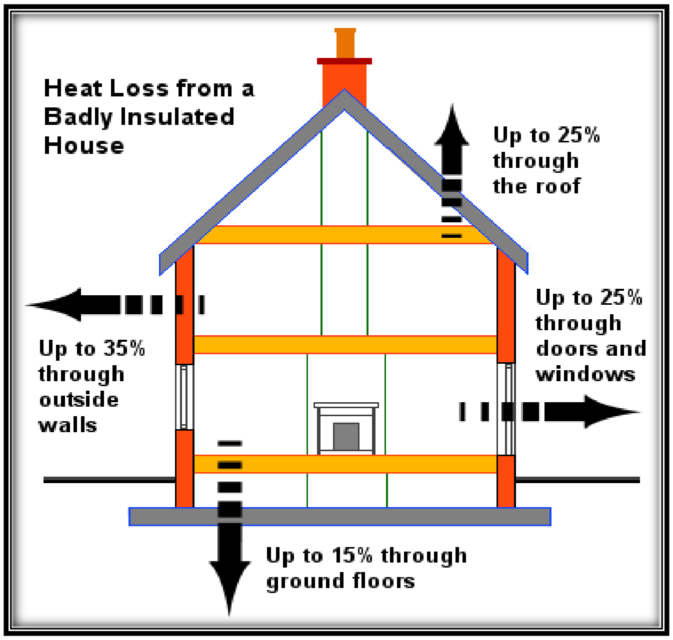

Figure 9 Heat Loss

Thermal insulation in buildings is an important factor to achieving thermal comfort for its occupants (human thermal comfort is defined by ANSI/ASHRAE Standard 55 as the state of mind that expresses satisfaction with the surrounding environment). Insulation reduces unwanted heat loss or gain and can decrease the energy demands of heating and cooling systems. In a narrow sense insulation can just refer to the insulation materials employed to slow heat loss, but it can also involve a range of designs and techniques to address the main modes of heat transfer - conduction, radiation and convection materials. In this project we focused on the insulation materials used for the building envelope. During this project we used as a guideline, the ASHRAE 90.1 which is a standard that provides minimum requirements for energy efficient designs for buildings; for further extension, it is possible to strictly follow this standard in order to get the LEED certification, not only just green building specification.

The effectiveness of insulation is commonly evaluated by its R-value. Under uniform conditions it is the ratio of the temperature difference across an insulator and the heat flux (heat transfer per unit area, $\dot{Q}_A$) through it or $R = \Delta T / \dot{Q}_A$.The R-value being discussed is the unit thermal resistance. This is used for a unit value of any particular material. It is expressed as the thickness of the material divided by the thermal conductivity. For the thermal resistance of an entire section of material, instead of the unit resistance, divide the unit thermal resistance by the area of the material. The bigger the number, the better the building insulation's effectiveness becomes. R-value is the reciprocal of U-value. However, an R-value does not take into account the quality of construction or local environmental factors for each building.

To compare the different types of insulation, we choose the same thickness of wall of 6 inches which is common in the industry.

In order to determine the savings (less heat loss), we compare the R values of the baseline model and alternatives in which you choose different insulation type for walls, windows and ceiling (we don't include different alternatives for the slab, because only 15% of the heat loss happen through the floor). Therefore, to establish an overall R-value of the building we use a wall-to-window ratio of 30% (interior wall area) to determine the window area, the wall area is calculated with the perimeter of the house by the height of 2 stories of 8 feet each and an inter-floor of 2 feet. Hereunder is the breakdown of the areas used to calculate the overall R-value of the building:

Table 2 Surface Area

	Area (sq ft)	% Area
Walls	1610,4	40,30%
Windows	585,6	14,65%
Ceiling	900	22,52%
Floor	900	22,52%
	3996	100,00%

The calculation of the savings is done through the following formula:

AREA (SqFt) x (1/Initial R-value - 1/Final R-value) x 24 x HDDZ

x (Cost/Unit of Heating Fuel) / (Btu/Unit of Heating Fuel) / (Heating System Efficiency)

= Annual Dollars Saved

Data input:

HDDZ: Heating degree days = 7500

Cost/unit of heating fuel: we only use gas fueled heating system, $0.133/therm

Heating system efficiency: in our model, we implement different technologies with different efficiencies (78%, 80%, 85%, 90%), we link the insulation with the heating system in our model.

For example, our baseline has an R-value of 9.42, and the one of the highest efficient alternative with foam wall and ceiling, and triple pane windows is 21.59. The savings are equal to $458 (in constant value) per year; however, it requires an additional capital cost of more than $15,000. Nevertheless, a saving in the gas usage allows a savings in CO2 emissions; in the previous example it helps saving 16,668 pounds per year.

The 2 main factors we take into account in our model are the R-value and the cost. However, a responsible future house owner should considerate some other factors which affect the type and amount of insulation to use in a building such as climate, ease of installation and replacement, durability, environmental impact, etc. We will mention some of them when introducing the different type of insulation.

Exterior Wall Construction

Wood frame

We use as a baseline wall the 2x6 stud wood frame. The main advantage is its cost but which is countered by its low R-value.

Figure 10 Wood Frame

ICF

Insulated Concrete Forms (ICFs) are formwork for concrete that stays in place as permanent building insulation for energy-efficient, cast-in-place, reinforced concrete walls, floors, and roofs.

The forms are interlocking modular units that are dry-stacked (without mortar) and filled with concrete. The forms lock together somewhat like Lego bricks and serve to create a form for the structural walls or floors of a building.

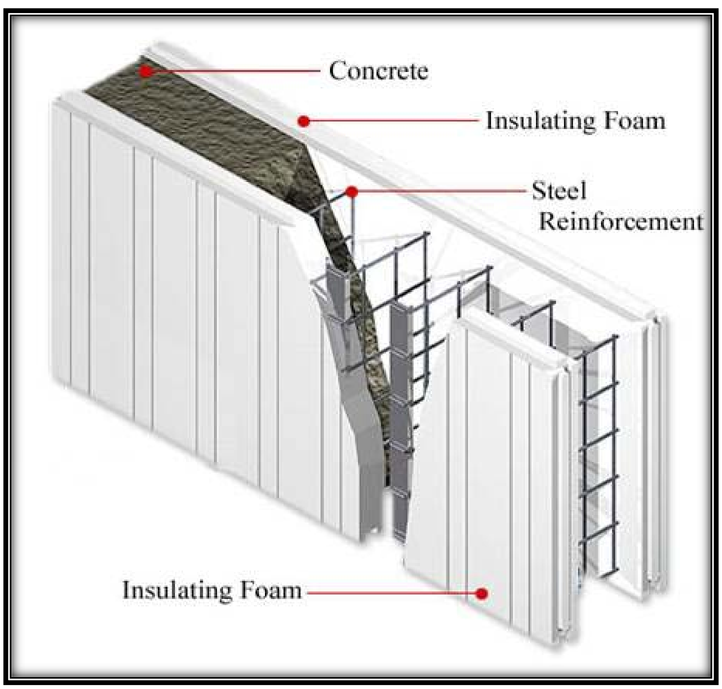

Figure 11 ICF

ICF forms are currently manufactured from any the following materials: polystyrene (expanded or extruded) - most common, polyurethane (including soy-based ones), cement-bonded wood fiber, cement-bonded polystyrene beads.

Concrete is pumped into the cavity to form the structural element of the walls. Usually reinforcing steel (rebar) is added before concrete placement to give the concrete flexural strength, similar to bridges and high-rise buildings made of concrete (see Reinforced concrete). Like other concrete formwork, the forms are filled with concrete in 1–4 foot "lifts" to manage the concrete pressure and reduce the risk of blowouts. After the concrete has cured, or firmed up, the forms are left in place permanently for the following reasons:

- Thermal and acoustic insulation
- Space to run electrical conduit and plumbing. The form material on either side of the walls can easily accommodate electrical and plumbing installations.
- Backing for gypsum boards on the interior and stucco, brick, or other siding on the exterior

Advantages

- ICF structures are much more comfortable, quiet, and energy-efficient than those built with traditional construction methods.
- Minimal, if any, air leaks, which improves comfort and reduces heat loss compared to walls without a solid air barrier
- High sound absorption, which helps produce peace and quiet compared with framed walls
- Structural integrity for better resistance to forces of nature, compared with framed walls
- Higher resale value due to longevity of materials
- More insect resistant than wood frame construction
- Concrete and Polystyrene do not rot when they get wet
- Construction methods are easy to learn, and manufacturers often have training available
- Insulating Concrete Forms create a structural concrete wall (either monolithic or post and beam) that is up to 10 times stronger than wood framed structures.
- Interior ICF polystyrene wall surfaces can be coated with gypsum drywall or a number of other wall coatings.

Disadvantages

- Adding or moving doors, windows, or utilities is somewhat harder once the building is complete (requires concrete cutting tools).
- During the first weeks immediately after construction, minor problems with interior humidity may be evident as the concrete cures. Dehumidification can be accomplished with small residential dehumidifiers or using the building's air conditioning system.

- Depending on the form material, concrete mix and pouring procedures, honeycombing may occur during the pour, where gaps are left in the concrete. This can be resolved with the use of a vibrator, using free draining form materials or self-consolidating concrete, though the latter option is much more expensive and not necessary.
- With polystyrene based forms, the exterior foam insulation provides easy access for groundwater and insects. To help prevent these problems, some manufacturers make insecticide-treated foam blocks and promote methods for waterproofing them.
- Vulnerability to pest, especially termites. The constant temperature of the concrete and the fantastic tunneling ability of the polystyrene create a perfect habitat and breeding ground for termites. Consequently, the installation of ICFs requires the addition of termite protection which increases the cost.

SIP

Structural insulated panels (SIPs), also called stressed-skin walls, use the same concept as in foam-core external doors, but extend the concept to the entire house. They can be used for ceilings, floors, walls, and roofs; but they cannot be used below ground because the wooden OSB cannot withstand contact with the ground. The panels usually consist of plywood, oriented strandboard, or drywall glued and sandwiched around a core consisting of expanded polystyrene, polyurethane, polyisocyanurate, compressed wheat straw, or epoxy. Epoxy is too expensive to use as an insulator on its own, but it has a high R-value (7 to 9), high strength, and good chemical and moisture resistance.

Figure 12 SIP

SIPs come in various thicknesses. When building a house, they are glued together and secured with lumber. They provide the structural support, rather than the studs used in traditional framing.

Advantages

- Strong. Able to bear loads, including external loads from precipitation and wind.
- Faster construction than stick-built house. Less lumber required.
- Insulate acoustically.
- Impermeable to moisture.
- Can truck prefabricated panels to construction site and assemble on site.
- Create shell of solid insulation around house, while reducing bypasses common with stick-frame construction. The result is an inherently energy-efficient house.
- Do not use formaldehyde, CFCs, or HCFCs in manufacturing.
- True R-values and lower energy costs.

Disadvantages

- Thermal bridging at splines and lumber fastening points unless a thermally broken spline is used (insulated lumber).

Spray polyurethane foam (SPF)

For large to mid-scale applications, a two component mixture comes together at the tip of a gun, and forms an expanding foam that is sprayed onto concrete slabs, into wall cavities of an unfinished wall, against the interior side of sheathing, or through holes drilled in sheathing or drywall into the wall cavity of a finished wall.

Figure 13 Spray Foam

Advantages

- Blocks airflow by expanding and sealing off leaks, gaps and penetrations.
- Can serve as a semi-permeable vapor barrier with a better permeability rating than plastic sheeting vapor barriers and consequently reduce the buildup of moisture, which can cause mold growth.
- Can fill wall cavities in finished walls without tearing the walls apart (as required with batts).
- Works well in tight spaces (like loose-fill, but superior).
- Provides acoustical insulation (like loose-fill, but superior).

- Expands while curing, filling bypasses, and providing excellent resistance to air infiltration (unlike batts and blankets, which can leave bypasses and air pockets, and superior to some types of loose-fill. Wet-spray cellulose is comparable.).
- Increases structural stability (unlike loose-fill, similar to wet-spray cellulose).
- Can be used in places where loose-fill cannot, such as between joists and rafters. When used between rafters, the spray foam can cover up the nails protruding from the underside of the sheathing, protecting your head.
- Can be applied in small quantities.
- Cementitious foam is fireproof.

Disadvantages

- The cost can be high compared to traditional insulation.
- Most of all, with the exception of cementitious foams, release toxic fumes when they burn.
- According to the U.S. Environmental Protection Agency, there is insufficient data to accurately assess the potential for exposures to the toxic and environmentally harmful isocyanates which constitute 50% of the foam material. Although the off-gassing of OSB adhesives has been measured and approved by the EPA, they may still cause negative health effects in some residents over time.
- Depending on usage and building codes, most foam requires protection with a thermal barrier such as drywall on the interior of a house. For example a 15-minute fire rating may be required.
- Can shrink slightly while curing if not applied on a substrate heated to manufacturer's recommended temperature.
- Although CFCs are no longer used, many use HCFCs or HFCs as blowing agents. Both are potent greenhouse gases, and HCFCs have some ozone depletion potential.
- Most, such as Polyurethane and Isocyanate insulation, contain hazardous chemicals such as benzene and toluene. These are a potential hazard and environmental concern during raw material production, transport, manufacture, and installation.
- Many foam insulations are made from petrochemicals and may be a concern for those seeking to reduce the use of fossil fuels and oil. However, some foams are becoming available that are made from renewable or recycled sources.

- R-value will diminish slightly with age, though the degradation of R-value stops once equilibrium with the environment is reached. Even after this process, the stabilized R-value is very high.
- Most foam requires protection from sunlight and solvents.
- It is difficult to retrofit some foam to an existing building structure because of the chemicals and processes involved.
- If one does not wear a protective mask or goggles, it is possible to temporarily impair one's vision. (2–5 days)

Others

For the information of the reader, there exists a plethora of other alternatives such as straw walls, aerogel insulation, vacuum insulated panels, etc. However we focus on the main technologies in use in the industry.

Summary of key values

Table 3 Wall R-values

Walls	R-value	Cost (per sq ft)
Woodframe	19	2,25
ICF	24	5,72
SIP	24	3,9
Sprayed foam insulation	36	6,48

Table 4 Ceiling R-values

Ceiling	R-value	Cost (per sq ft)
Uninsulated	2,2	1,3
4inch foam	24	4,32
4 inch foam roof	24	13,76

Windows

Windows are typically the weakest link in a building's thermal barrier. Heat is lost through windows by direct conduction through the glass and frame, by air leakage through and around the window assembly, and by the radiation of heat by room-temperature objects such as people and furniture. (In hot weather, the same processes work in reverse, resulting in heat gain.)

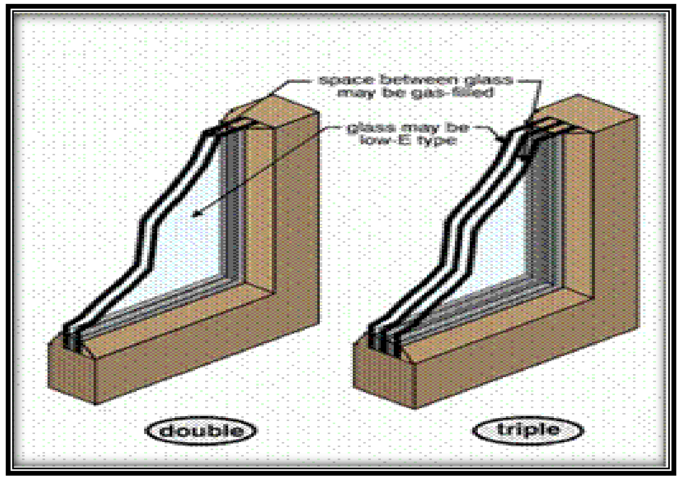

Figure 14 Window Section

An ordinary, well-sealed double-pane window has a whole-unit R-value of 2.0. Compare that with the high-performance windows that have become available in the past decade, which provide insulation of up to R-5 or more. Unfortunately, while most high-performance windows cost only 20–50% more than standard double pane units (see table), the payback period for such an upgrade in an existing house is typically 15–20 years. For most people, that's too long to be cost-effective. However, if you're planning to replace windows anyway, you'll recoup the extra cost of high-performance models in just a few years. In new construction, these windows can help pay for themselves further by reducing the size (and hence the cost) of heating and cooling systems required.

Low-Emissivity (Low-E) Coatings

Windows equipped with low-emissivity (low-e) coatings allow visible light through but selectively block infrared radiation (heat). That means heat has a much harder time escaping on cold days and entering on hot ones, boosting insulating efficiency. Some manufacturers make windows "tuned" to hot or cold climates. The basic difference is that hot-climate windows block more solar radiation to reduce cooling costs, whereas cold-climate windows admit more solar radiation to lower heating costs.

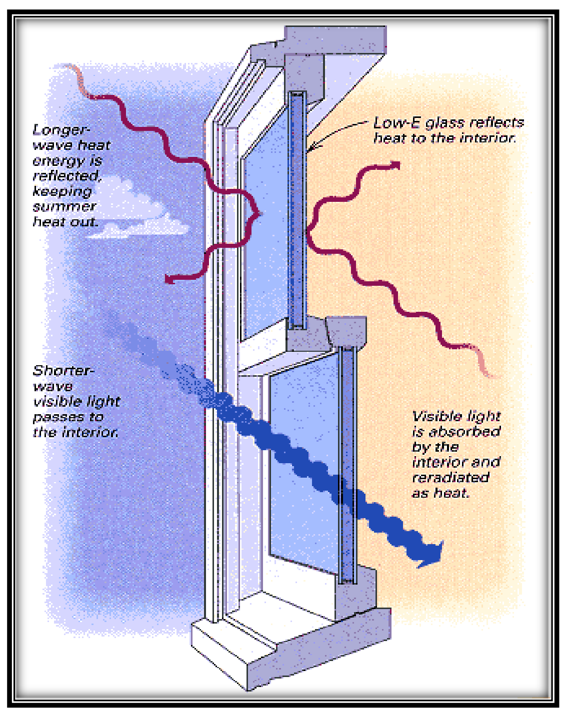

Figure 15 Low-E Coating

Gas Fills

The insulating value of a low-e window can be improved by 15–20% with low-conductivity argon or krypton gas sealed inside the window instead of air. A number of manufacturers are now gas-filling many of their models. Though more expensive, krypton insulates better than argon, allowing the window assembly to be thinner. These are inert gases that occur naturally in the atmosphere, and are harmless even if the window breaks.

Summary of key values

Table 5 Window Results

Windows	R-value	Cost (per sq ft)
Double-pane, wood frame	2	14
Double-pane low-e, wood frame	2,3	16
Double-pane low-e, gas fill, wood frame	2,6	16
Double-glass, plus suspended Heat Mirror	3,1	18
Double-glass, plus two films, gas fill, wood frame	4,5	15
Triple-glass, two low-e coats, gas fill, vinyl frame	4,8	24

Heating system

There are many different types of standard heating systems. Central heating is often used in cold climates to heat private houses and public buildings. Such a system contains a boiler, furnace, or heat pump to heat water, steam, or air, all in a central location such as a furnace room in a home or a mechanical room in a large building. In the scope of this project, we consider only the boiler and the furnace technologies both using gas as the burning fuel. The key factor is the efficiency, and we do consider several alternatives for the set of technology we have. Installing a programmable thermostat is ideal for people who are away from home during set periods of time throughout the week. Through proper use of pre-programmed settings, a programmable thermostat can save you about 17% of your total consumption of gas.


Figure 16 Heating System

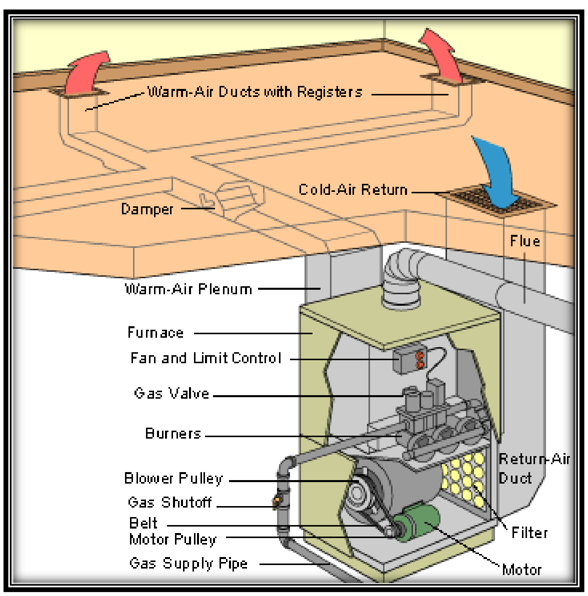

Figure 17 Boiler

Boilers use water as a heat fluid, whereas furnaces use air.

In addition, in our project, the heating system has for solely purpose to heat the house; it is not a combined system which would be able to do the water heating also.

We use one boiler with an efficiency of 80% for the baseline for the heating system.

The space heating account for 57% of the total energy consumption in the house, which is 69 Mbtu (this last number is changing according to the material used for the insulation).

Table 6 Heating Systems

Boiler (baseline)		
Consumption:	69811360,9	btu
Estimated Annual Cost:	928,4911	
Total Capital Cost:	4600	
Efficency:	80%	
Lifetime:	20	years
Furnace low-efficency with Programmable Thermostat		
Consumption:	61577200,4	btu
Energy Savings:	11,79%	
Estimated Annual Cost:	818,976765	
Total Capital Cost:	1100	
Efficency:	78%	
Lifetime:	18	years
Boiler 2 with Programmable Thermostat		
Consumption:	54534992,5	btu
Energy Savings:	21,88%	
Estimated Annual Cost:	725,3154	
Total Capital Cost:	5500	
Efficency:	85%	
Lifetime:	20	years
Furnace 2 with Programmable Thermostat		
Consumption:	53366907	btu
Energy Savings:	23,56%	
Estimated Annual Cost:	709,779863	
Total Capital Cost:	1400	
Efficency:	90%	
Lifetime:	18	years

Lighting

Lighting can amount to around 25% of a household's annual electricity consumption. The traditional lighting used in homes is incandescent light bulbs. However, today this can be replaced by the more efficient CFLs. CFLs are fluorescent lamps that have been specifically made in a compact form to replace incandescent lamps in traditional screw-in fixtures. These energy-efficient lamps come in a variety of styles and sizes and are suitable for a variety of applications. CFLs use 75% less energy than a standard incandescent bulb and last up to 10 times longer. Replacing a 100-watt incandescent with a 32-watt CFL can save approximately $30 in energy costs over the life of the bulb.

For the purpose of this project we are solely considering indoor lighting, and we will be using incandescent light bulbs as the baseline and CFLs as a more efficient alternative.

Incandescent Lighting

Nineteen 60-watt incandescent light bulbs are required to light the specified residence, considering that these will be on for 4 hours daily. These will consume 1668 kWh of electricity annually and will have a lifetime of 3.42 years.

Compact Fluorescent Lighting

The same nineteen light bulbs replaced by CFLs will consume 541 kWh of electricity annually and will have a lifetime of 6.85 years. This represents a 67.6% savings in annual electricity consumption.

Figure 18 Incandescent (Left) CFL (Right)

Refrigeration

Refrigeration consumes close to 8% of the total annual electricity consumption. The two refrigeration alternatives considered for this project was a conventional 18.2 Frigidaire refrigerator for the baseline and for a higher efficiency alternative we considered an ENERGYSTAR 18.2 Frigidaire refrigerator. ENERGYSTAR rated appliances must consume at least 20% less energy than non-ENERGYSTAR products.

Conventional Refrigerator

The conventional refrigerator consumes 479 kWh of electricity annually and has a capital cost of $351 with a 12-year expected life.

ENERGYSTAR Refrigerator

The ENERGYSTAR refrigerator, on the other hand, only consumes 381 kWh annually, which represents 20.5% energy savings. Its capital cost is $469 and its expected life is 12 years.

Water Heating

In the northeast region, water heating consumes 17% of the total household annual energy consumption. Water is heated most commonly by using natural gas; however, electricity is sometimes used as well. For this project, the alternatives that used electricity were disregarded at an early stage because using electricity is much more expensive than using gas and thus inconvenient.

Conventional Gas Storage

The conventional gas storage method is used as our baseline. It is the most common way to heat water and the most inexpensive; however it is also the least efficient and environmentally friendly. The conventional gas storage water heater consumes 210 therms of natural gas annually, but has a capital cost of only $850.

Condensing Gas Storage

A condensing gas storage water heater is significantly more efficient than the conventional gas storage one. It consumes 146 therms of natural gas annually, around 30% less. However, it has a capital cost of $2,000.

Solar Water Heater with Gas Backup

A second, and more efficient, alternative studied was a solar water heater with a gas backup for when the sun's energy is not sufficient. This alternative is the most efficient out of the three because it uses renewable energy. It consumes only 114 therms of natural gas annually, a 45.5%

reduction from the baseline, but costs $4,800. Financially, this is a very unattractive alternative; however, it does reduce a home's environmental impact significantly and must be considered for those reasons.

4.2. Renewable Energy

On-site Renewable Energy, Credit 2, encourages and recognizes increasing levels of on-site renewable energy self-supply, to reduce environmental and economic impacts associated with fossil fuel energy use. Use of on-site renewable energy systems will offset building energy cost. Project performance can be calculated by expressing the energy produced by the renewable systems as a percentage of the building annual energy cost. Projects can be assessed for non-polluting and renewable energy potential, including the use of photovoltaics in building elements such as the roof, exterior cladding, or window systems.

A building's energy use contributes significantly to its environmental impact. Incorporating clean, renewable energy sources into the design and construction of new and existing buildings reduces the carbon footprint, provides a hedge against volatile energy costs and makes a visible and positive environmental statement to the community. Installation of on-site renewable energy technologies is a component of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System™. The U.S. Green Building Council developed LEED to establish an industry standard for environmentally sustainable building practices. Projects seeking LEED certification must incorporate a variety of measures into the design to reduce the environmental impact on the building site, on the surrounding community and on the people who occupy the building itself. LEED promotes an integrated approach to design that incorporates energy systems into a project from the beginning. This way, renewable energy technologies and energy efficiency strategies can be combined to link aspects of the natural environment like sun, wind, hydro/wave/tidal and earth mass to designing the build environment. (http://www.focusonenergy.com/Information-Center/Renewables/)

In addition to the possible electricity savings that can be obtained by using more efficient appliances, incorporating renewable energies can significantly reduce environmental impact. For this project we have only considered solar power for electricity generation particularly because other alternatives, such as wind power, are much more site specific and thus outside the scope of this project.

Solar Photovoltaic System

Photovoltaic cells systems consist of an array of cells that contain a solar photovoltaic material that can convert solar radiation into direct current electricity. Several materials can be used as photovoltaic. Materials presently used are monocrystalline silicon, polycrystalline silicon, microcrystalline silicon, cadmium telluride and copper indium selenide.[7] The three basic types of photovoltaic panels are monocrystalline, polycrystalline, and amorphous cells. For the purpose of this report only the basic types will be considered because of the simplistic nature of the required system in residential neighborhoods.

Monocrystalline cells are cut from a single crystal of silicon. It has a smooth texture and one can actually see the thickness of the slice. These types of photovoltaic cell are the most efficient ones in the market because of their fine nature. However, they are also the most expensive ones to produce. They are fragile and must be mounted in a rigid frame for protection.[8] Monocrystalline cells will last at least 25 years and may even last more than 50 years; they are the longest lasting type of photovoltaic cell.[9]

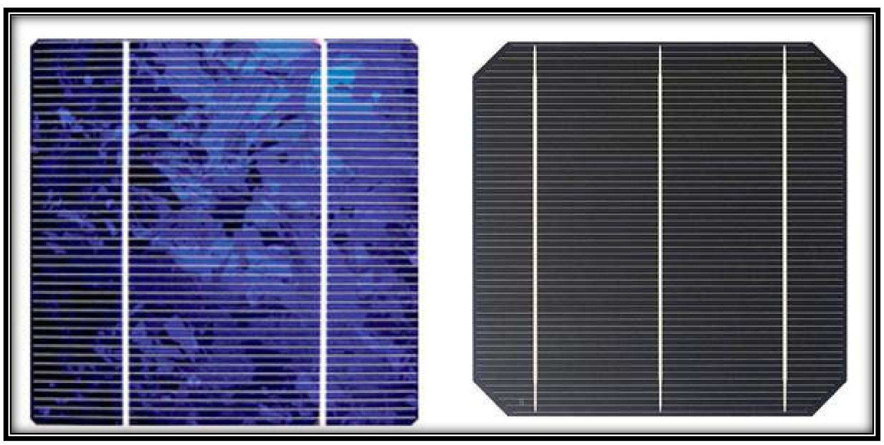

Figure 19 Polycrystalline (Left) vs. Monocrystalline PV Cells

Polycrystalline cells, on the other hand, are a slice from a block of silicon, meaning that the slice may consist of a large number of crystals. With these types of cells you can also see the thickness of the slice, but they have a reflective appearance. Compared to monocrystalline cells, these cells are somewhat less efficient but also less expensive. They also require a rigid frame for protection. These are the most common type of photovoltaic cells on the market today, and may be the most suitable for residential purposes.[10]

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[7] http://www.stanford.edu/group/efmh/jacobson/EnergyEnvRev1008.pdf
[8] http://www.solar-facts.com/panels/panel-types.php
[9] http://www.solarpowerfast.com/build-solar-panel/monocrystalline-solar-panels/
[10] http://solarpanelsbook.com/types-solar-panels.htm

The third basic type of photovoltaic cells are the amorphous cells which are those manufactured by placing a thin film of non-crystalline silicon onto a variety of surfaces. This type is by far the least efficient and least expensive to fabricate. Its advantage is that it is flexible and it permits the manufacturing of a flexible solar panel that can be used for other applications. However, for the purpose of this project, this type is not ideal.

Solar Photovoltaic System Design

The size of the solar photovoltaic system is determined by the client's needs. In Tompkins County, the average electricity generation from the solar resource is about 1100 kWh per kW of system capacity. To cost the system, the average price for solar panel per kW of capacity is $4,500 and the average annual maintenance cost is a mere $16 per kW of capacity.[11] For our calculations we chose not to incorporate the existing government incentives for residential solar energy systems because these are constantly changing.

[11] http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/1372/Solar_NewJersey.pdf?sequence=1

4.3. Water Efficiency

Introduction

According to the American Water Works Association (an international non-profit professional organization dedicated to the improvement of water quality and supply), an average person in the United State uses about 69.3 gallons of water per day. These means that an average house of 3 residents will consume about 207.3 gallons of water a day, and about 25,294.5 gallons per year. In addition to that according to the Ithaca Department of Water and Sewer the current utility cost for water is about \$3.33 per 100ft^3 which converts out to about \$0.0045/gal. This means that an average 3 person residence will have a water bill of about \$112.61/year.

In addition to that it is important to note that the total consumption per capita; as shown in Figure 19, is further broken up by the percentage of total water each individual consumes in the operation of specific water fixtures. From this it is evident that on an average day an individual will either use specific fixtures more often, or that a particular fixture consumes a larger amount of water with ever use. Because of these factors, water efficiency of the house, and lowering the total residential water consumption and utility cost became a large factor in the development of the green residence.

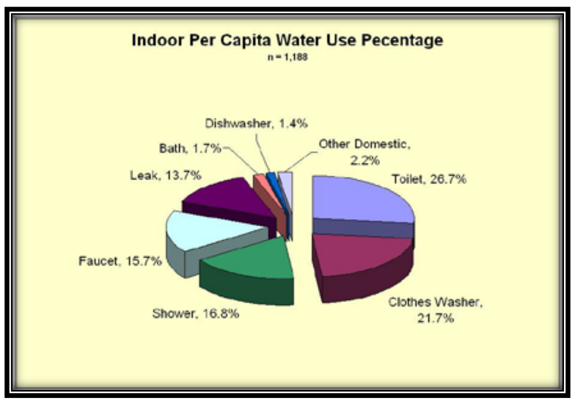

Figure 20 Water Use

In order to provide a lower the water consumption for the new green residence, it was important to first look at which water fixtures had the largest impact on the house's total water usage. As indicated from data provided by the AWWA on water usage it was determined that the fixtures which consumed the most water were toilets, bathroom faucets, showerheads, kitchen faucets, clothes washers, and dishwashers. It was decided that the best way to improve the water efficiency of the household would be to find better, more efficient technologies which would improve the water consumption of these 7 household fixtures.

In order to provide a wider range of comparative data for each fixture, a total of four different technologies with varying levels of efficiency were researched for each of the 7 major house household water fixtures. Each of the 4 different technologies was selected based on meeting specific criteria that would place it into one of four efficiency categories. The first a category known a level I, or Baseline would contain all fixtures that only met the federal minimum standard flow rate. The second category known as Level II, or High efficiency, would contain technologies which met the minimum requirements by organizations like LEED and Water sense to be considered highly efficient. The third category, Level III, or Very high efficiency fixtures contained technologies that saved significantly more water the level I and level II fixtures, but were still reasonably afford able to the average consumer. The last selection category, Level IV, or ultra-efficient fixtures contained technologies which provided the highest level of water savings possible for a particular fixture, regardless of installation cost.

Toilets:

Overall Assumptions/ Selection Criteria

The main selection criterion that was used for determining the efficiency levels for toilets were based off a combination of EPA minimum standards, Water Sense labeling, and USGBC LEED ratings for toilet water consumption. Just as a quick over view the EPA is a federal organization designed to protect human health and the environment. According to the EPA all modern toilets can have a flow rate no higher than 1.6 gallons per flush. All toilets which only met the minimum EPA standard were categorized as Level I toilets. In addition, all toilets which were Water Sense labeled and earn 1 LEED point under the USGBC's LEED rating system were categorized as Level II toilets. Just as a brief overview Water Sense Labeled fixtures are water fixtures which meet specific criteria set by the EPA to be officially recognized as a high efficiency fixture. To earn a Water Sense Label, a toilet must have a max flow rate of 1.28gpf. In addition to that the USGBC is non-profit organization committed to a prosperous and sustainable future for the nation through the development of cost-efficient and energy-saving green buildings. Under the USGBC a Green building certification system was developed to recognize building projects which implemented strategies for better environmental and health performance. The LEED rating system bases its certification criteria off of potential points that can be awarded for using higher efficiency water fixtures and other environmentally friendly technologies. Under this rating system each LEED point earned goes to an overall LEED sustainability rating of the building. Under the LEED rating system each toilet which has a max flow rate of between 1.3gpf and 1.1 gpf, would earn 1 LEED point per fixture. All Level III toilets were categorized based off of having a max flow rate less than 1.1gpf which would earn a total of 2 LEED points per fixture. The last efficiency level or Level IV was left for Ultra high Efficiency fixtures, or toilets which had a flow rate less than 0.5gpf.

In order to quantify the savings that each efficiency level would bring to the house, a set of toilet usage assumptions were used based off of individual usage estimations determined by the

USGBC. Under these estimations the assumption was made that the average person would use a toilet 5 times a day and since each house would have 3 residents and two toilets, the combined daily toilet usage of the house hold would end up being 15 times a day, or 5475 time per year.

Technology Overview

Niagara Stealth™ N7716 0.8 GPF Ultra High Efficiency Toilet

As one of the most unique low flow toilets on the market, the Niagara Stealth Toilet has a low profile body and utilizes a the breakthrough patented Stealth Flush Technology as shown in Figure 20, to deliver a quiet, effective flush using only 0.8 gallons of water. This is accomplished by harnessing the energy created by water filling that tank, and using a patented an air transfer system

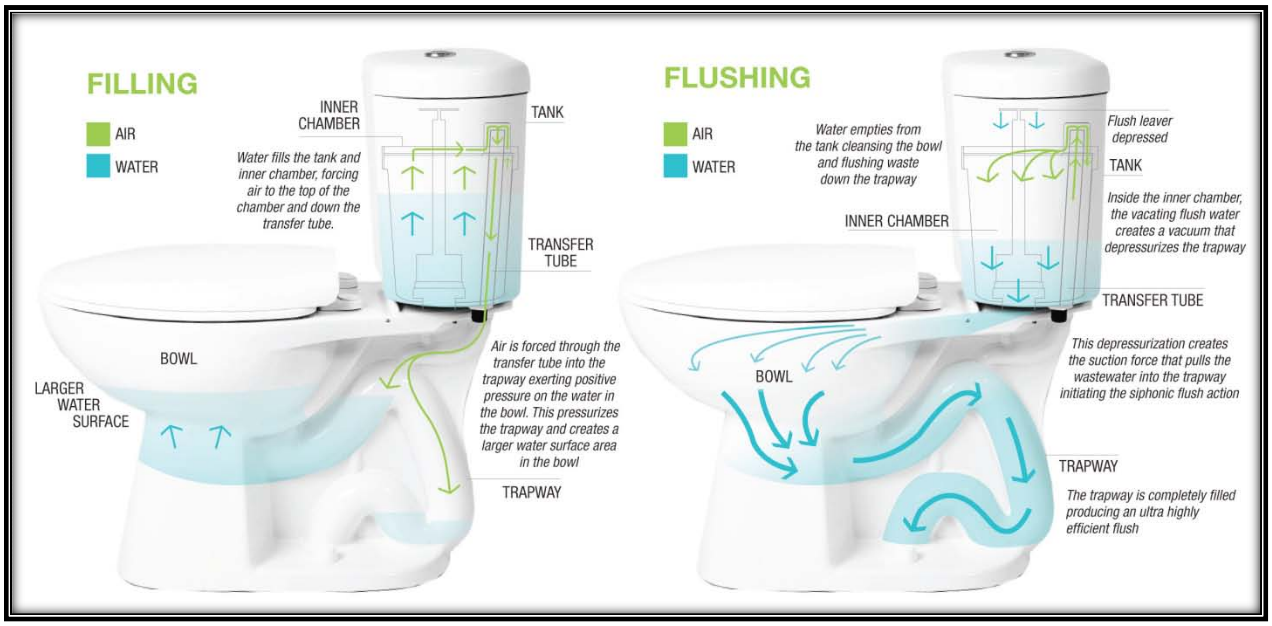

Figure 21 Toilet Overview

to pressurize the trap way, creating a swift, powerful, but quiet flush which evacuates all waste from the bowl. The system is not only capable of functioning efficiently at varying water pressure levels, but it has no expensive parts to replace, which a modern, compact design it is ideal for both new construction and retrofitting projects. Being that it on uses 0.8gpf, this toilet save 37% more water than the average High Efficiency Toilet. Due to the fact that the Niagra Stealth Toilet has a water usage of only uses 0.8gpf with a base cost of $240.00, this technology was categorized as a Very High Efficient or Level III toilet. (Note: Additional specifications on this technology can be found on the attached spec sheet in the Appendix)

Envirolet Waterless Remote Composting Toilet System

The advantage of this Composting System is that it offers a unique combination of both style and function. As shown in Figure 21, the Remote waste treatment center installs below the floor, directly under a Waterless Toilet, either in the basement or on the ground outside. Being manufactured from durable, easy-to-clean, high impact, all-weather HDPE plastic, this system will provide a longer service life with less maintenance than other composting systems. As shown in figure 4 this system features two fans (others have only one) and an Aeration Basket. These dual fans, operating in conjunction with natural microbe action, continuously circulate a large volume of air at a high flow rate around a specially shaped Aeration Basket to maximize waste surface area for better efficiency. This breakthrough technology also improves both waste reduction and recycling by increasing aeration, evaporation and microbe activity which allows for significant reduction of the System size, while still maximizing System performance.

Figure 22 Composting Toilet

With its Automatic Six-Way Aeration™, this system is over 100% more efficiency than other composters, giving it an increased capacity which is rated for up to 12 uses per day. In addition to that the Toilet can be installed on an upper floor some distance away from the treatment center, using an included Flex Duct for both drain and vent.

Since this system is a uses absolutely no water it was categorized as an Ultra High Efficient, or Level IV fixture. Unfortunately due to the fact that this system is not mass produced, it comes with a high custom fabricated price tag of $2179.00 per unit.

Note: addition information on this system can be found in the Appendix

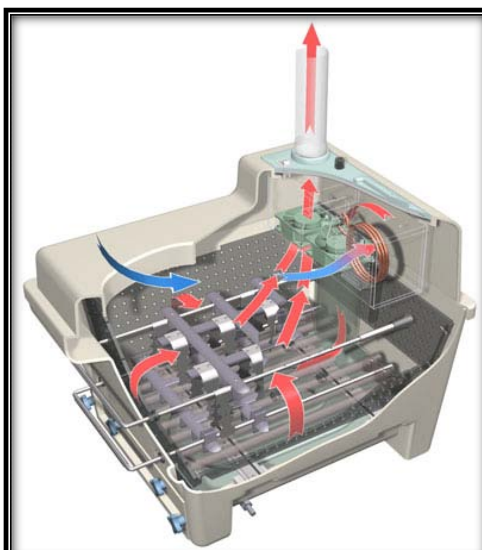

Figure 23 Composting Venting

Other Technologies

Toilets that were categorized into Levels I and II were baseline 1.6gpf toilets and standard High Efficiency toilets which had a lower flow rate of 1.28gpf. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

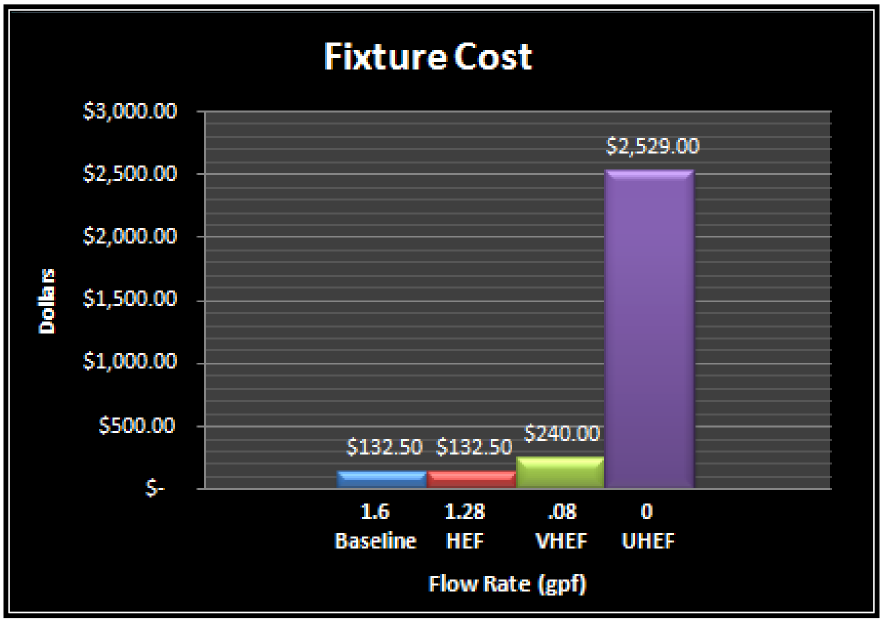

Figure 24 Toilet Cost

- Water Consumption Savings

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of a toilets annual usage of 5475time a year by the gallons of water consumed per flush for each different fixture. This calculated value was the subtracted by the total water consumption of the baseline, or Level I model.

Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix-

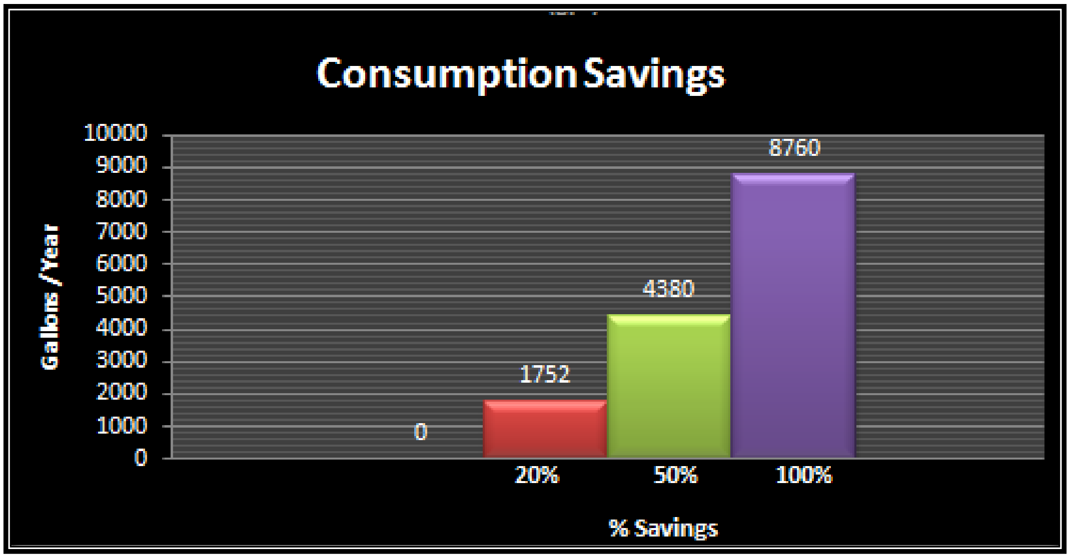

Figure 25 Toilet Consumption

- Utility Savings

In order to determine the utility savings of each fixture the utility cost of the baseline, or Level I fixture was determine by multiplying the previously calculated annual consumption by the previously established utility cost of $0.0045. The actual savings difference was the determined by calculating the difference in the utility cost between the Baseline and higher level fixtures.

Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

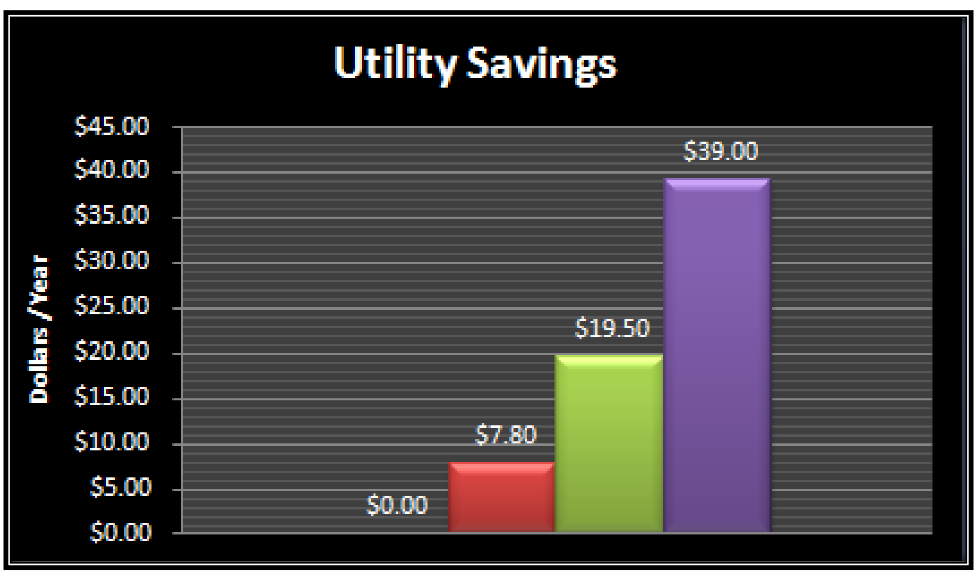

Figure 26 Toilet Utility Savings

Lavatory Faucets

Overall Assumptions/ Selection Criteria

The main selection criteria that were used for determining the efficiency levels for lavatory faucets once again were based off a combination of EPA minimum standards, Water Sense labeling, and USGBC LEED ratings for faucet water consumption. According to the EPA all modern faucets can have a max flow rate no higher than 2.2 gallons per minute. All faucets which only met the EPA's Minimum standard were categorized as level I faucets. In addition to that faucets which were Water Sense Labeled and earned 1 LEED point were categorized as Level II fixtures. Water Sense Labeled faucets must have a max flow rate of 1.5 gpm at 60 psi. Under the LEED rating system each faucet which has a max flow rate of between 2.0gpm and 1.5 gpm, would earn 1 LEED point per fixture. All Level III faucets were categorized Based off of having a max flow rate less than 1.5gpm receiving a total of 2 LEED points per fixture. The last efficiency level or Level IV was left for Ultra high Efficiency fixtures, or faucets which had a flow rate less than 1.0gpm.

In order to quantify the savings that each efficiency level would bring to the house, a set of Lavatory faucet usage assumptions were used based off of individual usage estimations determined by the USGBC. Under these estimations the assumption was made that an average person would use a lavatory faucet 5 times a day for about 1 minute. Since each house would have 3 residents and two lavatory faucets, the combined daily lavatory faucet usage of the household would end up being 15 times a day with total usage duration of 15 minutes. This comes out to be 5475 minutes a year in which the faucet is running.

Technology Overview

GPM Deluxe Touch Low Flow Faucet Aerator

This fixture has a unique fingertip control give the aerator the ability to reduce the fixtures flow to a trickle while keeping temperature consistent.

Figure 27 Aerator

- Additional Specifications:
    - Attaches to existing faucet fixtures
    - Saves 55% more water and energy then a standard 2.2 GPM aerator
    - California Energy Commission-certified
    - Fits male and female faucets
    - Unit cost:$8.95
    - Flow Rate: 2.2gpm-1.0gpm

Note: Due to the fact that this fixture is capable of reducing the flow rate of a standard faucet down to 1.0gpm it was categorized as a Very High Efficient, or Level III faucet fixture

0.5 GPM Low Flow Dual-Thread Faucet Aerator

This fixture is a High pressure 0.5 GPM flow rate faucet aerator which is designed to attach to existing faucet fixtures.

- Additional Specifications:
  - Flow control construction of long lasting Celcon plastic
  - Innovative dual-thread system to accommodate both male and female applications
  - Saves 77% more water and energy than a standard 2.2 GPM
  - Includes housing, flow control, tamperproof screen, and all other parts necessary for proper installation and operation
  - Internally and externally threaded with 15/16 x 27 threads outside and 55/64 x 27 threads inside
  - Does not contain any unplated brass components
  - Provides an even spray pattern
  - 10 year guarantee
  - Meets or exceeds ASME standards
  - California Energy Commission Certified
  - Unit cost: $4.75
  - Flow Rate: 0.5gpm

Figure 28 Low Flow Aerator

Note: Since the fixture is capable of reducing the flow rate of a standard faucet down to 0.5gpm it was categorized as an Ultra High Efficiency, or Level IV faucet Fixture.

Other Technologies

Fixtures that were categorized into Levels I and II were baseline 2.2gpm faucets and standard High Efficiency faucets which had a lower flow rate of 1.5gpm. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

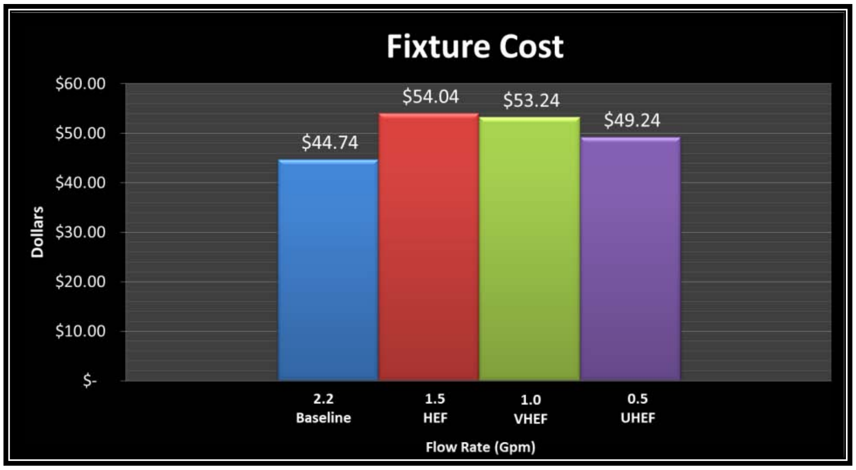

Figure 29 Lav Faucet Cost

- Water Consumption

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of the faucet's total usage of 5475 minutes a year by the flow rate for each fixture. This calculated value was then subtracted by the total water consumption of the baseline, or Level I model. Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix

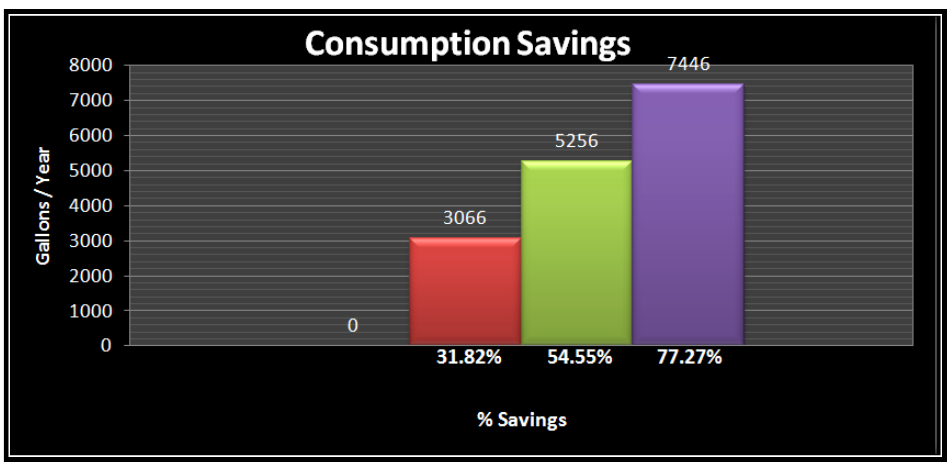

Figure 30 Lav Faucet Consumption Savings

- Utility Cost

The utility savings for lavatory faucets was calculated using the same method used for toilets. Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

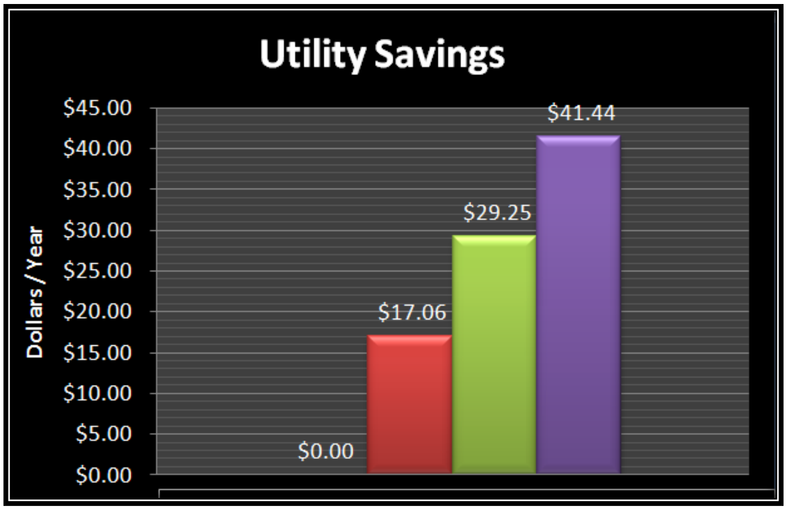

Figure 31 Lav Faucet Utility Savings

Showerheads

Overall Assumptions/ Selection Criteria

The main selection criteria that were used for determining the efficiency levels for Showerheads were also were based off a combination of EPA minimum standards, Water Sense labeling, and USGBC LEED ratings for faucet water consumption. According to the EPA all modern showerheads can have a max flow rate no higher than 2.5 gallons per minute. All showerheads which only met the EPA's Minimum standard were categorized as level I Showerheads. In addition to that showers which were Water Sense Labeled and earned 1 LEED point were categorized as Level II fixtures. Water Sense Labeled showers must have a max flow rate of 2.0gpm. Under the LEED rating system each showerhead which has a max flow rate of between 2.0gpm and 1.5 gpm, would earn 1 LEED point per fixture. All Level III showers were categorized based off of having a max flow rate less than 1.5gpm, receiving a total of 2 LEED points per fixture. The last efficiency level or Level IV was left for Ultra high Efficiency fixtures, or showerheads which had a flow rate of 1.25gpm or less.

In order to quantify the savings that each efficiency level would bring to the house, a set of shower usage assumptions were used based off usage estimations determined by the USGBC. Under these estimations the assumption was made that an average person would take a shower once a day for about 8 minutes. Since each house would have 3 residents and two showers, the combined daily shower usage of the household would end up being 3 times a day with usage duration of 24 minutes. This comes out to be 8760 minutes a year in which the shower is running.

Technology Overview

Niagara Earth Massage Showerhead

One of the most unique aspects about this technology is that there are 3 versions of this showerhead which have varying flow rates of 1.75, 1.5, and 1.25gpm. However the product specifications and price as show below remain the same for all versions. The only differences between the 3 versions are the variations in flow rates. In addition to that all 3 versions utilize a flow-compensating technology which creates a significant amount of force while using less water.

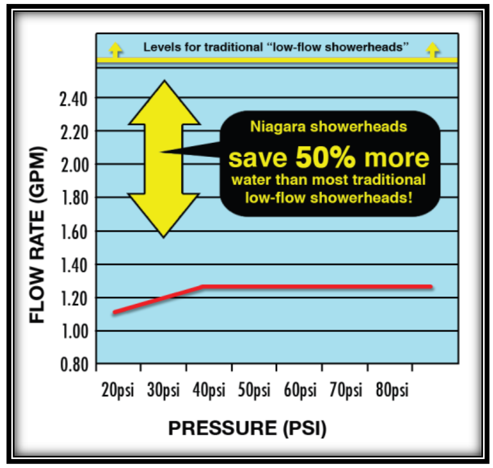

Figure 32 Flow Rate

- Base Specifications
  - Unit Cost: $13.50
  - Flow rate: N2917 – 1.75gpm
    - N2915 – 1.5gpm
    - N2912 – 1.25gpm

Figure 33 Niagra Showerhead

- Additional Specifications

- Conserves water and saves money while enhancing pressure, performance, appearance and luxury!
- 9-jet turbo massage is adjustable: gentle needle spray to forceful jet
- Consistent flow rate regardless of water pressure
- Saves 30% more energy and water
- Non-removable flow compensator
- Non-aerating spray means less temperature loss with maximum energy savings
- Self-cleaning and maintainence-free
- Installs easily, by hand and without tools
- Corrosion resistant high-impact ABS thermoplastic body
- Meets or exceeds ANSI specifications
- 10-year guarantee

Note: The 1.75gpm fixture was categorized as a High Efficient or Level II fixture, the 1.5gpm fixture was categorized as a Very High Efficiently, or Level III showerhead, and lastly the 1.25 fixture was classified as an Ultra High Efficiently, or Level IV showerhead.

Other Technologies

Fixtures that were categorized into Level I were baseline 2.5gpm Showerheads. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

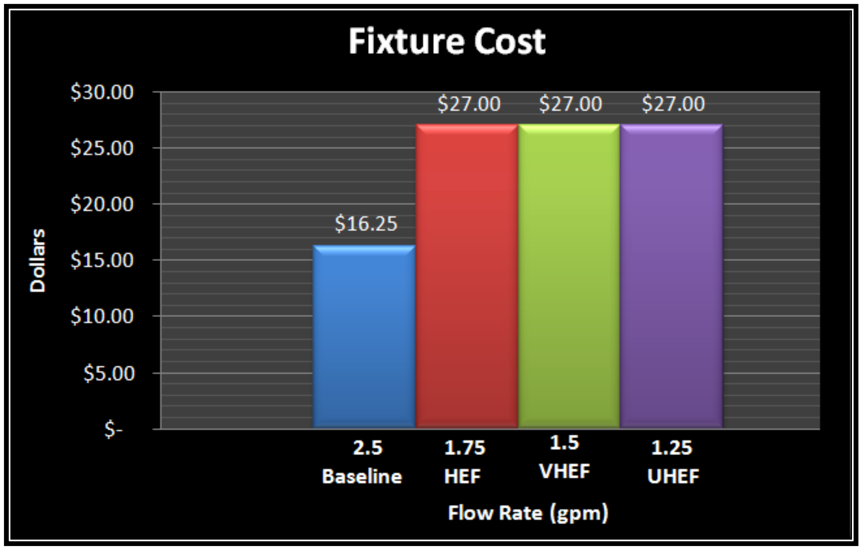

Figure 34 Showerhead Cost

- Water Consumption Savings

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of the showerhead's total usage of 8760minutes a year by the flow rate for each fixture. This calculated value was then subtracted by the total water consumption of the baseline, or Level I model.

Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix

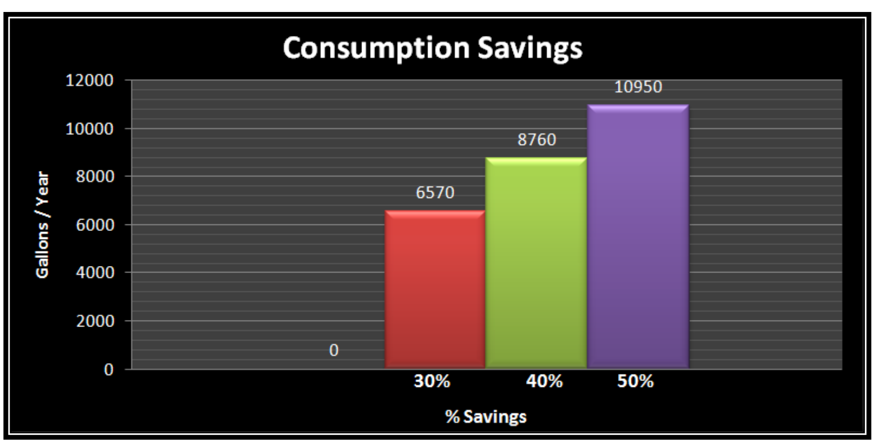

Figure 35 Showerhead Consumption Savings

- Utility Savings

The utility savings for Showerheads was calculated using the same method used for toilets.

Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

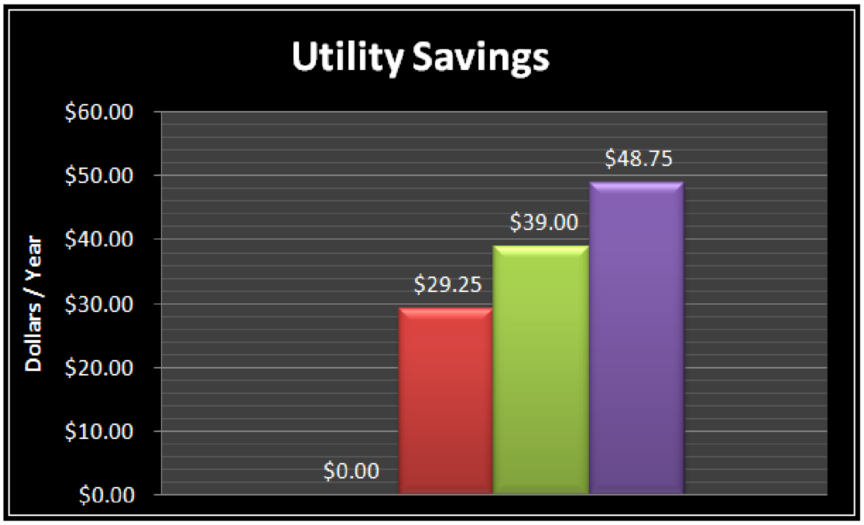

Figure 36 Showerhead Utility Savings

Kitchen Faucets

Overall Assumptions/ Selection Criteria

The main selection criteria that were used for determining the efficiency levels for kitchen faucets were the same as the criteria used to determine the efficiency Level for the lavatory Faucets.

In order to quantify the savings that each Efficiency Level would bring to the house, a set of kitchen faucet usage assumptions were used based off of individual usage estimations determined by the USGBC. Under these estimations the assumption was made that an average person would use a kitchen faucet 4 times a day for about 1minute. Since each house would have 3 residents and the combined daily kitchen faucet usage of the household would end up being 12 times a day with total usage duration of 12 minutes. This comes out to be 4380 minutes a year in which the faucet is running.

Technology Overview

GPM Deluxe Touch Low Flow Faucet Aerator

Details on this fixture can be found in the section on lavatory faucets

0.5 GPM Low Flow Dual-Thread Faucet Aerator

Details on this fixture can be found in the section on lavatory faucets

Other Technologies

Fixtures that were categorized into Levels I and II were baseline 2.2gpm faucets and standard High Efficiency faucets which had a lower flow rate of 1.5gpm. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

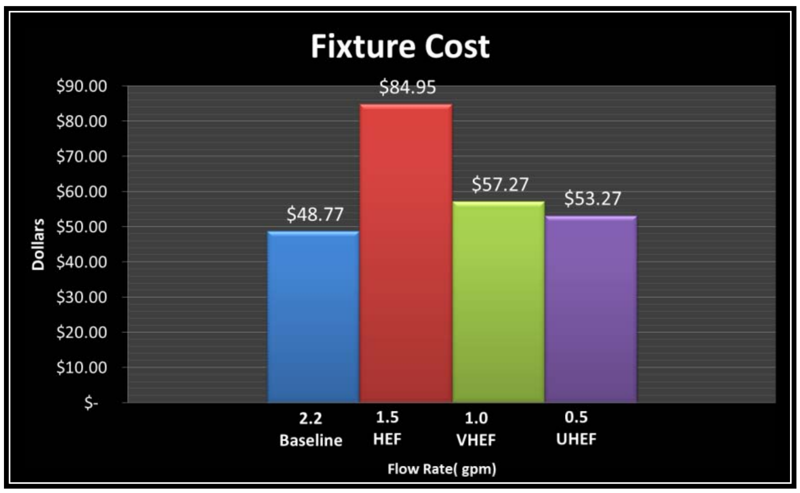

Figure 37 Kitchen Faucet Costs

- Water Consumption

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of the faucet's total usage of 4380 minutes a year by the flow rate for each fixture. This calculated value was then subtracted by the total water consumption of the baseline, or Level I model. Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix

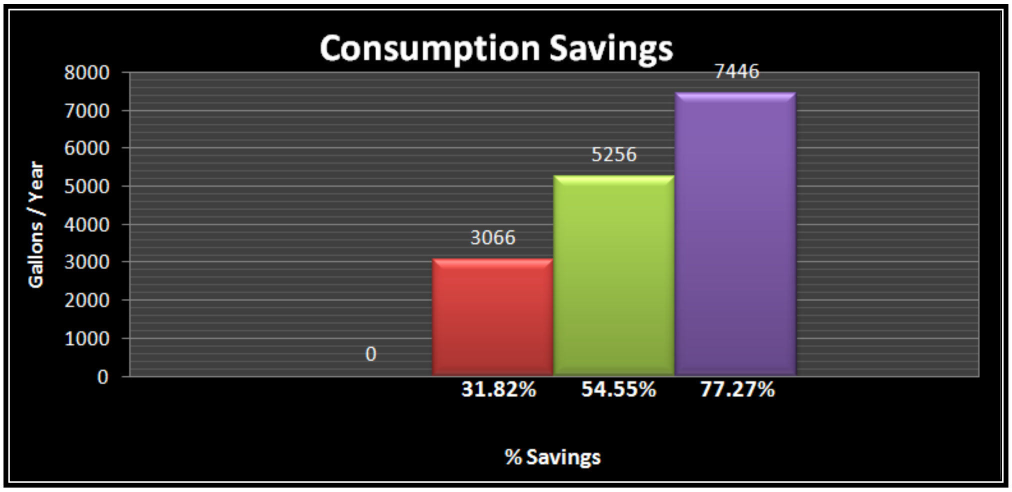

Figure 38 Kitchen Faucet Consumption Savings

- Utility Cost

The utility savings for kitchen faucets was calculated using the same method used for toilets. Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

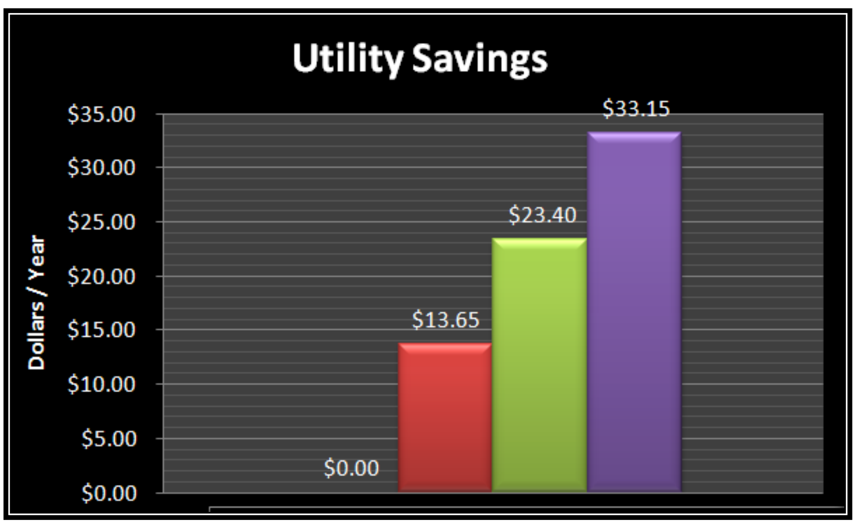

Figure 39 Kitchen Faucet Utility Savings

Dishwashers

Overall Assumptions/ Selection Criteria

The main selection criteria that were used for determining the efficiency levels for dishwashers were based off a combination of EPA minimum standards, ENERGY STAR, and CEE ratings for Dishwashers water consumption and annual energy usage. According to the EPA all modern dishwashers must have a minimum energy factor of 0.46cycles/kWh; however there is no maximum water factor or water usage in gal/cycle. All washers which met the EPA s minimum standard were categorized as Level I dishwashers. In order for a dishwasher to be categorized as a Level II washer it needed to meet the criteria for an ENERGY STAR rating. ENERGY STAR is a joint program with the EPA and US Department of Energy designed to simultaneously help consumers save money and protect the environment by providing an ENERGY STAR Label to appliances which meet a specific set of criteria set by the EPA officially recognizing the appliance as being energy efficient. In order for a dishwasher to be given an ENERGY STAR rating it must have a max water factor of 5.8gal/cycle, and a max energy usage of 324kWh/year. In addition to that in order for a washer to be categorized as a level III and Level IV washer they needed to meet the criteria to be given a CEE ,or Consortium for Energy Efficiency Tier I Rating for Level III washers, and a CEE Tier II rating to be categorized as a Level IV washer. The Consortium for Energy Efficiency is a non-profit public benefits corporation which helps promote the manufacture and purchasing of energy-efficient products and services. Just like with ENERGY STAR in order for an appliance to meet a specific CEE Tier it must meet certain water and energy efficiency criteria. In order to qualify for a CEE Tier I rating a dishwasher must have a minimum energy factor of 0.72cycles/kWh, a max energy usage of 307kWh/year, and a max water factor of 5.00gal/year. In order of a washer to qualify for a CEE Tier II rating it must have a minimum energy factor of 0.75cycles/kWh, a max energy usage of 295kWh/year, and a max water factor of 4.25gal/cycle.

In order to quantify the savings that each efficiency level would bring to the house, a set of usage assumptions were used based off of estimations determined by the EPA under the ENERGY STAR initiative. Under these estimations the assumption was made that the average house would use a dishwasher 215 times over the course of 1 year.

Technology Overview

Maytag Jet clean Plus Dishwasher

- Special features
  - Silverware BlastTM Spray Jets
  - JetClean Plus Wash System
  - ToughScrubTM Plus Option
- Additional Specifications
  - Energy Factor:0.72cycle/kWh
  - Water Factor:4.3gal/cycle
  - Energy Usage:302kWh/year
  - Unit Cost: $649
  - Most efficient Dishwasher with CEE Tier I Rating

Figure 40 Maytag Dishwasher

Note: Since the fixture met a CEE Tier I Rating it was categorized as a Very High Efficiency, or Level III Dishwasher.

Bosch 24" Evolution 800 Plus Series Was

Figure 41 Bosch Dishwasher

- Special Features
  - EcoAction™ Option Reduces Energy Usage by up to 25%
  - EcoSense™ Reduces Energy Usage by up to 20%
  - Half Load Option for Small Loads
  - Flow-Through Water Heater™
  - Virtually Silent: 42 dBA
  - Two Pumps Minimize Noise & Vibration
  - Solid Base Contains Sound & Prevents Leaks
- Additional Specifications
  - Energy Factor: 1.19 cycle/kWh
  - Water Factor: 1.56 gal/cycle
  - Energy Usage:180kWh/year
  - Unit Cost:$1,649
  - CEE Tier II Rating
  - Most Efficient Dishwasher on the market

Note: Since the fixture met a CEE Tier II Rating, it was categorized as an Ultra High Efficiency, or Level IV Dishwasher.

Other Technologies

Fixtures that were categorized into Levels I and II were baseline 0.46cycles/kWh Dishwashers and standard High Efficiency dishwashers which had a max water factor of 5.8gal/cycle, and a max energy usage of 324kWh/year. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

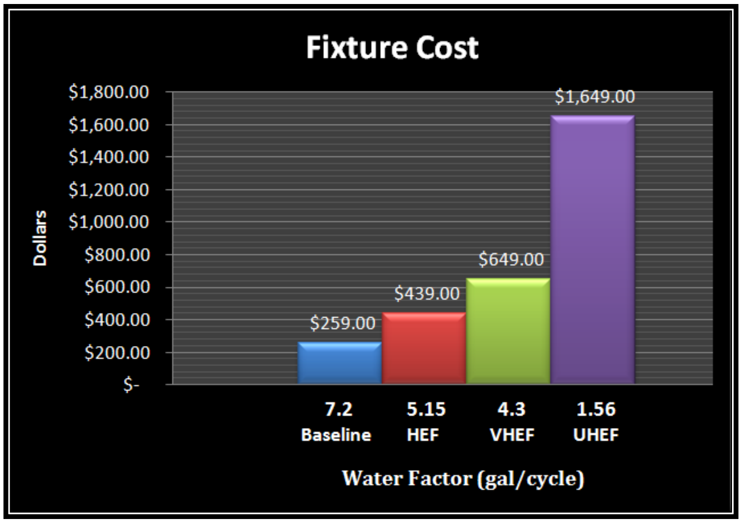

Figure 42 Dishwasher Costs

- Water Consumption

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of the dishwasher's annual usage of 215 times a year by the gal/cycle of water used by each fixture. This calculated value was then subtracted by the total water consumption of the baseline, or Level I model. Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix

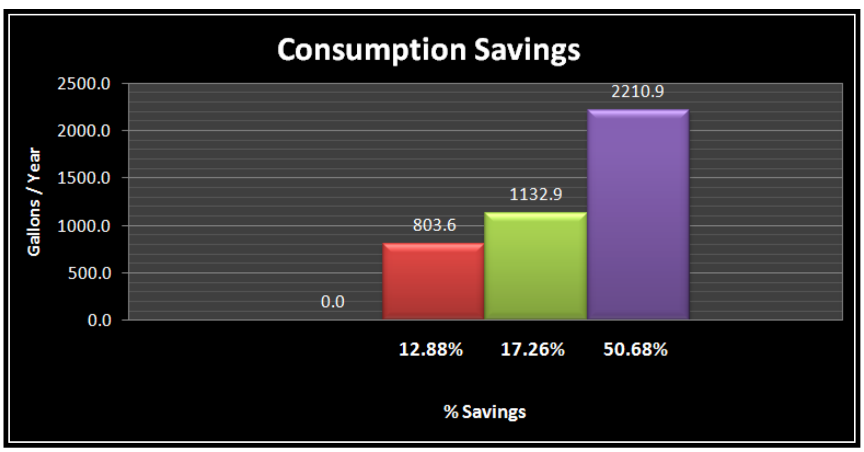

Figure 43 Dishwasher Consumption Savings

- Utility Cost

The utility savings for Dishwashers was calculated using the same method used for toilets.

Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

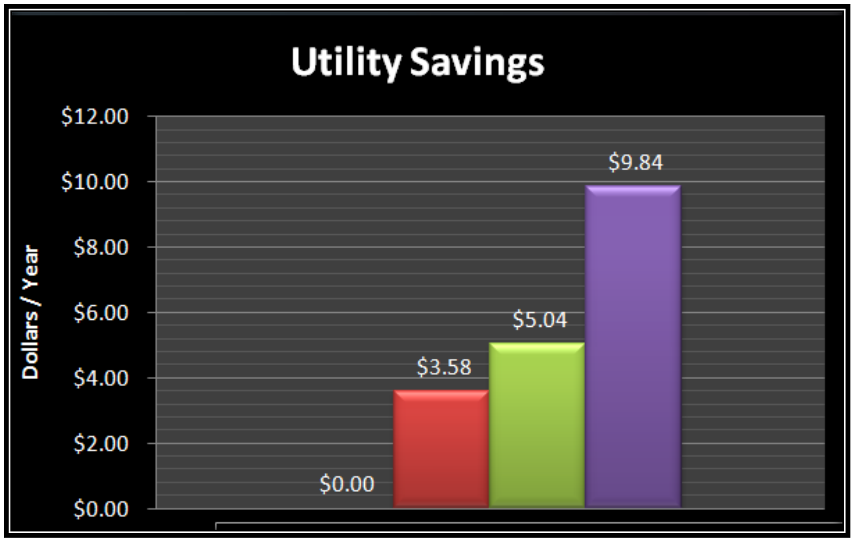

Figure 44 Dishwasher Utility Savings

Clothes Washers

Overall Assumptions/ Selection Criteria

The main selection criteria used for determining the efficiency levels for clothes washer were very similar to those used for Dishwashers. The Levels were categorized based off a combination of EPA minimum standards, and CEE ratings for in regards to the clothes washer's water consumption and annual energy usage. According to the EPA all modern clothes washers must have a minimum energy factor of 1.26ft^3/kWh/cycle, and max water factor of 9.5gal/cycle/ft^3. All washers which meet the EPA s minimum standard were categorized as Level I clothes washer. In order for a Washer to be categorized as a Level II washer it needed to meet the criteria for a CEE Tier I rating. In order for a clothes washer to be given a CEE I rating it must have an energy factor of between 2.00 and 2.2ft^3/kWh/cycle, and max water factor between 6.0 and 4.5gal/cycle/ft^3. All Clothes washers which were to be categorized as level III washers needed to meet a CEE Tier II rating. In order to meet this rating a cloth washer needed to have a minimum energy factor between 2.40 and 2.2ft^3/kWh/cycle, and max water factor between 4.5 and 4.0gal/cycle/ft^3. Finally in order to be categorized as a Level IV fixture, the washer needed to meet a CEE Tier Rating of III. In order to accomplish this, a clothes washer needed to have a minimum energy factor of 2.40ft^3/kWh/cycle or greater and max water factor of 4.0gal/cycle/ft^3 or less.

In order to quantify the savings that each efficiency level would bring to the house, a set of usage assumptions were used based off of estimations determined by the EPA under the ENERGY STAR initiative. Under these estimations the assumption was made that the average house would use a clothes washer 392 times over the course of 1 year.

Technology Overview

GE® 3.6 DOE cu. ft. Stainless Steel Capacity Washer

- Special Features
    - HydroWave™ wash system-smooth, arcing agitation with nearly a full 360-degree rotation at high speed gives clothes a longer, slower* travel through the water for thorough, yet gentle, cleaning.
    - Rotary electronic controls with cycle status lights-Make it easy to select and monitor wash cycles.
    - PreciseFill with 5 water level selections-Washer will automatically measure the load size and add just the right amount of water, or choose from 5 pre-set water levels
- Additional Specifications
    - Energy Factor: 2.07ft3/kWh/cycle
    - Water Factor: 6gal/cycle/ft^3
    - Energy Usage: 186kWh/year
    - Unit Cost: $549
    - CEE Tier I Rating
    - Most Efficient Dishwasher Tier I Washer

Figure 45 GE Clothes Washer

Note: Since the fixture met a CEE Tier I Rating it was categorized as a High Efficiency, or Level II clothes washer.

GE® ENERGY STAR® 3.5 DOE Cu. Ft. Capacity Frontload Washer

- Special Features
    - Adaptive Logic™ system-Adaptive Logic™ automatically tracks data on household variables (like water pressure and distance from the water heater) and consumer laundry habits over the preceding 10 cycles, then uses that data to calculate accurate estimated cycle times. If data begins to change, due to fluctuations in water pressure or electrical supply, or if the appliance is moved to a new home, the system will adapt to its new environment within the subsequent 10 cycles.
    - Rotary electronic controls with cycle status lights make it easy to select and monitor wash cycles.

- HydroHeater™ internal heater-The HydroHeater™ internal water heater boosts incoming water temperature to brighten whites while helping eliminate common bacteria.
- HydroMotion™ wash action-HydroMotion™ reversing-tumble wash action cleans the wash load by gently lifting the wash load and dropping it back into the wash basket. This agitator-less wash system provides gentle, yet thorough cleaning.

- Additional Specifications
  - Energy Factor: 2.2ft^3/kWh/cycle
  - Water Factor: 4.2gal/cycle/ft^3
  - Energy Usage: 144kWh/year
  - Unit Cost: $899
  - CEE Tier II Rating
  - Most Efficient Tier II washer on the market

Figure 46 GE Energy Star Clothes Washer

Note: Since the fixture met a CEE Tier II Rating it was categorized as a Very High Efficiency, or Level III clothes washer.

Whirlpool Energy Star qualified Duet 5.0 Cu. Ft. I.E.C. equivalent Front Load Washer

- Special Features
  - 6th Sense™ Technology-Measures the size of the load and determines how much water is needed to clean it. Sensors monitor the inlet temperature, gradually warming water to keep cleaning enzymes at optimal effectiveness. Plus, sensors prevent oversudsing in low-water systems
  - EcoBoost Option-Get additional energy efficiency without giving up cleaning performance. This option lowers water temperature and increases the tumbling action to use less energy while still delivering great cleaning and gentle performance

Figure 47 Whirlpool Energy Star Clothes Washer

  - Allergen Cycle-The Allergen cycle has been tested to remove up to 95% of harmful allergens from your clothes.* *Allergens tested were dust mites and pet dander.
- Additional Specifications
  - Energy Factor: 3.5ft^3/kWh/cycle

- Water Factor: 2.7gal/cycle/ft3
- Energy Usage: 151kWh/year
- Unit Cost: $1,599
- CEE Tier III Rating
- Most Efficient Clothes washer on the market

Note: Since the fixture met a CEE Tier III Rating, it was categorized as an Ultra High Efficiency, or Level IV Clothes washer.

Other Technologies

Fixtures that were categorized into Levels I were baseline 1.26ft^3/kWh/cycle, and 9.5gal/cycle/ft^3 clothes washers. More detailed information on these additional fixtures can be found in the attached appendix.

Savings Comparison

- Installed Cost

Note: for all graphs the Level I fixture is represented as the blue bar, Level II is identified as the red bar, Level III is the green bar and Level IV fixtures are identified as the purple bar.

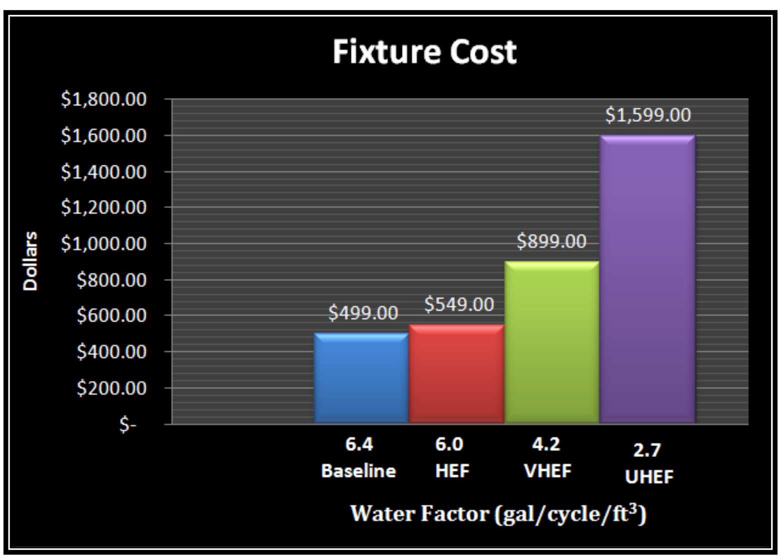

Figure 48 Clothes Washer Costs

- Water Consumption

The consumptions saving for each fixture was calculated by multiplying the previously mentioned assumption of the clothes washer's annual usage of 392 times a year, the fixtures water factor (gal/cycle/ft^3), and the fixtures max capacity in ft^3.This resulting value was then subtracted by the total water consumption of the baseline, or Level I model.

Note: To find additional information on consumption savings calculations reference the Water Calculation spread sheet in the attached appendix

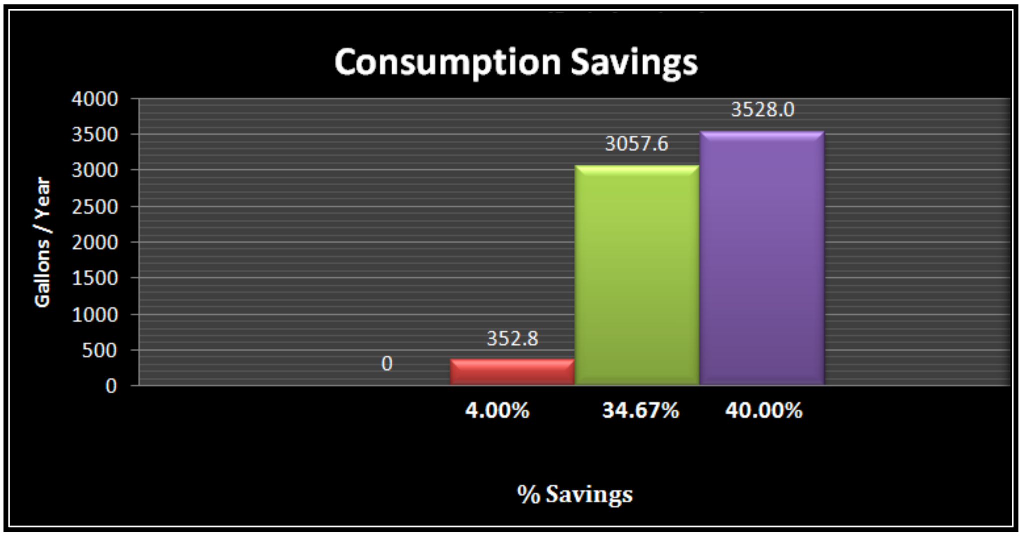

Figure 49 Clothes Washer Consumption Savings

- Utility Cost

The utility savings for clothes washers was calculated using the same method used for toilets. Note: To find additional information on the utility savings reference the Water Calculations spread sheet in the attached appendix-

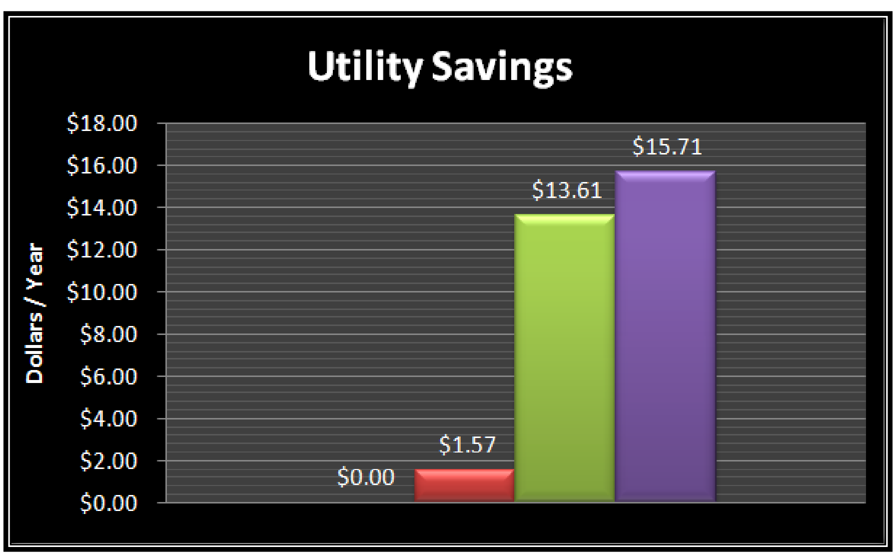

Figure 50 Clothes Washer Utility Savings

4.4. Indoor Environmental Quality

There are certain technologies beneficial to indoor environmental quality that our group suggests be implemented in this green residential development. These technologies provide qualitative benefits that cannot be modeled mathematically (at least within the scope of this project) but are essential for a healthy and comfortable living environment within a green home. Cost estimates and life spans were analyzed and estimated for the lifecycle cost analysis of this project.

Low/Zero-VOC Paints

The use of Low or Zero-VOC paints is almost becoming a standard especially in any sustainable home. There is no direct economic benefit of using Zero-VOC paints because these paints often cost slightly more than traditional paints. However, the health benefits and comfort of living in toxin and odor free home outweigh those costs.

The main governing agency that regulates the levels of VOC in paints is the United States EPA. However, there are three main independent third-party certifiers that help set a more stringent standard than the EPA's to promote sustainability, health, and indoor air quality. These three organizations are Green Seal, Green Guard, and Master Painters Institute[12].

Green Seal is a non-profit organization that offers sustainable standards for products, services, and companies. It is the largest US-based "ecolabeling" organization and meets the United States EPA's criteria as a third party certifier. What Green Seal has done for paint suppliers and consumers is create a higher standard for these Low-VOC paints, the latest being GS-11, which requires them to contain lower than 50 grams of VOC per liter of flat paint. The EPA has set that VOC content limit at 250 g/L, which is still a significant amount over the latest third-party standards in Low and Zero-VOC paints. There are also varying degrees of the requirements for different uses of paints such as flat, non-flat, exterior, reflective, and anti-corrosive, but for simplification we will mainly focus on the most stringent requirement.

Green Guard is another organization that primarily focuses on what is emitted from the paint after application. The organization not only watches VOC levels in products, but also other harmful particles and chemicals that harm indoor air quality such as formaldehyde. To get Green

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[12] "Low & Zero-VOC Paint Certification & Seals of Approval". The Patriotic Painting Blog. http://patrioticpainting.com/blog/low-voc-paint-certifications

Guard certification a paint product needs to fulfill the requirement of less than or equal to 0.5 mg of total VOCs per cubic meter of paint.

The Master Painters Institute (MPI) looks at all aspects of paint products from the way it is manufactured, what is emitted, and how long it lasts. MPI's requirements are said to the strictest with their standards GPS-1 and GPS-2 for paints. These standards are similar to Green Seal in that they require interior flat paint to be less than 50 g/L in VOC content.

Typically for a paint product to be officially labeled a Zero-VOC paint by these third-party certifiers and the product's company is for it to contain less than or equal to 5 g/L of VOCs. Since it is almost impossible to completely eliminate VOCs from paints, the title for these products is slightly misleading.

Below is a calculation of applying these paints in our model home and what benefits the residents will have.

Interior Surface Area calculations

Floor Height: 8 ft.

Ceiling Space (1st and 2nd floors): 1805 SqFt.

First Floor Surface Area	Second Floor Surface Area
Master Bedroom	**Bedroom 1**
181.28 sqft.	176 sqft.
264 sqft.	168 sqft.
Bathroom 1	**Bedroom 2**
160 sqft.	261.28 sqft.
213.28 sqft.	168 sqft.
Dining and Kitchen	**Bathroom 2**
317.28 sqft.	168 sqft.
100 sqft.	144 sqft.
92 sqft.	
	Lounge and Upper Gathering Room
Gathering Room	352 sqft.
245.28 sqft.	272 sqft.
240 sqft.	
Foyer and Stairs	
132 sqft.	
90.64 sqft.	

Table 7 Surface Area Calculations

Subtotal wall area: 3745.04 SqFt.

Plus an estimated 10% increase: 4119.54 SqFt.

Total interior surface area with ceiling: 5924.54 SqFt.

Our model home requires about 6,000 square feet of paint. On average a typical one gallon bucket of paint covers about 350 square feet of surface area, so we would need about 17 gallons for at least one layer of paint. Below is our analysis between the three types of paint:

- The prices of Zero-VOC paints are on average about $30.00 per gallon with a lifespan of about 10 years. This will cost $30.00 per gallon x 17 gallons = $510.00 for 10 years.
- The price of Low-VOC paints are on average about $10.00 per gallon with a lifespan of about 10 years. This will cost $10.00 per gallon x 17 gallons = $170.00 for 10 years.
- The price of normal household paints is on average about $7.00 per gallon with a lifespan of about 5 years. This will cost $7.00 per gallon x 17 gallons = $119.00 for 5 years. Since it needs to be reapplied earlier than its higher quality alternatives, an estimated cost for an equivalent 10 years is $218.00 or double the 5 year amount.
- The calculated costs above only cover one layer of paint, so it would cost twice as much for two layers.
- Labor costs from a licensed contractor would range anywhere from $3,000-$4,000 for a 1,800 SqFt. home regardless of what type of paint is used.
- An additional $25-$50 would be added for primer, brushes, rollers, drop clothes, and other supplies needed if the contractor does not supply them.

For this 1805 SqFt. home example, our analysis shows that it would be more cost-effective and beneficial for indoor air quality to use Low-VOC paints as the ideal product to purchase at this time. Until Zero-VOC paints become about the same price as Low-VOC paints or lasts almost three times as long over its lifespan, Low-VOC paints would be the ideal choice for a green home.

Non-Hydraulic Lime Plaster Walls

Lime plaster walls have unique benefits and are a wonderful option for sustainable homes. The use of lime plaster walls has been found to date back to ancient Egypt, ancient China, and early Venetian architecture. Non-hydraulic lime specifically is a self-healing and breathing material, great for use as wall material in homes. It is attractive as a sustainable building material and for indoor environmental quality because it sets through a carbonation process, absorbing carbon dioxide in the environment. In addition, lime plaster walls have reflective lighting characteristics to make rooms brighter with natural sunlight; it is recyclable and biodegradable; and it acts as a passive fireproofing material that slows the spread of a fire because it releases water vapor when exposed to flames.

To clarify, there is a difference between hydraulic and non-hydraulic lime. The difference is that non-hydraulic lime sets through a carbonation process versus hydraulic lime which requires a complex chemical reaction between calcium hydroxide and impurities in the lime initiated by the application of water.

The research of how much energy is put into mining lime quarries and the amount of CO_2 from the process used to change limestone into quicklime goes beyond the scope of this project and our model. However, sources estimate that the total emissions of an efficient industrial lime plant generates about 1 ton of CO_2 per ton of limestone[13] versus about 0.97 tons of CO_2 per ton of cement in the US (based on a national average of cement plants)[14]. This is almost a negligible difference.

To better understand the amount of carbon dioxide that is absorbed from the atmosphere, one must first understand the chemical reaction that takes place for mined limestone to set as a lime plaster wall through carbonation. The following diagram shows the process from mined limestone to set lime mortar or plaster[15].

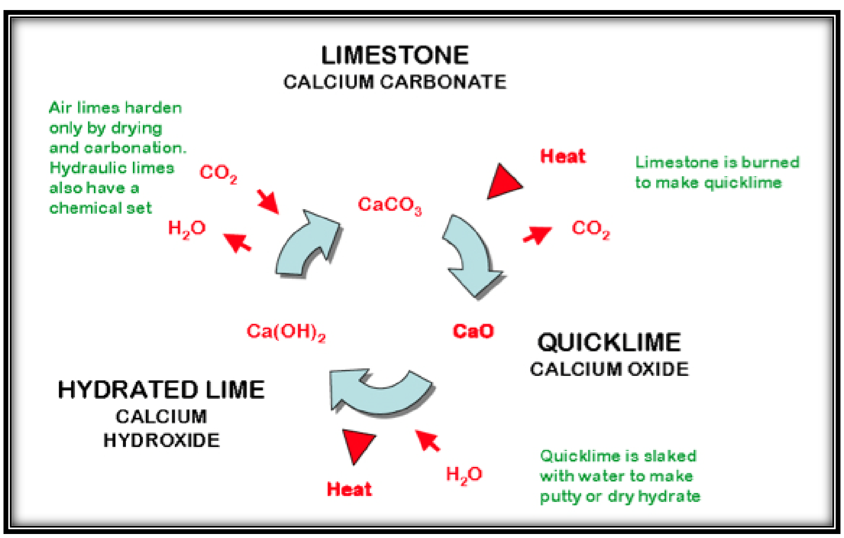

Figure 51 Lime Cycle

This is the chemical reaction known as carbonation that takes place near the end of the cycle when the hydrated lime turns back into a set lime plaster wall: $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$.

[13] "Lime Kiln" Wikipedia. http://en.wikipedia.org/wiki/Lime_kiln
[14] "CO_2 Emissions Profile of the U.S. Cement Industry". EPA. http://www.epa.gov/ttnchie1/conference/ei13/ghg/hanle.pdf
[15] "Facts about Lime". Hemp Technologies. http://www.hemp-technologies.com/page34/page34.html

Research from the University of Bath in the United Kingdom (Lawrence et al.) has found that actual amount of carbonation that occurs within a wall is not only dependent on time, but also what type of filler (sand and stone) the lime mortar is mixed with in a 1:3 ratio (one part non-hydraulic lime mortar and three parts sand). The university determined the carbonation profile of these materials using thermogravimetric analysis and compared crushed bioclastic stone, crushed oolitic stone and silicate sand[16].

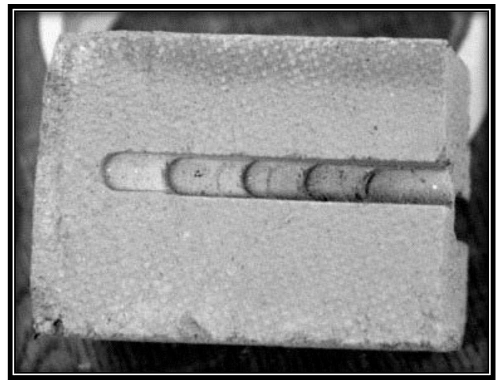

Figure 52 Example of the sampling technique used by University of Bath for a 50mm wide lime wall specimen.

Due to the pore distribution of the lime mortar, the core (or deepest part of a wall) has a tendency to carbonate at a slower rate. If the lime mortar has larger pores, then there is more access for environmental carbon dioxide to be absorbed into the core. Their data shows that 29.17% of the silicate sand mortar has pores larger than 10µm which allows for almost 100% of the calcium hydroxide or $Ca(OH)_2$ to carbonate within 180 days at a depth of 24mm; oolitic mortar seems to carbonate the slowest. Therefore, one can find from this research that depending on the filler material and simply the depth of the walls, some buildings' lime plaster walls may not fully carbonate in the deepest sections over several years. However, a large amount of carbon dioxide is still absorbed near the surface and a single residence can absorb anywhere from the range of 5,000 to 10,000 lbs. of carbon dioxide from the environment over the lifespan of the building (most of it absorbed within a year).

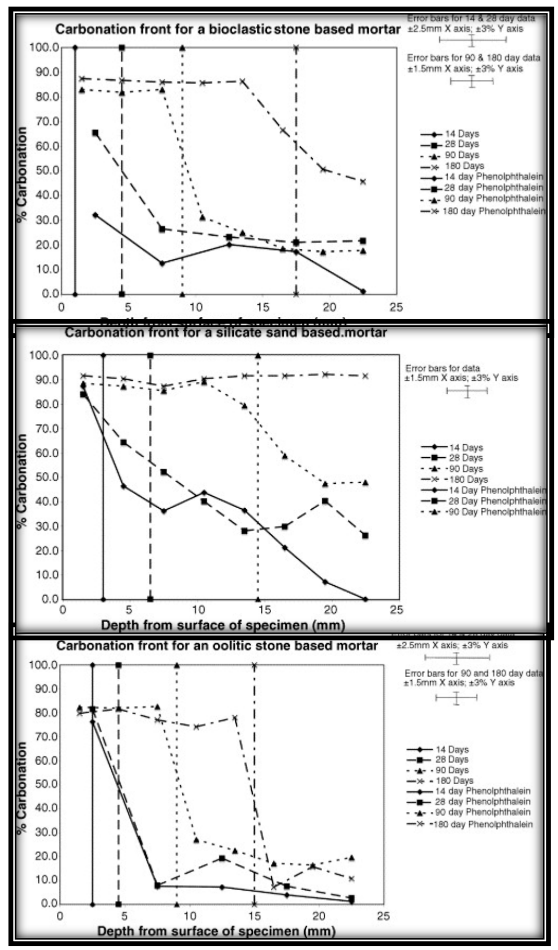

Figure 53 Carbonation profiles of the three fillers

16 http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6THV-4JT3RYF-1&_user=492137&_coverDate=05%2F15%2F2006&_rdoc=1&_fmt=high&_orig=gateway&_origin=gateway&_sort=d&_docanchor=&view=c&_searchStrId=1746007502&_rerunOrigin=google&_acct=C000022719&_version=1&_urlVersion=0&_userid=492137&md5=0470212db3e04b461a88867cacc1ff05&searchtype=a

CO_2 Monitoring

Since it is now required in building codes (established from industry standards from the American Society of Heating, Refrigerating, and Air Conditioning Engineers or ASHRAE) to install CO_2 sensors in homes and the fact that it is a pre-requisite for all LEED certified homes, additional monitoring or sensor systems are negligible in this green home model. Additional CO_2 exhaust from a home to provide healthy indoor air quality is covered by the Heat and Energy Recovery Ventilator systems explained below.

HEPA Filtration with Heat or Energy Recovery Ventilators

There are standalone air purifier systems that would be ideal for any green home. Usually HEPA filters can be installed or retrofitted into existing HVAC systems, but if a home does not have these all-in-one system or do not need air conditioning because of the location (such as Tomkins County), these standalone devices called Heat Recovery Ventilators (HRVs) or Energy Recovery Ventilators (ERVs) are now pre-manufactured with HEPA filtration systems.

The difference between HRVs and ERVs is that HRVs simply bring fresh air from the outdoors while exhausting stale air from inside the home as well as replacing cold air with hot air. ERVs, in addition to recovering heat, will also change the humidity content of the fresh outside air and replace the stale indoor air to balance the moisture levels within a home. Both balance the air pressure inside the home for comfort. For this case, we will choose an HRV system because it is suggest for homes in cold climates with longer heating seasons[17].

When analyzing HEPA filter devices, one uses cubic feet per minute (CFM) of air flow to determine the necessary size and quality of a device to fit a certain sized home. Some manufacturers will boast high levels of CFM air flow for their ventilators, so as to not confuse home owners, an organization called the Home Ventilating Institute (HVI), a nonprofit association of the manufacturers of these products, regulates an HVI-certified standard of air flow. The HVI-certified CFM air flow rate is the actual amount of fresh clean air being delivered into the home rather than the total air circulation provided by the machine (intake and exhaust). According to HVI, a rule of thumb when looking for an HRV/ERV is to calculate 5 CFM per 100 square feet of floor area of a home. In this project's case,

Figure 54 Broan HEPA Filtration and Heat Recovery Model GSHH3K

[17] The Home Ventilating Institute. http://www.hvi.org/faqs.html#whatisHVI

for a 1,805 square foot home, we would need an HRV/ERV with at least 90 CFM or more air flow to provide 0.35 air changes per hour as standard[18].

There about two large manufactures of HRVs and ERVs: Broan and Venmar. Their products are very similar, so we simply took Broan's HEPA Filtration and Heat Recovery Model GSHH3K product as an example of an HRV we would install into this house. This model provided HVI-rated 105 CFM air flow with a maximum power consumption of 232 Watts and 2.0 amp draw.

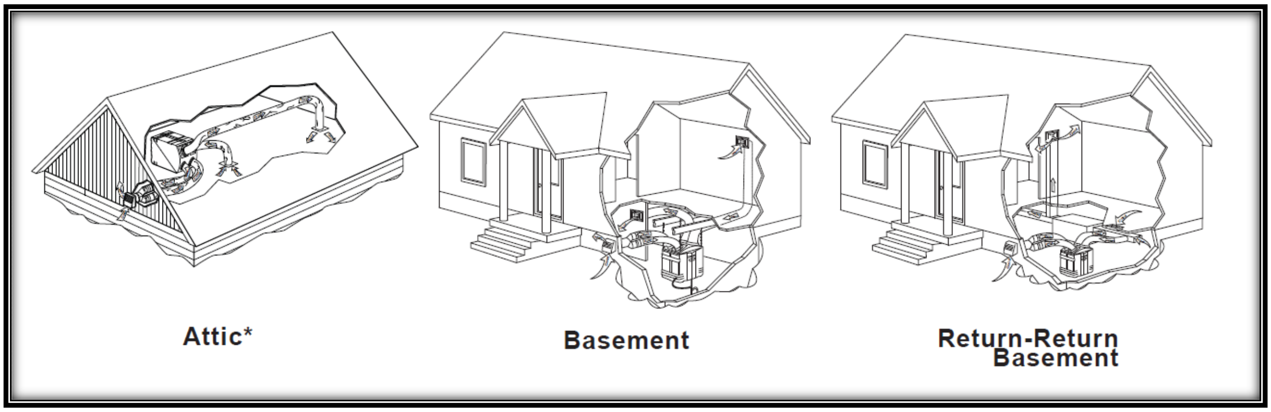

Figure 55 Example installation setups for the Broan HRV system (Appendix C)

Because the calculation of air leakage per year and its effect on heating for our 1805 square foot home is outside the scope of this project, we used a simplified calculator provided by Wisdom and Associates, a private company that provides inspections, energy ratings, indoor air quality inspections, and education on these topics. We provide the parameters of our HRV system and the standard exhaust fan system to compare the energy usage and cost of each system. Some assumptions we make in this model are 16 hours of ventilation use per day and an average outdoor temperature of 40 degrees Fahrenheit which is an estimation of the combined averaged summer and winter temperatures of Tompkins County (an HRV system would be even more cost effective in our calculations the colder it is if we assumed a lower average outdoor temperature). We use 16 hours of ventilation as a conservative estimate not only to maintain heat levels in the home, but also to filter air and change the air within the home. See below for our calculations[19]:

[18] "How Much to Vent". The Home Ventilating Institute. http://www.hvi.org/resourcelibrary/HowMuchVent.html
[19] Wisdom and Associates. http://www.wisdomandassociates.com/education/bpi/calculators/HRV%20Vs.%20Exhaust%20Only%20Ventilation%20Cost%20Effectiveness%20Calculator%20Based%20on%20Temperature.htm

Heat Recovery Ventilator Cost Estimates

Exhaust Only Ventilation Cost Estimates

Cost per therm of heating fuel	1.33	Cost per therm of heating fuel	1.33
Cost per BTU of heating fuel	$0.00001330	Cost per BTU of heating fuel	$0.00001330
Full Speed CFM of Exhaust	108.00	CFM of Exhaust	100.00
Full Speed CFM of Supply	105.00		
Hours Per Day of Run Time	16.00	Hours Per Day of Run Time	16.00
Hours Per Year of Run Time	5,840.00	Hours Per Year of Run Time	5,840.00
Yearly air leakage from unbalanced flow	1,051,200.00	CFM of Exhaust per Year	35,040,000.00
Average Indoor Temperature	70	Average Indoor Temperature	70
Average Outdoor Temperature	40	Average Outdoor Temperature	40
AFUE of Heating Appliance	80.00%	AFUE of Heating Appliance	80.00%
Average difference between inside and outside temperature	30	Average difference between inside and outside temperature	30
Pounds of Air Leakage over 1 year	78,841.97	Pounds of Air Leakage over 1 year	2,628,000.66
BTU required to raise 1 year of air leakage 1 degree	18,922.07	BTU required to raise 1 year of air leakage 1 degree	630,720.16
BTU required to raise 1 year of air leakage the average temperature difference between inside and outside	567,662.19	BTU required to raise 1 year of air leakage the average temperature difference between inside and outside	18,921,604.73
Total BTU adjusted for AFUE	709,577.74	Total BTU adjusted for AFUE	23,652,005.91
Cost of Unbalanced Flows	$9.44	Estimated Cost of exhausted air	$314.57
HRV Efficiency	75.00%		
Cost of HRV Efficiency	$125.66		
KWH electrical costs	0.19	KWH electrical costs	0.19
Amp Draw of HRV Motor	2	Amp Draw of Exhaust Fan	1
Electrical cost of running HRV	$266.30	Electrical cost of running fan	$133.15
Total operational Cost of HRV	$401.40	Total operational Cost of Exhaust Only Ventilation System	$447.72

Additional Calculations for CO_2 emissions:

Annual gas saved using the HRV system: $23{,}652{,}005.91 - 709{,}577.74 = 22{,}942{,}428.17$ BTU
Annual electricity used by HRV system: 1402 kWh
Annual saved CO_2 emissions:

$$\frac{22{,}942{,}428.17\ BTU}{3412.1416\frac{BTU}{kW\square}} \times 0.413\frac{lbs.\ CO2}{kW\square} - 1402\ kW\square \times 0.940\frac{lbs.\ CO2}{kW\square} = 1{,}459\ lbs.CO2$$

The use of an HRV system results in a $30.20 cost savings per year in utilities (in the first year) and with no payback period (given a $1,800.00 cost difference between the two systems). The negative net present value or cost of essentially installing this system that would be beneficial to residents' health and the environment by reducing 1,459 lbs. of CO_2 emissions per year is $4258.48 over the lifespan of this model home (replacing the unit after 15 years).

For a well-insulated home, it is now standard to include high quality ventilation systems such as HRVs/ERVs, so when we apply this to our model, we assume using an HRV system when using any green alternative insulation.

Note that it is suggested that when calculating HRV systems into lifecycle cost analysis, to use a 15 year lifespan because they last for sometimes over 20 years. However, the warranty on this product and similar HRV products are often just 2 years on the parts. We assume that this HRV may need minor repairs or replacement of filters, but will last up to 15 years in this project model. So we will add an additional $50.00 (estimated cost of a part replacement) every two years.

As explained before in the Literature Review, since these HRVs use HEPA filters that capture a standard 99.97% of airborne particles as small as 0.3 microns, the overall health benefits are very high. Residents will experience allergy relief, less skin or eye irritation, and a better breathing environment indoors. These HEPA filters remove bacteria, pollutants such as VOCs, and sometimes odors that irritate lungs. In combination with a home using Low/Zero-VOC paints, a HEPA filtration HRV system will handle most of the other harmful airborne particles in a home.

Urea-Formaldehyde Free Products

Urea-formaldehyde is commonly used as an adhesive for wood products in homes and thus companies are creating better technologies that will replace this adhesive. A company named Columbia Forest Products has developed a green alternative called PureBond Formaldehyde-Free Technology which is a soy-based adhesive. And another alternative adhesive made by Roseburg is phenol-formaldehyde (PF) which is claimed to emit only 0.01 parts per million of formaldehyde, significantly less than the formaldehyde emissions from products that use the standard UF adhesive. Some examples of UF free products are Smith & Fong's PlybooPure and Roseburg's SkyBlend UF-Free Particle Board.

Urea-formaldehyde free products are still in the early stages of becoming a widely used. Data from the EPA has shown that it can cause health issues to people's eyes, skin, nose, and throat. However, Formaldehyde Council, Inc. (FCI) has explained that formaldehyde is a natural chemical that is even produced in the human body and is still being tested in research to be considered a known carcinogen for humans. Even though, UF has been banned in some countries mentioned before in the literature review, the US is slowly making strides in regulating its use. The California Air Resource Board (CARB) has made California the first state to regulate UF in wood products by requiring manufacturers to reduce emissions to the following[20]:

- Particleboard – less than or equal to 0.08 ppm
- Hardwood Plywood – less than or equal to 0.03 ppm
- Medium-Density Fiberboard – less than or equal to 0.08 ppm (by 2012)

We may see this trend continue for other states within the US as more research on formaldehyde is released. But as of now, the only benefit developers may see from using these UF-Free products is the LEED certification points.

[20] "Formaldehyde in Engineered Wood Products". Holz Build. http://www.holzbuild.com/05wellbeing/formaldehyde-free.html

4.5. Materials and Resources

Certified and Local Wood

For certified wood, we focused mainly on using Forestry Stewardship Council (FSC) certified wood for this building because it is becoming a large industry standard for green homes and because it is cost-effective. FSC-certified wood can be ordered from practically anywhere in the United States now because so many logging companies are looking to get their forests certified. And in this project, we look toward ordering certified wood from within 500 miles of the Tompkins County area to support local lumber mills.

The way the FSC determines a forest gets certification is by following their 10 Principles and 56 associated Criteria. Below is a list of the10 key Principles:

Table 8 FSC Certification Key Principles[18]

Principle 1: Compliance with all applicable laws and international treaties.
Principle 2: Demonstrated and uncontested, clearly defined, long–term land tenure and use rights.
Principle 3: Recognition and respect of indigenous people's rights.
Principle 4: Maintenance or enhancement of long-term social and economic well-being of forest workers and local communities and respect of worker's rights in compliance with International Labour Organisation (ILO) conventions.
Principle 5: Equitable use and sharing of benefits derived from the forest.
Principle 6: Reduction of environmental impact of logging activities and maintenance of the ecological functions and integrity of the forest.
Principle 7: Appropriate and continuously updated management plan.
Principle 8: Appropriate monitoring and assessment activities to assess the condition of the forest, management activities and their social and environmental impacts.
Principle 9: Maintenance of High Conservation Value Forests (HCVFs) defined as forests containing environmental and social values that are considered to be of outstanding significance or critical importance.
Principle 10: In addition to compliance with all of the above, plantations must contribute to reduce the pressures on and promote the restoration and conservation of natural forests.

After a forest has been certified, the types of labels that can be found on FSC-certified wood from these forests are[21]:

- FSC 100% label – Products come only from well-managed forests that have met FSC's high social and environmental standards.

[21] "Forest Stewardship Council". Wikipedia. http://en.wikipedia.org/wiki/Forest_Stewardship_Council

- FSC mixed sources – Products support the development of responsible forest management worldwide. The wood comes from FSC-certified well-managed forests, recycled material and/or controlled wood which come from non-controversial sources.
- FSC 100% recycled – Products support the re-use of forest resources which helps to reduce the pressure on natural forests.

Other than the fact that by ordering locally available FSC-certified wood with any one of these labels supports good sustainable forestry management and practice, we find that it has more of a functional purpose today as the incremental costs are almost negligible. The cost of FSC-certified wood is typically 0-15% more expensive than non-certified lumber. Because building material costs are usually less than 10% of the total costs that go into constructing a home that means the additional costs of using FSC-certified wood adds only modestly to the total cost of the home. Installation of certified wood is also no different from its non-certified counterparts.[22]

Rapidly Renewable Resources

As mentioned in the literature review, there are a variety of rapidly renewable resources that can be used in green building. For residential homes, we looked into what uses would be more applicable for rapidly renewable resources, mainly flooring.

Plyboo[23] is essentially plywood made from the rapidly renewable resource that is bamboo. Bamboo is actually a part of the grass family, meaning it's not wood, and has a very fast harvest cycle of three to five years. In contrast, other typical hardwood species have a harvest cycle of about 50 to 100 years. Smith & Fong, the makers of Plyboo since 1989, has since enhanced their normal Plyboo product to being UF-free allowing developers to gain LEED credits from their use in buildings. Plyboo has also gained recognition by the FSC, gaining the world's first non-wood FSC certification for its bamboo resource from China.

Figure 56 Plyboo

Pre-finished bamboo flooring typically costs in the range of \$2.00 to \$6.00 per square foot depending on the quality of finish used; a finish with very low formaldehyde emission for example, would be in the higher price range. Standard pre-finished wood flooring such as oak and maple can range from \$1.50 to \$6.00 per square foot leaving a large range to choose from in quality for a

[22] "FSC Certified Wood". Built It Green. http://www.calhomedesigns.com/greensheets-pdfs/FSC%20Certified%20Woods%2073.pdf
[23] Smith& Fong Plyboo. http://www.plyboo.com/plyboopure-information.html

home. Because the price differences between standard hardwood floors and bamboo have become nearly negligible, we did not include these rapidly renewable resources for flooring in the model.

I-Joists

I-Joists were originally developed by Trus Joist Corporation in 1969, but were very expensive when they were introduced to the market and has not become cost-effective or widely used until the late 1990s and now. Their performance is significantly greater compared to regular dimension lumber because it takes advantage of the I-beam physical shape. The University of Massachusetts, Amherst has broken down the physical characteristics of I-Joists into the following[24]:

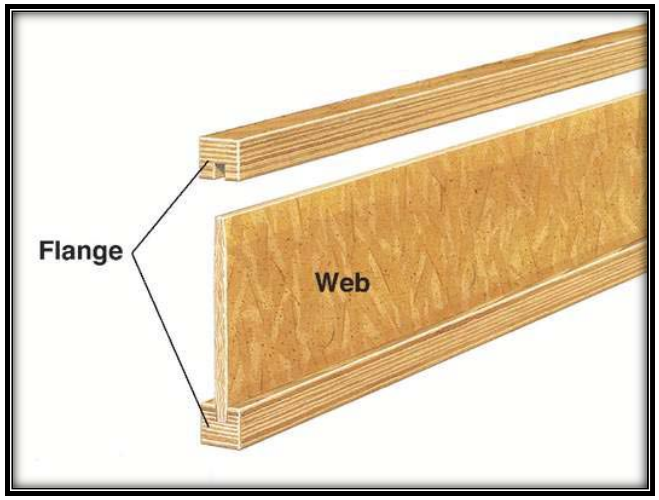

Figure 57 I-Joist Cross Section

Strength of a joist is determined by wood species, grade and size.

- Choose a species and grade of lumber that is twice as strong and it will carry twice the load.
- Double the thickness of a joist and it will carry twice the load.
- Double the depth of a joist and it will carry 4 times the load.

Stiffness is also affected by species, grade and size.

- Use a species and grade of lumber that is twice as stiff (E value indicates stiffness) and deflection is cut in half.
- Double the thickness of a joist and the deflection is cut in half.
- Double the depth of a joist and the deflection is reduced to 1/8.

One can see that I-Joists are ideal because of the advantage in strength, stiffness, lighter weight, increased span potential, and waste reduction. In a green home such as the one for this project, we would typically see builders use I-Joists in the framing for floors and ceilings.

[24] "The Evolution of Engineered Wood I-Joists". University of Massachusetts, Amherst. http://bct.eco.umass.edu/publications/by-title/the-evolution-of-engineered-wood-i-joists/

The governing body that standardized the use of I-Joists in the industry was APA-The Engineered Wood Association. APA saw a need for I-Joists to be standardized once builders became interested in learning more about how they could use I-Joists in their own projects. Even though I-Joists are specially engineered to carry more weight, it is important that people know how to properly use them based on the structural specifications in which they are manufactured or else there would be safety issues. APA stamps the I-Joists of its member mills with the maximum spans of 12", 16", 19.2", and 24". Interestingly, only 20% of the manufacturers who produce I-Joists support this method of standardization because the rest of the manufactures believe that APA is just increasing its member revenue share and that it may limit incentives for further innovation this product. However, 100% of building officials support it because they want a uniform identification system that APA seems to provide.

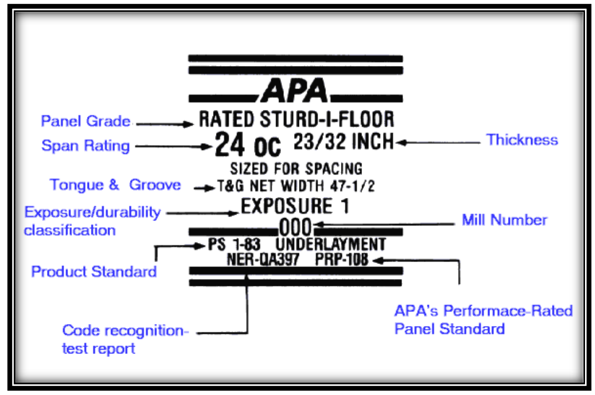

Figure 58 APA I-Joist Label

Because I-Joist now only cost anywhere from $1.30 to $3.30 per linear foot depending the flange size and depth, it is comparable and even cheaper than dimension lumber which typically costs $3.00 per linear foot or more. We did not include I-Joists in our model like the other materials because we are more concerned about the ways to reduce carbon emissions and water savings. Using I-Joists would help reduce costs and help save trees, but the research in how many trees we are actually saving by buying I-Joists goes beyond the scope of this project. We would also have to calculate the type and amount of I-Joists we would need for a specific home which leaves little room for flexibility. Essentially if we increase costs slightly by using certified wood and rapidly renewable wood like bamboo and reduce costs by using I-Joists in our model, the costs of these green materials would cancel out.

4.6. Sustainable Site Work

Sustainable site development and landscaping involves the different steps that are taken to prepare a physical site for construction and planting, and how this site is then maintained so as to ensure minimal impact on the environment. Given the scope of our project to only cover technologies that fall within the outside walls of the homes to be designed, this portion of the project instead focused on the different roofing technologies that can contribute to driving energy efficiency within the homes. Research touched briefly on certain technologies that fall outside the scope of the project, but due to a dearth of information governing how exactly to quantify the benefits of these technologies, we instead considered the implications of investing in these technologies, and the qualitative benefits that may be derived from implementing them in/around the homes.

COOL ROOFING

It is common practice for people who live in tropical climates to wear light-colored clothing as a means of keeping themselves cool. They do this because they know that light(er) colors reflect heat and sunlight more effectively than dark(er) colors, which are more known for absorbing heat and light. In this way, buildings are similar to people, and having a dark-colored roof usually results in higher building temperatures than if a light-colored roof was in use.

As the name implies, a cool roof is one that reflects the sun's heat and emits absorbed radiation back into the atmosphere, instead of transferring it to the building below, and thus helps maintain the building at a cooler and more constant temperature. By literally staying cooler and reducing the amount of heat transferred to the

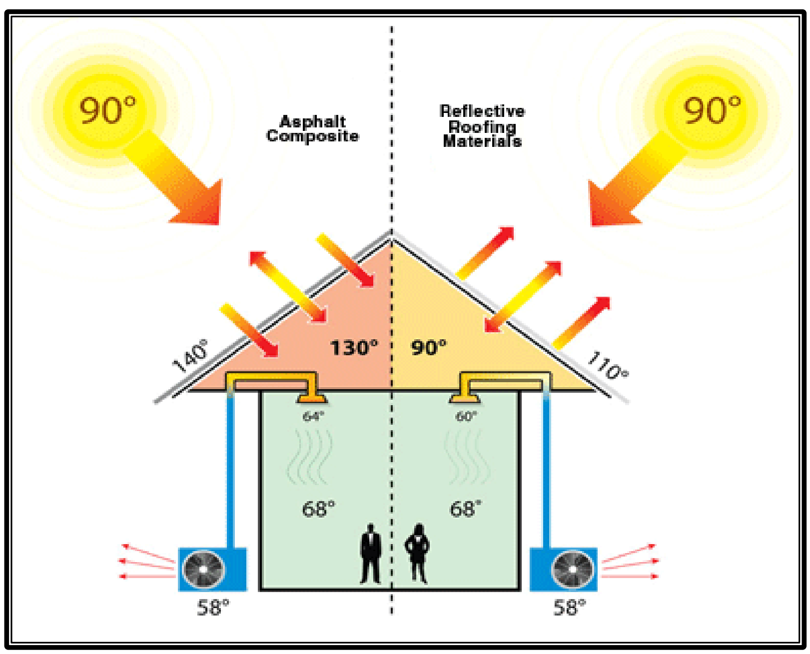

Figure 59 Roofing Comparison

[25]building below, a cool roof functions like white t-shirt, and keeps the internal temperature of a building cooler[26]. It is the general misconception that for a roof to be cool, it must be white. This is however not the case. There are countless "cool color" products which make use of darker-colored pigments that are highly reflective in the near infrared (non-visible) portion of the solar spectrum. With the advents in "cool color" technologies, there are roofs that come in a wide variety of colors and still maintain a high solar reflectance.

Traditional roofs in the United States can reach summer peak temperatures of 150 to 185°F (66-85°C), thus creating a series of hot surfaces as well as warmer air temperatures nearby. In contrast, cool roofing products are made of materials that can remain approximately 50 to 60°F (28-33°C) cooler than the traditional materials during peak summer weather.

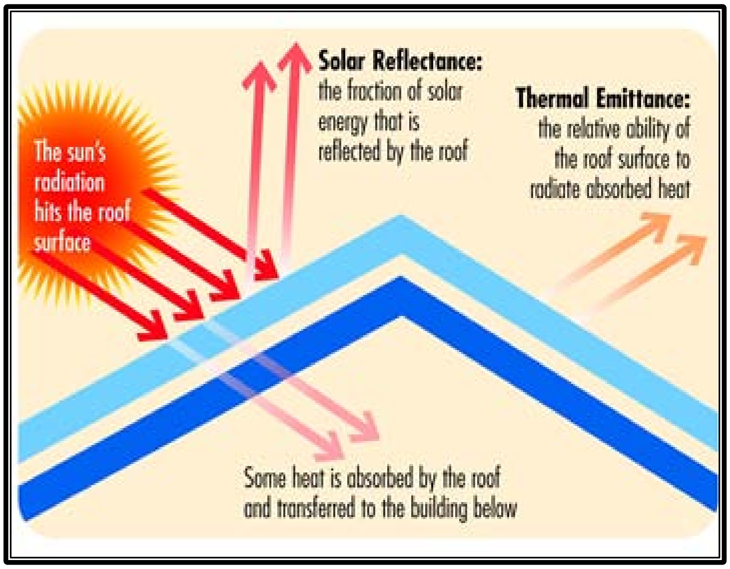

Figure 60 Characteristics of Cool Roofing Materials

When measuring the "coolness" of a roof, the two basic characteristics that are considered are the solar reflectance (SR) and thermal emittance (TE) of the roofing materials[27]. Both properties are rated on a scale from 0 to 1, with 1 being the most reflective or emissive. Solar Reflectance or Albedo is the percentage of solar energy reflected by a surface. By measuring how well a material reflects energy at each solar energy wavelength, and then calculating the weighted average of these value researchers have been able to determine solar reflectance of different materials. With low solar reflectance of 5 to 15 percent, traditional roofing materials absorb 85 to 95 percent of the energy reaching them instead of reflecting the energy back out to the atmosphere. The coolest roof materials have a high solar reflectance of more than 65 percent, absorbing and transferring to the building 35 percent or less of the energy that reaches them. These materials reflect radiation across the entire solar spectrum, especially in the visible and infrared (heat) wavelengths. Though secondary to solar reflectance in determining a roof's coolness, thermal emittance is also a part of the equation. According to the principle of thermal equilibrium, any surface exposed to radiant energy will get hotter until it reaches a temperature where it is giving off

[25]]http://www.tridentroofing.com/newsletters/cool-roofs.htm
[26] http://www.coolroofs.org/HomeandBuildingOwnersInfo.html
[27] http://www.coolroofs.org/

as much heat as it is receiving. A material's Thermal Emittance determines how much heat that material will radiate per unit area at a given temperature. In other words, it determines how readily a surface gives up heat. Because it gives off its heat more readily, when in sunlight, a surface with high thermal emittance will reach thermal equilibrium at a lower temperature than a surface with low emittance.

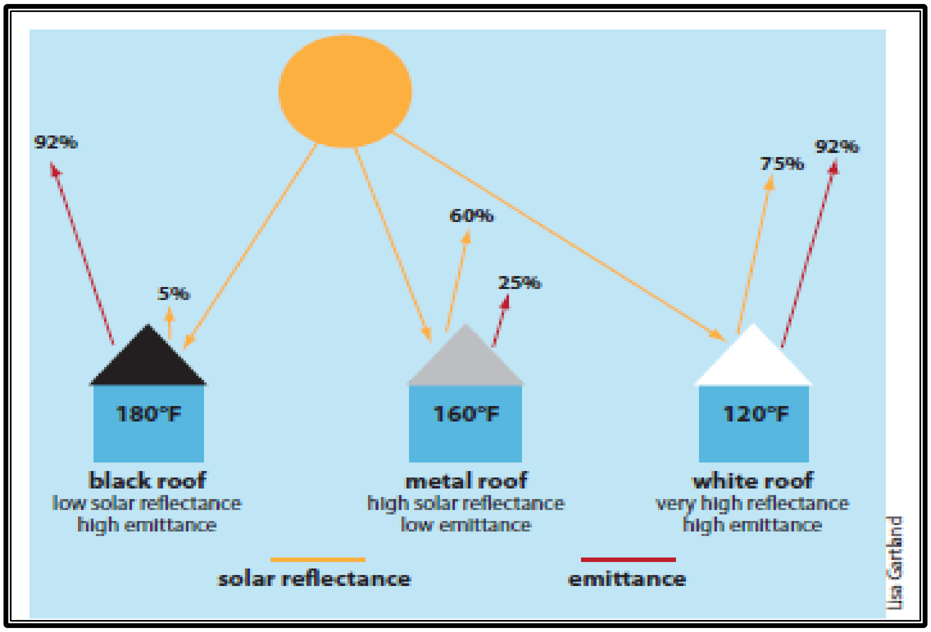

Figure 61 Effects of Solar Reflectance & Thermal Emittance on Roof Temperature

The Cool Roof Rating Council (CRRC), an independent, non-profit organization that maintains a third-party rating system for the radiative properties of roof surfacing materials, measures these two properties for roofing products, both for the product's initial values and after three years of weather exposure. The results for this allow interested persons compare the rated values of various product types and brands, and are published on the online Rated Products Directory, which is available to the general public at no charge[28].

BENEFITS OF COOL ROOFS

Cool Roofs provide numerous direct benefits to the building owner and occupants, including:

- Increased occupant comfort, especially during the hot summer months
- Further reducing the need for air conditioning use, resulting in energy cost and consumption savings ranging from 10 – 30 %
- Decreased roof maintenance and replacement costs due to longer roof life span[29]

[28] http://www.coolroofs.org/HomeandBuildingOwnersInfo.html
[29] http://www.epa.gov/heatisland/resources/pdf/CoolRoofsCompendium.pdf

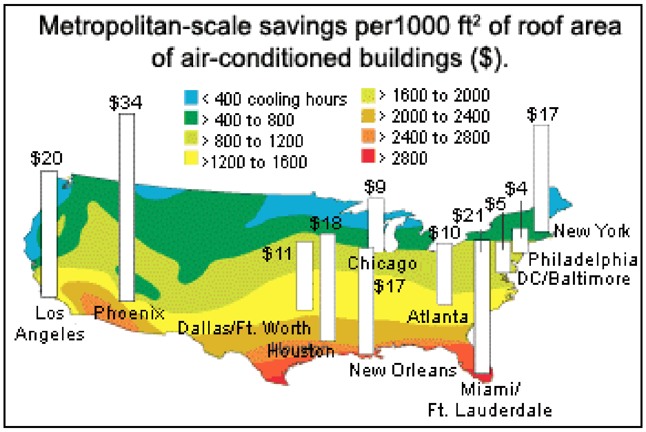

Figure 62 Cost Saving benefits of Cool Roofs

In addition to these well-known benefits to the building owner and occupants, cool roofs also benefit the environment and public health[30]. By reducing the need for, and use of air conditioning in buildings, the associated energy savings from the use of cool roofs occur when the demand for electricity is at its peak. The cool roofs therefore help reduce the stress on the energy grid during the hot summer months, and thus helps avoid shortages that can cause black outs and brownouts. Cool roofs directly reduce the emission of greenhouse gases by conserving electricity for air condition therefore emitting less CO2 from power plants[31]. Also, by simply reflecting the sun's energy as light back to the atmosphere, cool roofs help in the mitigation of global warming. According to a study by the Lawrence Berkeley National Laboratory, if the whole world were to switch to reflective roofing, this change will produce a global cooling effect that is equivalent to offsetting 24gigatons of CO2 over the lifetime of the roofs. (www.coolroofs.org)

A topic of contention with cool roofs, especially as it relates to this project, is the effect they have in regions with cool climates. Though it is clear that cool roofs are extremely beneficial in warmer climates, the question still arises that are they able to produce the same benefits in cooler climates. In most climate zones worldwide, cool roofs can significantly reduce a building's cooling load. However, cool roofs can also increase heating costs in winter months. Cool roofs can have a wintertime heating penalty because they reflect solar heat that would help warm the building. Although building owners must account for this penalty in assessing the overall benefits of cool roofing strategies, in most U.S. climates this penalty is not large enough to negate the summertime cooling savings. One reason for this is that the amount of useful energy reflected by a cool roof in the winter tends to be less than the unwanted energy reflected in the summer. This difference occurs primarily because winter days are shorter, and the sun is lower in the sky. The sunlight strikes the Earth at a lower angle, spreading the energy out over a larger area and making it less

30 http://www.coolroofs.org/documents/IndirectBenefitsofCoolRoofs-WhyCRareWayCool.pdf
31 http://www.greenyour.com/home/home-improvement/roof/tips/install-a-cool-roof

intense. In cities such as Ithaca, where heating requirements are higher, there also are more cloudy days during winter, which reduces the amount of sun reflected by a cool roof. Snow cover on roofs in these climates also can reduce the difference in solar reflectivity between cool and non-cool roofs.

MODEL INPUT

About two-thirds of US residential roofing is constructed of wood covered with asphalt shingles. Asphalt is less expensive and requires a lower weight bearing structure than concrete, clay or slate. Asphalt is less expensive than all other roofing materials and often looks more appealing than metal but it is also not as long lasting[32]. For the purposes of this project, a dark roof made of Asphalt Shingles with solar reflectance of 0.05 (5%) and thermal emittance of 0.9 (90%) was used as the "Baseline Model." Another governing body that maintains a rating system for cool roofing products is EnergyStar, which is a joint EPA and DOE program that helps consumers save money and protect the environment through energy-efficient products and practices. Roofing products that are EnergyStar qualified reflect more of the sun's rays, lower roof surface temperatures by up to 100F, decrease the amount of heat transferred into a building, and also reduce peak cooling demands. Solar reflectance is the most important characteristic of a roof product in terms of yielding the highest energy savings during warmer months. The higher the solar reflective value the more efficient the product is in reflecting sunlight and heat away from the building and reducing roof temperature. In warm and sunny climates highly emissive roof products can help reduce the cooling load on the building by releasing the remaining heat absorbed from the sun. However, there is also evidence that low emissivity may benefit those buildings located in colder climates by retaining heat and reducing the heating load. Given the location of Tompkins County, and its climate, this characteristic of emissivity was of particular importance in the selection criteria for the alternate roofing technology. The alternate technology was taken from the EnergyStar qualified roof products list, and it is a Galvalume Metal Roof with solar reflectance of 0.74 (74%) and thermal emittance of 0.06 (6%).

Using the US Department of Energy Oak Ridge National Laboratory (ORNL) Cool Roof Calculator[33], we were able to determine the annual cost savings, the annual cooling energy savings, and the annual heating energy savings/penalty on a square-foot basis of using the selected roof in comparison to the baseline roof model. To generate these savings comparisons, the calculator required input on the building's geographical location, and the regional costs of energy. It also

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[32] http://www.roofingcontractorpittsburgh.com/roofing
[33] http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm

required information about the buildings insulation, the solar reflectance & thermal emittance of the proposed roof, and the efficiency of the heating & cooling systems in use in the building. Using the result from this calculator, we were then able to manipulate the numbers to fit into our model and determine the annual consumption and energy savings as a result of the implementation of the alternate technology. (http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm)

5. Sustainability Model

The model is based on the difference between a baseline and green alternatives. Each of the different technologies described before has a financial statement (which includes capital and annual costs) and an environmental one (which includes energy savings, that is the CO_2 emissions savings and water savings).

FINANCIAL ANALYSIS						
	Year	0	1	2	3	
BASELINE	$3 064,78					
Capital Cost		$ 499,00	$ -	$ -	$ -	$
Annual Electricity Cost		$ -	$ 86,95	$ 89,56	$ 92,25	$ 95
Annual Water Cost		$ -	$ 39,27	$ 40,44	$ 41,66	$ 42
Total Expense:		$ 499,00	$ 126,22	$ 130,00	$ 133,90	$ 137
ALTERNATIVE 1	$4 816,43					
Capital Cost		$ 549,00	$ -	$ -	$ -	$
Annual Electricity Cost		$ -	$ 186,00	$ 191,58	$ 197,33	$ 203
Annual Water Cost		$ -	$ 37,69	$ 38,83	$ 39,99	$ 41
Total Expense:		$ 549,00	$ 223,69	$ 230,41	$ 237,32	$ 244
ALTERNATIVE 2	$4 538,35					
Capital Cost		$899,00	$ -	$ -	$ -	$
Annual Electricity Cost		$ -	$ 144,00	$ 148,32	$ 152,77	$ 157
Annual Water Cost		$ -	$ 25,65	$ 26,42	$ 27,22	$ 28
Total Expense:		$ 899,00	$ 169,65	$ 174,74	$ 179,99	$ 185
ALTERNATIVE 3	$5 906,19					
Capital Cost		$1 599,00	$ -	$ -	$ -	$
Annual Electricity Cost		$ -	$ 151,00	$ 155,53	$ 160,20	$ 165
Annual Water Cost		$ -	$ 23,56	$ 24,27	$ 24,99	$ 25
Total Expense:		$1 599,00	$ 174,56	$ 179,80	$ 185,19	$ 190

ENVIRONMENTAL IMPACT					
	Year	0	1	2	3
BASELINE	13258				
Electricity Consumption			470	470	470
Annual CO2 Released			442	442	442
ALTERNATIVE 1	5247				
Electricity Consumption			186	186	186
Annual CO2 Released			175	175	175
ALTERNATIVE 2	4062				
Electricity Consumption			144	144	144
Annual CO2 Released			135	135	135
ALTERNATIVE 3	4259				
Electricity Consumption			151	151	151
Annual CO2 Released			142	142	142

Figure 62 Model Snapshot

In the main tab of the calculations of the alternative, we create the option to choose between the different alternatives in technologies, the user is free to create their own combination.

Refrigerator		18.2 Frigidaire ENERGYSTAR Refrigerator	2		
Lighting		13-watt Compact Flourescent Lights	2		
Dishwasher		High Efficiency / Frigidaire 24" Built-In Dishwasher	2		
Clothes Washer		Baseline / Frigidaire 24" Built-In Dishwasher	3		
Toilets		High Efficiency / Frigidaire 24" Built-In Dishwasher Very High Efficiency / Maytag Jetclean Plus Dishwasher	2		
Showerheads		Ultra High Efficiency / Bosch 24" Evolution 800 Plus Serie	4		
Lavatory Faucets		Ultra High Effciency: Faucet Attachment (faucet no	4		
Kitchen Faucets		High Efficency: Low Flow Rate (Water Sense Rated	2		
Ventilation		HRV	2		
Space Heating		Boiler	1		
Insulation	Walls	SIP			Double-glass, plus two films,
Water Heating		Condensing Gas Storage	2		
Roofing		High Efficiency / Galvalume Metal Roof	2		
PV System		5 kW	Generates	5500 kWh/year	

Figure 63 Model Options

The decisions are linked with the results mentioned before in a main table:

The different results are then compared to the baseline in order to quantify the benefits of the different alternatives.

FINANCIAL ANALYSIS					
Year	0	1	2	3	
Capital Cost:					
Space Heating	$ 4 600,00	$ -	$ -	$ -	$
Insulation	$ 18 952,56	$ -	$ -	$ -	$
Roofing	$ 8 100,00	$ -	$ -	$ -	$
Water Heating	$ 2 000,00	$ -	$ -	$ -	$
Refrigerator	$ 469,00	$ -	$ -	$ -	$
Lighting	$ 25,27	$ -	$ -	$ -	$
Dishwasher	$ 439,00	$ -	$ -	$ -	$
Clothes Washer	$ 899,00	$ -	$ -	$ -	$
Toilets	$ 265,00	$ -	$ -	$ -	$
Showerheads	$ 27,00	$ -	$ -	$ -	$
Lavatory Faucets	$ 98,48	$ -	$ -	$ -	$
Kitchen Faucets	$ 169,90	$ -	$ -	$ -	$
Ventilation	$ 2 000,00	$ -	$ -	$ -	$
PV sytem	$ 22 500,00	$ -	$ -	$ -	$
TOTAL CAPITAL COSTS:	$ 60 545,21	$ -	$ -	$ -	$
Annual Expenses:					
Gas Expenses					
Space Heating	$ -	$ 928,49	$ 956,35	$ 985,04	$
Water Heating	$ -	$ 98,72	$ 101,68	$ 104,73	$
Cooking	$ -	$ 38,37	$ 39,52	$ 40,71	$
Insulation savings	$ -	$ (354,55)	$ (365,19)	$ (376,15)	$
Roofing Savings	$ -	$ (154,80)	$ (159,44)	$ (164,23)	$
Electricity Expenses					
Space Cooling	$ -	$ 193,83	$ 199,64	$ 205,63	$
Refrigerator	$ -	$ 70,49	$ 72,60	$ 74,78	$
Lighting	$ -	$ 100,07	$ 103,07	$ 106,17	$
Electronics	$ -	$ 147,73	$ 152,16	$ 156,73	$
Dishwasher	$ -	$ 58,83	$ 60,59	$ 62,41	$
Clothes Washer	$ -	$ 144,00	$ 148,32	$ 152,77	$
Computers	$ -	$ 78,21	$ 80,56	$ 82,97	$
Other small electric appliances	$ -	$ 65,84	$ 67,82	$ 69,85	$
Ventilation	$ -	$ 99,47	$ 102,45	$ 105,53	$
PV system maintenance	$ -	$ 80,00	$ 82,40	$ 84,87	$
PV system savings	$ -	$ (1 017,50)	$ (1 048,03)	$ (1 079,47)	$
Water Expenses					
Dishwasher	$ -	$ 8,99	$ 9,26	$ 9,53	$
Clothes Washer	$ -	$ 25,65	$ 26,42	$ 27,22	$
Toilets	$ -	$ 31,20	$ 32,13	$ 33,10	$
Showerheads	$ -	$ 48,75	$ 50,21	$ 51,72	$
Lavatory Faucets	$ -	$ 12,19	$ 12,55	$ 12,93	$
Kitchen Faucets	$ -	$ 29,25	$ 30,13	$ 31,03	$
TOTAL ANNUAL EXPENSES:	$ -	$ 733,22	$ 755,22	$ 777,87	$
TOTAL COSTS	$ 60 545,21	$ 733,22	$ 755,22	$ 777,87	$
Construction cost	$ 158 331,57				
TOTAL COSTS	$ 218 876,78				

Baseline / Alternative dynamic / Results / Results static / Lighting / R

Figure 63 Model Results

6. Results

We ran our model under three different scenarios in order to compare results. The three scenarios are compared to the baseline, which has the following characteristics:

Refrigerator: 18.2 Frigidaire Refrigerator

Lighting: 60-watt Incandescent Lighting

Dishwasher: Baseline Frigidaire 24" Built-in Dishwasher

Clothes Washer: Whirlpool Federal minimum standard

Toilet: Low Consumption Windham Toilet

Showerhead: EPA minimum standard flow rate Delta Showerhead

Lavatory Faucet: EPA minimum standard flow rate Moen faucet

Kitchen Faucet: EPA minimum standard flow rate Moen faucet

Water Heating: Conventional Gas Storage water heater

Ventilation: Standard Exhaust

Space Heating: Boiler

Wall Insulation: Wood frame

Windows: Double-pane Wood Frame windows

Ceiling Insulation: No insulation

Roofing: Asphalt Shingles

The Baseline has a total capital cost of $21,668.43 and a cost per square foot of $100. It has an annual electricity consumption of 6,308 kWh and an annual gas consumption of 936.5 therms. This translates to 7.83 tons of carbon dioxide released per year. In addition, the baseline consumes 64 thousand gallons of water per year.

6.1. Scenario 1: Highest Efficiency

For this scenario the most efficient alternative for each feature of the house was chosen. No renewable energy is installed under this scenario.

The results are shown on the following table.

Highest Efficient		
	Green Building	Baseline
Capital cost	$ 53,710.08	$ 21,668.43
Cost psf	$ 117.80	$ 100.00
Annual cost	$ 1,304.56	$ 2,528.52
Additional Investment	**$ 32,041.65**	
Annual savings	**$ 1,223.95**	
IRR	3.72%	
NPV	$ (11,199.62)	
CO2 savings (pound/yr)	5.82	
Water savings (thousand gal/yr)	42.20	

Figure 64 Scenario 1

As you can see, under this scenario a 17.8% increase in the total house cost translates to 5.82 tons of carbon dioxide emissions saved and 42.2 thousand gallons of water saved annually. This scenario has a net present value of negative $11,199.62 over a 30-year period.

6.2. Scenario 2: Efficient

In this second scenario the efficient features of the house are chosen taking into consideration their economic advantages as well. Those alternatives for each feature that make the most sense financially were chosen. The house characteristics under this scenario are as follows:

Refrigerator: 18.2 Frigidaire ENERGYSTAR Refrigerator

Lighting: 13-watt Compact Fluorescent Lighting

Dishwasher: High Efficiency Frigidaire 24” Built-in Dishwasher

Clothes Washer: Very High Efficiency GE ENERGYSTAR clothes washer

Toilet: High Efficiency Windham Toilet

Showerhead: Ultra High Efficiency Niagara 1.25 gpm showerhead

Lavatory Faucet: Ultra High Efficiency 0.5 gpm low flow dual-thread faucet

Kitchen Faucet: Ultra High Efficiency 0.5 gpm low flow dual-thread faucet

Water Heating: Condensing Gas Storage water heater

Ventilation: HRV system

Space Heating: High Efficiency Furnace with programmable thermostat

Wall Insulation: Sprayed Foam Insulation

Windows: Double-pane Low-e Wood Frame windows

Ceiling Insulation: 4-inch foam insulation

Roofing: Galvalume Metal Roof

The results are shown on the following table.

Efficient	Green Building		Baseline	
Capital cost	$	39,522.28	$	21,668.43
Cost psf	$	109.92	$	100.00
Annual cost	$	1,392.88	$	2,537.99
Additional Investment	**$**	**17,853.85**		
Annual savings	**$**	**1,145.12**		
IRR		7.76%		
NPV	$	1,645.68		
CO2 savings (pound/yr)		5.68		
Water savings (thousand gal/yr)		33.32		

Figure 65 Scenario 2

As shown, under this scenario a 9.9% increase in the total house purchase cost translates to 5.68 tons of carbon dioxide emissions saved and 33.32 thousand gallons of water saved annually. Unlike the past scenario, this scenario has a positive net present value of $1,645.68 over a 30-year period.

The Second Nature neighborhood model under the efficient scenario consumes 3 kWh/SF/yr of electricity and about 18,000 btu/SF/yr of gas. This can be compared with actual values for calendar year 2010 from the Ecovillage at Ithaca community. In the community, a subset of 43 houses were found to consume 31,500 btu/SF/yr of gas and a subset of 31 houses were found to consume 2.49 kWh/SF/yr of electricity. Note that the number of houses that were possible to sample is different for gas and electricity due to the individual characteristics of the various houses in the community, and the way in which utility supplies are configured. However, since there are 60 houses total, the numbers sampled are a large subset of the total and are thought to be quite representative of the whole population.

6.3. Scenario 3: Efficient with Solar PV system

This third scenario is identical to the second scenario except that it adds a 1.2 kW solar photovoltaic system to the house. The size of the photovoltaic system was determined by making sure that the overall net present value of the project remained positive. This way the environmental savings of the house can be increased to its maximum without it becoming a financial burden.

The results are shown on the following table.

Efficient + PV (1.2 kW)				
	Green Building		Baseline	
Capital cost	$	44,922.28	$	21,668.43
Cost psf	$	112.92	$	100.00
Annual cost	$	1,167.88	$	2,537.99
Additional Investment	**$**	**23,253.85**		
Annual savings	**$**	**1,370.12**		
IRR		7.03%		
NPV	$	77.08		
CO2 savings (pound/yr)		6.24		
Water savings (thousand gal/yr)		33.32		

Figure 67 Scenario 3

As you can see, under this scenario a 12.9% increase in the total house cost translates to 6.24 tons of carbon dioxide emissions saved and 33.32 thousand gallons of water saved annually. This scenario has the highest savings in carbon dioxide emissions while maintaining a slightly positive net present value of $77.08.

In practice, since the NPV is so close to breakeven (IRR=7.03% vs. MARR=7%), the decision maker might decide not to invest. However, given the additional green benefits of the PV system and the uncertainty of future energy prices, there would be a strong advantage to do so.

7. Recommendations

The results of the first scenario make it very evident that some advanced technologies are not economically justifiable. For such a staggering increase in cost, the resulting savings in environmental impact are too small to be significant., such as triple-glass, gas-filled windows and composting toilets. However, it is worth noting that when deciding to incorporate green features into a home it is not convenient to do so with the objective of embarking on a prosperous financial venture, because at this time you can always find a more convenient investment. Green features should be incorporated for their environmental advantages that in the long run pay for themselves.

The following table and graph compare the different scenarios.

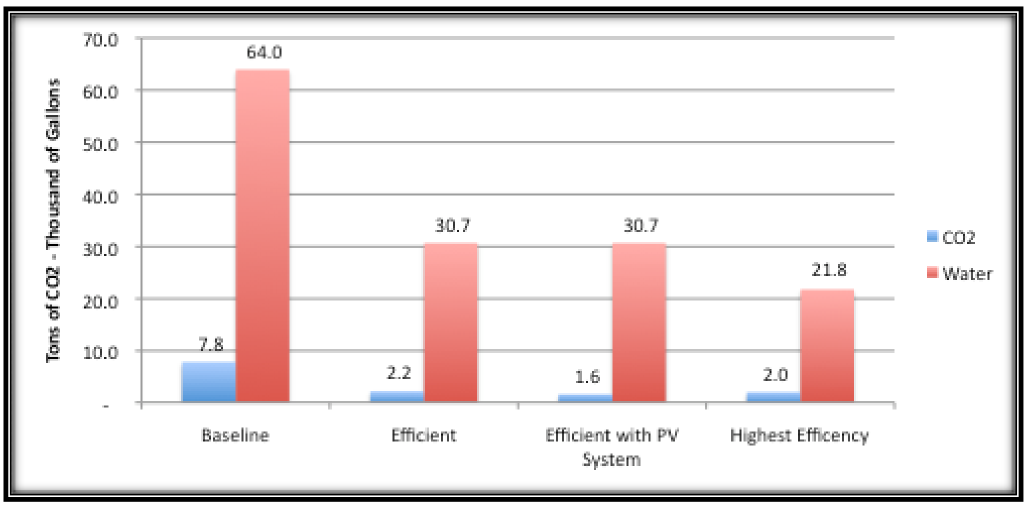

Figure 66 Comparison of Environmental Impact by Scenario

Table 9 Scenario Comparison

Scenario	Incremental Cost/ sq. ft	CO2 Savings	Water Savings
Efficient	$ 9.92	5.68	33.32
Efficient with PV System	$ 12.92	6.24	33.32
Highest Efficiency	$ 17.80	5.82	42.20

By comparing the three scenarios we quickly conclude that incorporating the greenest features is not a great idea. An efficient scenario with a photovoltaic solar system can save significantly more carbon dioxide emissions with a much lower cost. When building a new home we strongly recommend taking a strategy such as the one described earlier for the efficient scenario and we recommend incorporating a solar photovoltaic system as well. Choosing the green features for a new home based on a combination of both their economic and environmental performance is the smart thing to do. Some significant technologies have matured to the point that their energy savings make them much more economical than their baseline counterpart. The only disadvantage to these technologies is that the initial investment is much greater, but we strongly believe that the smarter decision is to make the heftier initial investment, which in the long run will represent significant energy savings.

We recommend incorporating the solar photovoltaic system because it provides a source of reliable energy and a reduction in carbon dioxide emissions at a low cost over 30-years. It also allows you to be less exposed to unpredictable energy costs in the future. The difference in net present value between the efficient scenario and the efficient scenario with a PV system is only a little over $1,500 and this is without considering government incentives. Over a thirty-year period and considering the size of the investment of building a new home, a $1,500 increase in cost is not too significant. We judge that the benefits fairly justify the cost.

8. Future Expansion

Specific Site

An important aspect of this type of project that was not covered due to time restraints and project scope was an evaluation of a specific site location. The location of the site and surrounding area can play a large role in the overall sustainability of a development. Evaluating the available resources and topography will help to determine what additional or specific types of energy sources and technologies that are available for utilization. There are many technologies that only operate within specific environmental conditions to be efficient and utilized properly.

Development Site Plan

Another important aspect that was not covered due to time restraints and project scope was an evaluation and design of a site plan. The locations, directions, and density of the individual units can create benefits for the sustainability of a development. Proper location of individual units and proximity to resources is just as important as the technologies in each unit. With proper research and forethought, the same development could utilize its resources well and create a more sustainable development.

Development Size

For this project we did not evaluate the increased savings due to an economies of scale. All of the assumptions used in this report were based on a single unit and then multiplied to determine a whole developments savings and costs. However, in reality there are a lot of savings in cost just by producing many similar units. The initial startup cost gets shared among multiple units and reduces the overall cost.

Also, energy savings could be increased by researching for technologies that operate on a development wide scale rather than a per unit basis. There could be greater savings by utilizing a community laundry services or community wide waste water treatment plant that could reuse grey water for landscaping, etc. There are a plethora of technologies that were not discussed because of the scale of the project. There is room for a big improvement in savings by evaluating the economy of scale.

Water Efficiency

Looking back on the project there were two main in water efficiency that was originally intended to be research, however due to time constraints and the overall scope of the project these two areas were not covered. Water efficiency was originally intended to cover both indoor water conservation and water reuse technologies however because of the volume of research required to meet the parameters set by the project scope for indoor water conservation research into water reuse technologies had to be suspended. However, there are still some basic technologies for water reuse in the literature review which future groups can work off of.

In addition to limiting the overall scope of water efficiency to only indoor water conservation, there were specific technologies within indoor water use which were left out of the project. When doing research into alternative technologies for dishwashers it was discovered that there were two types of washers, compact and standard dishwashers. After discovering this, the original intention was to research four technologies for each of the two types of dishwashers. However, due to project constraints research had to be limited to only standard size dishwashers.

Lastly if more time was allotted to do more than it would have been develop a more standardized basis for the specific fixture models that were used. If all of the different technologies for a specific fixture were chosen from one manufacture, for example all of the selected clothes washer were manufactured by GE, it would create more of a standard for comparing the different efficiency levels for the fixture because there would be less fluctuation in unit cost and other factors which can be different depending on the manufacturer of that unit.

9. Team management reflections

This project did not have a sole technical purpose; it was also an opportunity for the team members to deal with project management aspects. You will find here under the personal reflections on the project of each team members and you will find in Appendix D – Management reports the different management reports (midterm and final).

Anson Lin's reflections

Judging from where we ended up in this project and looking back at my personal goals, I am satisfied with how much I learned personally and the quality of the project we delivered. I was able to contribute to most aspects of the project even though we divided it up into separate sections for each team member. And through that process, I was able to learn about what goes into designing an efficient and cost-effective green home.

I especially enjoyed going into depth about specific technologies on my part: the HRV system and lime plaster walls. Not all of it was included in the model, but doing the research into how complex these systems can be and how they affect the environment made me realize how detrimental the average home is to the environment (or at least the material that goes into building one). Now I am also very aware of how bad indoor air quality can be, so I would make sure the apartments and homes I end up staying in use Low-VOC paints. Simply adding an HRV system into a home helps cut down on gas usage which saves a lot in terms of CO_2 emissions. And considering the use of lime plaster walls—even though they may be expensive—they help absorb large quantities of CO_2 to offset much of what normal materials would emit.

We made the assumption that we would just duplicate the model green home we analyzed into 30 units for a residential development, but I would have liked to see what we could have done given a specific site in Tompkins County. This would probably be a year-long project instead if we went into researching what kind of ways we could make a residential development site sustainable.

I think I would personally use some of these technologies that we researched in a home that I may invest in the future. Anyone who reads our report will find some of the products we suggest to use in a green home to be very attractive to purchase. In conclusion, I am glad this project's research can be useful to all of us.

Enrique Martinez's reflections

Working on this project was a great experience overall. It taught me very valuable lessons in both project management and on sustainable development.

Usually when working on a team that has no clear leader that has more responsibility and power than the rest of the members things do not come together very smoothly. Those who are more committed to the project end up dedicating much more effort than the rest. Through this project I learned that this is not necessarily true. With a good team structure and good work distribution we were able to complete the project very successfully while keeping all members satisfied. Setting realistic goals that were in the interest of all members made it a much simpler and enjoyable task.

With regards to the subject matter, sustainable development, I also gained very valuable knowledge. Sustainable development is something that I was very interested previously, so I really appreciated the opportunity to work on this. Through this project I got the opportunity to evaluate the impact of different energy efficient features on a house's performance. This is something that I feel will be useful and very relevant in my future.

Fona Osunloye's reflections

At the beginning of the semester, the goals I set for myself ranged from improving my teambuilding/team-working by being an active member of the project group, to stepping out of my comfort zone when it came to choosing team responsibilities and if possible choosing areas that I did not have prior experience so as to increasing my learning potential from the overall project.

At the end of the semester, I am glad to say that I achieved these, and the other personal goals I set for myself. By being an active member of this team, I was able to further improve my team-working and teambuilding skills; traits that will both prove extremely useful in the working environment.

This project also proved to be a great learning experience for me as prior to it I had little to no experience with Green Technologies specifically targeted at Residential Buildings. Through the work we did individually and collectively as a team, I increased my knowledge on Sustainability and learned about the different technologies that come into play when designing a cost-effective and sustainable home. It was very interesting to find out how the different appliances and fixtures within an average home contribute immensely to its consumption, and how an upfront investment in seemingly more expensive items/appliances/fixtures can help to reduce these costs drastically in the long-run.

The one point of contention that I had with the whole project was the lack of time necessary to ensure that the team could achieve a more in-depth look at all the facets that could possibly affect the design of the development. Going forward, it would be interesting to see what improvements can be made on our design, and how (if) being site-specific would affect our initial results.

Thomas Ruggieri's reflections

Personal goals:

1. To gain additional knowledge and experience to further develop my skills in managing large team based projects
2. To further develop interpersonal and a communication skills.
3. To broaden my cohesive capabilities in order to become a more effective member of a team.
4. To further my knowledge in energy efficiencies and the requirements for LEED certification so that it can be applied in my father career in the Army.
5. To further develop my time management skills
6. To learn how to become a more effective and efficient worker and manager.
7. To further develop my team based and individual leadership skills in a project based environment.
8. To further develop my public speaking and presentation skills.
9. To learn what it takes to run and manage a large scale construction/development project.
10. To learn about the financial ins and outs of a construction/ design project for a sustainable residential community.
11. To learn about the legal and safety requirements that must be considered when developing a new residential community.

While looking back at the original set of personal goals that were set to be accomplished during the project it, through my experiences in I believe that if not fully met, there were certain goals that I partially met just through partial self-improvement in those areas. The majority of these improvements which were met had to do with improvements in public speaking, and communication. In addition, I learned more about what it takes to be part of a team and how when working as a team it is important to remember that other people are relying on you to do your part. This is also an area where having effective time management comes in to play. It is also obvious that through this project I was successfully able to broaden my knowledge in the areas of sustainability, and the construction and financial aspect of green building design. However, the only thing that interreges me about this project is the though it is a management project, there did not seem to be as much of a structured hierarchy as so certain type of management skills and goal in regards to managing a team might not have been met. This intern prevented the development of upper level management skills. However by the end of the project it was clear that more of the original goals that were set out to be made were either fully or partially met through constant improvement.

Quentin Tourancheau's reflections

Overall, I am really satisfied with this project.

Technically speaking, I developed and enhanced my knowledge in the green building technologies. It was one of my goals to get a certain degree of expertise in this domain for my personal culture but also for a professional purpose if one day I have to consider those aspects for another project. I appreciate the fact that I broaden my knowledge.

In addition, I am really satisfied with the angle we treated the subject. Having qualitative (the report on technologies) and quantitative (the Excel model) data makes this project really complete. The model looks good to me and I am happy to have worked on it, getting more familiar with the software and producing a user-friendly tool.

Moreover, I feel I have improved my communication skills, both written and oral, which represented a challenge for me as a foreigner. I think I managed well to understand and be understood all along this project.

Finally, it was really interesting to work in this team project, because I learnt a lot on a management point of view. Team management and team members management represented a good experience for my professional and personal growth.

Thomas Virgin's reflections

Appendix A – Water Efficiency

Fixture Efficiency Levels:

Note: All raw data for individual fixtures are located in Water Efficiency Raw Data Work Book

Toilets

Level I: Windham™ 12" Rough-in Toilet (Baseline - 1.6 gpf)

Level II: Windham™ 12" Toilet (High Efficiency - 1.28 gpf)

Level III: Niagara Stealth™ N7716 0.8 UHET Toilet (Very High Efficiency - 0.8 gpf)

Level IV: Envirolet Waterless Remote Composting Toilet (Ultra High Efficiency – No Flow)

Lavatory Faucets

Level I: Moen 4900 Chateau Two Handle Centerset Lavatory Faucet (Baseline *–2.2GPM)*

Level II: KOHLER Coralais Low-Arc Bathroom Faucet (High Efficiency Fixture- 1.5GPM)

Level III: Deluxe Touch Low Flow Faucet Aerator (Very High Efficiency Fixture - 1.0 GPM)

Level IV: Low Flow Dual-Thread Faucet Aerator (Ultra High efficiency Fixture –0.5 GPM)

Shower Heads

Level I: Delta Traditional Collection Touch-Clean Showerhead (Baseline *–2.2GPM)*

Level II: Niagara N2917CH 1.75 Earth Massage Showerhead (HEF- 1.75GPM)

Level III: Niagara N2915CH 1.5 Earth Massage Showerhead (VHEF- 1.5GPM)

Level IV: Niagara N2912CH 1.25 Earth Massage Showerhead (UHEF–1.25 GPM)

Kitchen Faucets

Level I: Moen 7900 Chateau Two-Handle Kitchen Faucet (Baseline *–2.2GPM)*

Level II: Delta Classic Single Handle Kitchen Faucet (High Efficiency Fixture- 1.5GPM)

Level III: Deluxe Touch Low Flow Faucet Aerator (Very High Efficiency Fixture - 1.0 GPM)

Level IV: Low Flow Dual-Thread Faucet Aerator (Ultra High efficiency Fixture –0.5 GPM)

Dishwashers

Level I: Frigidaire 24" Built-In Standard Dishwasher (Baseline –7.2gal/cycle; 365kWH/year)

Level II: Frigidaire 24" Built-In HE Dishwasher (HEF – 5.15 gal/cycle; 318 kWH/year)

Level III: Maytag Jet clean Plus Dishwasher (VHEF – 4.3gal/cycle; 302kwh/year)

Level IV: Bosch 24" Evolution 800 Plus Series Washer (UHEF –1.52gal/cycle; 180kWH/year)

Clothes washers

Level I: Whirlpool 3.5 Cu. Ft Top Load Washer (Baseline –6.4gal/cycle/ft^3; 470kWH/year)

Level II: GE® 3.6 DOE cu. ft. capacity SS washer (HEF- 6.0gal/cycle/ft^3; 186kWH/year)

Level III: GE® Energy Star® 3.5 DOE Cu. Ft. Washer (VHEF – 4.2gal/cycle/ft^3; 144kWH/year)

Level IV: Whirlpool Duet 5.0 Cu. Ft. I.E.C. FL. Washer (UHEF –2.7gal/cycle/ft^3; 155kWH/year)

Water Efficiency research references

I. General Information

A. Usage Statistics

http://www.aquacraft.com/Projects
http://www.drinktap.org/consumerdnn/Home/WaterInformation/Conservation/WaterUseStatistics/tabid/85/Default.aspx

B. Water and sewer costs for Ithaca

http://www.ci.ithaca.ny.us/departments/dpw/water/rates.cfm

C. Total Water Consumption Calculator

http://www.csgnetwork.com/waterusagecalc.html

D. General Conservation Information

http://www.watersmart.net/conserve/indoorhttp://www.watersmart.net/conserve/indoor
http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13050
http://www.epa.gov/watersense/
http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2135

II. Indoor Water Usage

A. Toilets

1 .Background Information
http://www.epa.gov/watersense/docs/spec_het508.pdf

Baseline – Standard (1.6GPF)
http://www.sterlingplumbing.com/toilets-and-bathroom-sinks/toilets/Windham-TM-Round-Front-Toilet-with-Pro-Force-R-Technology402015detail?productNumber=402015&resultId=1452460760-0

Technology 1-High Efficiency (<1.3 GPF)
http://www.sterlingplumbing.com/toilets-and-bathroom-sinks/toilets/Windham-TM-Round-Front-Toilet-with-ProForce-R-Technology402080detail?productNumber=402080&resultId=1215870392-0

Technology 2- Very High Efficiency (<1.1 GPF)
http://www.conservationwarehouse.com/niagara-n7716-stealth-toilet-uhet.html
http://www.youtube.com/watch?v=wBRH-H-Sg2E&feature=player_embeddedhttp://www.youtube.com/watch?v=wBRH-H-Sg2E&feature=player_embedded

Technology 3- No Flow Composting Toilet (0.0 GPF)
http://www.envirolet.com/enwatremsysn.html
http://www.envirolet.com/enwatremsys2.html

B. Lavatory Faucets:

Background Information
http://www.epa.gov/WaterSense/docs/faucet_suppstat508.pdf
http://www.epa.gov/watersense/docs/faucet_spec508.pdf

2. Baseline – Standard (2.2GPM)
http://www.faucetdepot.com/moendepot/productdetail.asp?link={0B3FB90A-ECBE-4E35-860F-9CF9339F0C6A}&Product=5948
http://www.faucetdepot.com/pdfs/4900.pdf

Technology 1-High Efficiency (<2.0GPM)
http://www.us.kohler.com/savewater/how/bathroom/faucets/detail.htm?productNumber=15240-7&business=KPNA&resultPageKey=-1355333055-0

Technology 2-Very High Efficiency (<1.5GPM)
http://www.conservastore.com/productdetail.php?p=337

Technology 3-Ultra High Efficiency (0.5GPM)
http://www.conservastore.com/productdetail.php?p=23http://www.conservastore.com/productdetail.php?p=23

C. Shower Heads:

Background Information
http://www.epa.gov/watersense/docs/showerheads_finalspec508.pdf

Baseline – Standard (2.5GPM)
http://www.americanstandard-us.com/assets/documents/amstd/spec/SpecSheet_974.pdf
http://www.homedepot.com/Bath-Bathroom-Faucets-Shower-Heads-Hand-Showers-Shower-Heads/h_d1/N-5yc1vZarq5/R-100079217/h_d2/ProductDisplay?langId=-1&storeId=10051&catalogId=10053#BVRRWidgetIDhttp://www.homedepot.com/Bath-Bathroom-Faucets-Shower-Heads-Hand-Showers-Shower-Heads/h_d1/N-5yc1vZarq5/R-100079217/h_d2/ProductDisplay?langId=-1&storeId=10051&catalogId=10053#BVRRWidgetID

Technology 1-High Efficiency (<2.0GPm)
http://www.conservationwarehouse.com/earth-massage-showerhead-chrome.html
http://lib.store.yahoo.net/lib/yhst-18576604904413/N2917.pdf

Technology 2-Very High Efficiency (1.5GPM)
http://www.conservationwarehouse.com/earth-massage-showerhead-chrome.html
http://lib.store.yahoo.net/lib/yhst-18576604904413/earth-massage-showerhead-1-5-gpm-n2915ch.pdf

Technology 3-Very High Efficiency (<1.5GPM)
http://www.conservationwarehouse.com/earth-massage-showerhead-chrome.html
http://lib.store.yahoo.net/lib/yhst-18576604904413/N2912.pdf

D. Kitchen Faucets:

Background Information
http://www.hometips.com/buying-guides/faucets-kitchen.html

Baseline – Standard (2.2GPM)
http://www.faucetdepot.com/prod/Moen-7900-Chateau-Two-Handle-Kitchen-Faucet-Chrome-6797.asp
http://www.faucetdepot.com/pdfs/7900.pdf

Technology 1-High Efficiency (<2.0GPM)
http://greenexpressdirect.com/details.tpl?eqskudatarq=10200508
http://www.deltafaucet.com/kitchen/details/140-WE-DST.html

4. Technology 2-Very High Efficiency (<1.5GPM)
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Technology 3-Ultra High Efficiency (0.5GPM)
http://www.conservastore.com/productdetail.php?p=23http://www.conservastore.com/productdetail.php?p=23

E. Dishwasher (Regular Size):

Background Information
http://www.fypower.org/res/tools/products_results.html?id=100125
http://www.epa.gov/greenhomes/Kitchen.htm#kitchen-components
http://downloads.energystar.gov/bi/qplist/Dishwashers%20Product%20List.pdf
http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers
http://www.energystar.gov/index.cfm?fuseaction=dishwash.search_dishwashes
http://www.cee1.org/resrc/manu/appliances.php3
http://www.cee1.org/resid/seha/dishw/dw-spec.pdf
http://www.cee1.org/resid/seha/dishw/dw-prod.pdf
http://www.cee1.org/resid/seha/dishw/dw_survey.pdf

Baseline – Federal Standard (6.5 Gallons/Cycle)
http://www.frigidaire.com/products/kitchen/dishwashers/fbd2400kb

Technology 1-High Efficiency (Energy Star Qualified; 5.8 gal/Cycle)
http://www.frigidaire.com/products/kitchen/dishwashers/fdb1502rgc

Technology 2-Very High Efficiency (CEE Tier 1; 5.0 gal/cycle)
http://www.maytag.com/catalog/product.jsp?cat=3&prod=2282

Technology 3-Ultra High Efficiency (CEE Tier; 4.25 gal/cycle)
http://www.boschhome.com/us/products/dishwashers/dishwashers/SHE68E05UC.html?source=browse

F. Clothes Washer:

Background Information
http://www.epa.gov/greenhomes/Basement.htm
http://downloads.energystar.gov/bi/qplist/res_clothes_washers.pdf
http://www.cee1.org/resrc/manu/appliances.php3
http://www.cee1.org/resid/seha/rwsh/reswash_specs.pdf
http://www.cee1.org/resid/seha/rwsh/rwsh-prod.pdf

Baseline – Federal Standard (9.5gal/cycle/ft^3)
http://www.whirlpool.com/catalog/product.jsp?src=WASHERS&cat=115&prod=2032

Technology 1-High Efficiency (Energy StarQualified /CEE Tier 1 ; 6.0 gal/cycle/ ft^3)
http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=GTWN4250MW
S

Technology 2-Very High Efficiency (CEE Tier 2; 4.5 gal/cycle/ft^3
http://products.geappliances.com/ApplProducts/Dispatcher?REQUEST=SpecPage&Sku=WCVH6800JWW

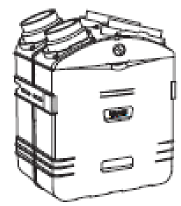
Technology 3-Ultra High Efficiency (CEE Tier 3; 4.0 gal/cycle/ft^3
http://www.whirlpool.com/catalog/product.jsp?parentCategoryId=113&categoryId=115&subCategoryId
=116&productId=2052#tabs

Appendix B – Indoor Environmental Air Quality

BROAN

SPECIFICATION SHEET

GSHH3K
FRESH AIR SYSTEM



Whole-House HEPA Filtration + Fresh Air + Heat Recovery = Better IAQ

FEATURES

- Fully integrated Whole-house High Efficiency Particle Arrestment (HEPA) filtration with fresh air ventilation and heat recovery - unit slows the moisture transfer between the outdoor and indoor air, making it a great solution for areas with high moisture content.
- Allows homeowners to benefit from fresh air, cleaned with the best available HEPA filtration technology, keeping the house free of dust and allergen material (99.7% efficiency at particles as small as 0.3 microns).
- Unit also removes stale air from the house with an energy efficient heat recovery process. Stale air is exhausted out and fresh air is drawn in simultaneously without the risk of contamination.
- Ideal for tightly built single-family houses, houses that need fresh air ventilation, or houses that need to remove stagnant air generated from materials or pollutants, while also controlling pollen or dust from the indoor air.
- One simple-to-install and simple-to-use unit; eliminates need for multiple, individual units. Easy to install with a patented tandem "Y"-shaped transition with only a single outdoor outlet.
- Easy-to-use wall switches for unit control.
- 3 products for the price of 1: An affordable way to have whole-house HEPA filtration, fresh air ventilation, and heat recovery.

GENERAL SPECIFICATIONS

- For houses up to 6,000 sq. ft.
- 165 to 270 cfm (0.4 in. w.g.)
- Voltage: 120 VAC
- Frequency: 60 Hz
- Dimensions: 29.4" x 22.9" x 17.8"
- Weight: 42 lbs
- Shipping Weight: 57 lbs
- Warranty: 2 years on parts
- HVI Rated of air flow: 105 cfm
- Power Consumed (max): 232 Watts
- Low mode: --
- High mode: --
- Recirculation mode: --
- Supply air duct connections: 5" or 6" diameter
- Exhaust air duct connections: 8" diameter
- Filter: HEPA
- Cabinet: ABS and EPS
- Mounting: Suspension by chains and springs
- Wall control modes: Off, Normal, Boost, and Recirculation
- Power: 152 Watts
- Current: 2.0 Amps
- Continuous duty, permanently lubricated motors
- 36" power cord

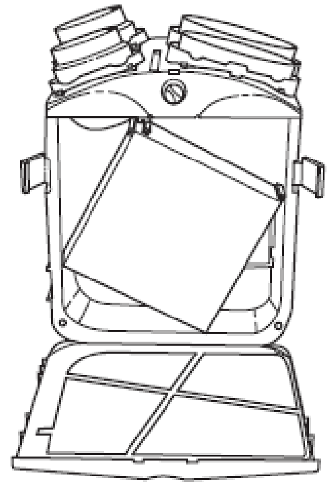
c UL us   2100 HVI CERTIFIED

Broan-NuTone LLC   Hartford, Wisconsin   www.broan.com   800-558-1711

REFERENCE	QTY.	REMARKS	Project
			Location
			Architect
			Engineer
			Contractor
			Submitted by Date

80F   GSHH3K.indd

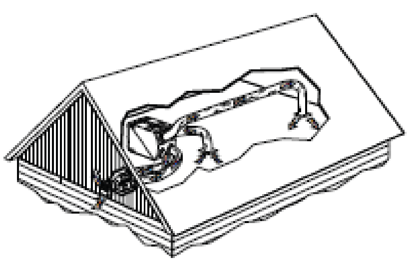
MODEL GSHH3K
PERFORMANCE SPECIFICATIONS



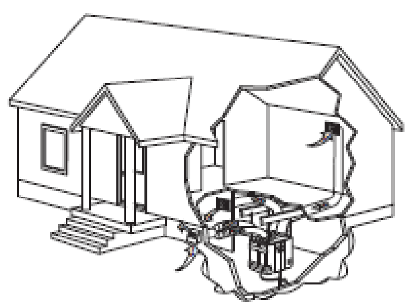
Ventilation Performance						
Fresh Air		Exhaust		Recirculation		Average Power
L/s	cfm	L/s	cfm	L/s	cfm	Watts
58	124	57	121	131	277	237
55	116	51	108	119	252	229

Energy Performance					
		65 cfm 5"-L sp	70 cfm 6"-L sp	95 cfm 5"-L sp	105 cfm 6"-L sp
Heating (32°F/O°C)	Apparent Sen Eff	60%	59%	53%	50%
	Latent/Moisture Eff	0%	0%	0%	0%
	Total Rec Eff	42%	41%	37%	35%
Heating (13°/-25°C)	Apparent Sen Eff	60%	59%	53%	50%
	Latent/Moisture Eff	0%	0%	0%	0%
	Total Rec Eff	45%	44%	40%	37%
Cooling (95°F/35°C) 50% RH	Apparent Sen Eff	60%	59%	53%	50%
	Latent/Moisture Eff	0%	0%	0%	0%
	Total Rec Eff	20%	20%	18%	17%

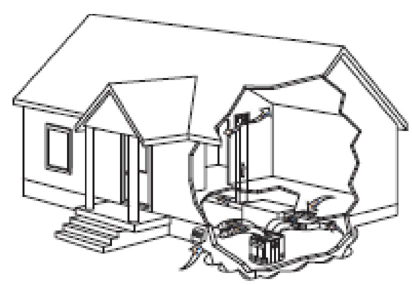
INSTALLATION OPTIONS



Attic*



Basement



Return-Return Basement

*Contact your broan sales representative for information on attic installation requirements.

BROAN Broan-NuTone LLC Hartford, Wisconsin www.broan.com 800-558-1711

Appendix C – Sustainable Site Work

CALCULATIONS

$\boldsymbol{Total\ GSF} = 1800\ sq.ft.$

$\boldsymbol{Energy\ Costs}$:

Cost of Energy Source	
Electricity	$0.1850 / kwh
Gas	$1.33 / therm

$\boldsymbol{Annual\ Cost\ Savings\ from\ ORNL\ Calculator}(\boldsymbol{with\ Alternate\ Technology})$:

$Cooling =$ \$0.039/sq. ft. per year

$Heating =$ \$0.047/sq. ft. per year

$\boldsymbol{Baseline\ Energy\ Consumption}$:

	btu	kWh	Fuel
Space Heating	69811361	20460	Gas
Space Cooling	3574977	1048	Electric

$\boldsymbol{Annual\ Energy\ Costs}\ (\boldsymbol{Baseline\ Model})$:

$$Cooling = \frac{\$0.1850}{kwh} * \frac{1048kwh}{1800ft^2} = \$0.108/ft^2 \text{ per year}$$

$$Heating = \frac{\$1.33}{therm} * \frac{698.1\ therms}{1800\ ft^2} = \$0.516/ft^2 \text{ per year}$$

$\boldsymbol{Annual\ Energy\ Costs}(\boldsymbol{Alternate\ Technology})$:

$Cooling = \$(0.108\ - \$0.039)/\ ft^2$ per year = $\$0.069/ft^2$ per year

$Heating = \$(0.516 - \$0.047)/\ ft^2$ per year = $\$0.469/ft^2$ per year

$\boldsymbol{Annual\ Energy\ Consumption}\ (\boldsymbol{Alternate\ Technology})$:

$$Cooling = \frac{1800ft^2 * \$0.069/ft^2}{\$0.1850/kwh} = 668 \text{ kWh}$$

$$Heating = \frac{1800ft^2 * \$0.469/ft^2}{\$1.33/therm} = 634.7 \text{ therms}$$

$\boldsymbol{Annual\ Energy\ Savings}\ (\boldsymbol{with\ Alternate\ Technology})$:

$$Cooling = \frac{1048\ kwh - 668\ kwh}{1048\ kwh} * 100 = \mathbf{36.22\%}$$

$$Heating = \frac{698\ therms - 635\ therms}{698\ therms} * 100 = \mathbf{9.11\%}$$

Roofing						
BASELINE:	**Asphalt Shingle (SR - 5, TE - 90)**					
	COOLING		**HEATING**		**TOTAL**	
Consumption:	1048	kWh	698	therms	21507	kWh
Estimated Annual Cost:	$ 193.83		$ 928.49		$ 1,122.32	
Annual Cost/Sq. FT	$ 0.11	per sq. ft/yr	$ 0.52	per sq. ft/yr		
Unit Cost	$ 1.50	per sq. ft	$ 1.50	per sq. ft		
Capital Cost:	$ 1,620.00		$ 1,620.00			
Lifetime:	15		15	years		
ALTERNATIVE:	**Galvalume Metal Roof (SR - 74, TE - 6)**					
	COOLING		**HEATING**			
Consumption:	668	kWh	635	therms	19278	kWh
Energy Savings:	36.22%		9.11%			
Estimated Annual Cost:	$ 123.63		$ 843.89		$ 967.52	
Annual Cost/Sq. FT	$ 0.07	per sq. ft/yr	$ 0.47	per sq. ft/yr		
Unit Cost	$ 7.50	per sq. ft	$ 7.50	per sq. ft		
Capital Cost:	$ 8,100.00		$ 8,100.00			
Lifetime:	30	years	30	years		

Warmer Roof Options				Cooler Roof Options			
Roof Type	Reflectance	Emittance	Cost ($/ft²)	Roof Type	Reflectance	Emittance	Cost ($/ft²)
Built-up Roof With dark gravel With smooth asphalt surface With aluminum coating	 0.08-0.15 0.04-0.05 0.25-0.60	 0.80-0.90 0.85-0.95 0.20-0.50	**1.2-2.1**	**Built-up Roof** With white gravel With gravel and cementitious coating Smooth surface with white roof coating	 0.30-0.50 0.50-0.70 0.75-0.85	 0.80-0.90 0.80-0.90 0.80-0.90	**1.2-2.15**
Single-Ply Membrane Black (PVC)	 0.04-0.05	 0.80-0.90	**1.0-2.0**	**Single-Ply Membrane** White (PVC) Color with cool pigments	 0.70-0.78 0.40-0.60	 0.80-0.90 0.80-0.90	**1.0-2.05**
Modified Bitumen With mineral surface capsheet (SBS, APP)	 0.10-0.20	 0.80-0.90	**1.5-1.9**	**Modified Bitumen** White coating over a mineral surface (SBS, APP)	 0.60-0.75	 0.80-0.90	**1.5-1.95**
Metal Roof Unpainted, corrugated Dark-painted, corrugated	 0.30-0.50 0.05-0.08	 0.05-0.30 0.80-0.90	**1.8-3.7**	**Metal Roof** White painted Color with cool pigments	 0.60-0.70 0.40-0.70	 0.80-0.90 0.80-0.90	**1.8-3.75**
Asphalt Shingle Black or dark brown with conventional pigments	 0.04-0.15	 0.80-0.90	**0.5-2.0**	**Asphalt Shingle** "White" (light gray) Medium gray or brown with cool pigments	 0.25-0.27 0.25-0.27	 0.80-0.90 0.80-0.90	**0.6-2.1**
Liquid Applied Coating Smooth black	 0.04-0.05	 0.80-0.90	**0.5-0.7**	**Liquid Applied Coating** Smooth white Smooth, off-white Rough white	 0.70-0.85 0.40-0.60 0.50-0.60	 0.80-0.90 0.80-0.90 0.80-0.90	**0.6-0.8**
Concrete Tile Dark color with conventional pigments	 0.05-0.35	 0.80-0.90	**1.0-6.0**	**Concrete Tile** White Color with cool pigments	 0.70 0.40-0.50	 0.80-0.90 0.80-0.90	**1.0-6.0**
Clay Tile Dark color with conventional pigments	 0.20	 0.80-0.90	**3.0-5.0**	**Clay Tile** White Terra cotta (unglazed red tile) Color with cool pigments	 0.70 0.40 0.40-0.60	 0.80-0.90 0.80-0.90 0.80-0.90	**3.0-5.0**
Wood Shake Painted dark color with conventional pigment	 0.05-0.35	 0.80-0.90	**0.5-2.0**	**Wood Shake** Bare	 0.40-0.55	 0.80-0.90	**0.5-2.0**

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Appendix D – Management reports

Mid-term Management Report

Team Structure

The team was split into two subgroups and each person was given the responsibility of one of the 5 LEED categories. The two larger sub-groups became obsolete after each person was responsible for a particular LEED category. We think that this group breakdown structure was the most efficient use of people. Under this team structure members have been able to focus on their specific areas, gaining expertise, accountability and not losing time bouncing back and forth different topics, and preventing us from overlapping research. This could pose a problem later on if an individual falls behind in their work because of the amount of responsibility he/she has on a vital part of the project. However, this issue has not occurred yet, but could be one as the project becomes more demanding.

Communication

Communication has been generally fine, being a small team has facilitated it; as it stands we have several ways of communicating, meeting, email, digital drop box, and a Google group account. Using email has been the most efficient way of sharing information; but intermittently there have been issues in the lack of response to emails. The submission of group project deliverables has not been an issue because individuals have been are aware of those responsibilities and deadlines. We are afraid though that later on when we try to compile individual work, that there will be delays because team members work at different paces and schedules. We believe this is happening is because each member has other academic responsibilities of varying degrees of time commitment. DropBox is a good tool for sharing information, however the restriction for installing software on Cornell office computers prevented us from using the full potential of this tool because it requires to go on the website, but the issue should be solved soon by the installation of the software by the administrator of Cornell office. We think the use of the Google group more often would be more efficient and less email obtrusive. The liaison with the advisor has been good so far conferring us all of his expectations.

Currently we have set Wednesday evenings (after our weekly meeting with the project advisor) as our main group meeting time which seems to pose a bit of an issue because we believe at that time the members are already exhausted from the day's work. Our recommendation is to set another time on another day for a one hour meeting to organize on specific deliverables together so we are on the same page and can consult with one another about any questions we need clarified. We have tentatively set 5:00pm on Thursdays as our new meeting time.

Project Progress

We believe that our team is on schedule to complete all deliverables on time. However, we are heavily end loaded, but we believe the allocation of the kind of deliverables we are committing to has left us pushing back more of the core deliverables we should be working on such as the excel model. It is a bulk of the work along with the initial research, but it seems like it has been put off. Right now we are on track to be revising the draft model we have created over the next few weeks.

The initial background preparation for the model has been good set up by the advisor has been good, but WE think further setting smaller and more frequent deliverables for the model (from the team itself) is appropriate for getting this project completed on time. One negative aspect in regards to the team's progress is the lack of knowledge regarding each individual's progress on their individual research topic. It would be better if the team were to start setting internal group deadlines for certain parts of the project so the group as a is more prepared to present material when meeting with the "Customer". So far we have done a good job of setting deadlines and milestones, so we are on pace to finish by the presentation deadline, but it seems like we are cramming a lot of the model work toward the last half of this project timeline. After spring break we would expect the project to start moving forward and developing at a much faster rate than it has because now we are a lot clearer on our objectives and we know what we have to do to move forward.

Having a team member who is LEED certified has also proved to be very useful, because he has a whole wealth of information that is relevant to the project and helpful to those of us who don't have the necessary background and experience.

Overall Assessment

For the first half of the semester everything has moved forward in the right direction, although it feels like progress is slow. We think everyone was getting to know each other and figure out each other's preferred working styles. There was also a learning curve for everyone to figure out what the project is designed to achieve. The material has been dense and there is a lot of information to compile and sort through, so we believe the team has not been very motivated to do so much of that research since it seems like a lot. There is still a plethora of work ahead of us, but we are excited to review our results and examine our conclusions. As the semester progresses and the project gets even more underway, it will be interesting to see how things play out given the things that have worked to date and hopefully continue working, and the already identified problems and the moves made to fix said problems; using the model will help the team feel like we are getting results which should be motivating in that it shows the fruits of our work.. With the help and guidance of Professor Vanek, we believe that our group now fully understands what is expected of us and our project and progressing accordingly. We believe the team's motivation will increase as the project progresses and starts looking more concrete.

Anson Lin
Mid-term Management Report

Team Structure

Due to the small number of members of this project team, it seems that idea to break up the responsibilities into the five LEED New Construction criteria was the best option. My impression of the structure right now is that it helps members stay focused on their assigned criterion. This could pose a problem later on if an individual falls behind in their work because of the amount of responsibility he/she has on a vital part of the project. However, this issue has not occurred yet, but could be one as the project becomes more demanding.

Communication

Communication in the group has been good, but intermittently there have been issues in the lack of response to emails. The submission of group project deliverables has not been in issue because individuals have been are aware of those responsibilities and deadlines. I'm afraid though that later on when we try to compile individual work, that there will be delays because team members work at different paces and schedules. I believe this is happening is because each member has other academic responsibilities of varying degrees of time commitment.

Currently we have set Wednesday evenings (after our weekly meeting with the project advisor) as our main group meeting time which seems to pose a bit of an issue because I believe at that time the members are already exhausted from the day's work. My recommendation is to set another time on another day for a one hour meeting to organize on specific deliverables together so we are on the same page and can consult with one another about any questions we need clarified. We have tentatively set 5:00pm on Thursdays as our new meeting time.

Project Progress

The current rate of the project has been good, but I believe the allocation of the kind of deliverables we are committing to has left us pushing back more of the core deliverables we should be working on such as the excel model. It is a bulk of the work along with the initial research, but it seems like it has been put off. Right now we are on track to be revising the draft model we have created over the next few weeks.

The initial background preparation for the model has been good set up by the adviser has been good, but I think further setting smaller and more frequent deliverables for the model (from the team itself) is appropriate for getting this project completed on time. So far we have done a good job of setting deadlines and milestones, so we are on pace to finish by the presentation deadline, but it seems like we are cramming a lot of the model work toward the last half of this project timeline.

Overall Assessment

Generally, for the first half of this project, the team has been learning to work with each other in feeling out our comfort zones in working efficiently. The material has been dense and there is a lot of information to compile and sort through, so I believe the team has not been very motivated to do so much of that research since it seems like a lot. However, the project adviser has been very helpful in setting a direction for the team and guiding them in their research. As the project team dives into working on the excel model according to each members' respective LEED criteria, the overall team should start feeling a lot motivated in completing this project. Using the model will help the team feel like we are getting results which should be motivating in that it shows the fruits of our work.

Enrique Martinez

Mid-Term Management Report

Team Structure

The team was divided into two groups, which are further divided into subgroups covering the five LEED New Construction criteria. In my opinion this was the most favorable way to organize the team because it allowed for the most efficiency. Under this team structure members have been able to focus on their specific areas, gaining expertise and not loosing time bouncing back and forth different topics. Little time is lost to confusion. So far it has worked great. The only thing that worries me about this structure is that it may be possible that down the road we may run into complications if some member falls behind. To prevent this weekly meeting are held to update on individual progress.

Communication

Communication has been generally fine, but I think our team meetings have not been very successful. We agreed to meet every Wednesday after our meeting with Professor Vanek, however, following a meeting with another meeting does not seem to be the best idea. Team members are exhausted and not as enthused to participate after a long day of work. A change has already been agreed upon, we will now be meeting on Thursdays at five pm. I believe this will be the solution to that problem.

On the positive side, communication among members of the group has been good enough that deliverables have been always submitted on time. This show commitment from all team members and is a way to communicate to the team that we all want the team to succeed.

Project Progress

In my opinion, the project is progressing at an acceptable speed. A lot of time has been spent bouncing back ideas and setting up a structure for the project. After spring break I would expect the project to start moving forward and developing at a much faster rate than it has because now we are a lot clearer on our objectives and we know what we have to do to move forward. Research is moving along, which will help polish the model and actually start giving the model a more realistic feel.

Overall Assessment

Overall, I feel pretty good with how the team is working together and with the progress that has been achieved so far. There is a lot of material to research, compile and make sense off. The individuals of the group have been doing a good job of sorting through this information and making sense of it. By now, I feel that the group is comfortable with each other and have learned about individual members and how to work with them. I look forward to keep moving forward with the excel model, and I believe the teams motivation will increase as the project progresses and starts looking more concrete.

Fona Osunloye

Mid-term Management Report

Team Structure:

At the beginning of the semester, it was decided to break up the team into 2 small groups so as to streamline the different areas that the team was going to focus on. As the semester went on, the team decided to use the LEED New Construction criteria as the basis for the project. The two sub-groups became even more loosely grouped, with members taking responsibility for at least one of the LEED New Construction based off previous experience and strengths. This situation has each team member being responsible for a sizable portion of the project, and the potential problem that could arise with this is if some team member fails to deliver on their portion of the project, thus making it essential for the rest of the team to pick up the slack.

Communication:

Communication within the team got off to a good start. I chose to continue on as the team's liaison with our project advisor, and to ensure that all necessary information is passed on to all team members. So far, there has not been any problems or complaints from the other team members, though sometime I feel that I may not be doing as great a job as I ceould possibly do as I sometimes fail to get the information out in a timely manner. This lack of timeliness is something I plan to continue working on as the semester goes on. Besides this, overall communication within the group is at a good enough level where everyone knows what their respective responsibilities and how this relates to the entire project. Team members have been good with volunteering when it comes to compiling the different project deliverables to date, but every now and then, there are time lags in when all this information is made available to whoever is responsible for compiling the information due to people working at different paces and having other obligations. To fix this problem, I would suggest that the team set hard dates when deliverable have to be submitted by, to give the compiler enough time to put the submissions together.

Meetings

Initially, we decided to have out team meetings on Thursdays, but when we found out that we would also have to schedule a meeting time with our project advisors, we decided to move our own team meetings to after the advisor check-in meetings on Wednesdays. The problem with this switch is that once we finished meeting with our project advisor, people were already tired and as such we more often than not ended up not having actual meetings, but instead relied on email to discuss whatever we needed to discuss outside of the advisor meetings. To fix this problem, the team decided to set up an alternative time that's conducive for the entire team as our new meeting time.

Overall Assessment:

All in all, I feel that the team has gotten off to a great start in our approach to the given project. Team dynamics have been very good, and all team members relate very well with one another. Having a team member who is LEED certified has also proved to be very useful, because he has a whole wealth of information that is relevant to the project and helpful to those of us who don't have the necessary background and experience. As the semester progresses and the project gets even more underway, it will be interesting to see how things play out given the things that have worked to date and hopefully continue working, and the already identified problems and the moves made to fix said problems.

Thomas Ruggieri

Mid-Term Management Report

Team Structure

Pros:

The basic structure of the Management team seems to be for the most part, doing well. This basic structure entails dividing up the work based on the five LEED New Construction rating criteria: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality, and Materials and Resources. At this point in the project life cycle this team structure seems to be working well, and was a good collaborative decision for the team to make. Using this break down structure gives each individual the responsibility of committing to doing research for one key LEED criteria. This in turn breaks up all research required by the team into smaller sub categories, making it more easy to manage since only one person becomes responsible for all research in a specific area.

In addition, with each technology basis being covered by a single group member, it gives the team the opportunity of acquiring more in depth research for each category. This setup gives each member the flexibility of only focusing their research efforts on one topic, instead of having to do research in multiple areas. This method also helps reduce the chance of research overlap between multiple group members that may have been researching the same technology. For example, I am solely responsible for water efficiency, so all research in that area is being collected by only me, so I won't have to be concerned about the risk of doing in depth research into a technology that another team member has already covered.

Assigning each member to provide research on one specific LEED criteria also helps as a driving factor for individual participation. Since each team member has their own research responsibilities that must be full filled for the project to progress, it requires each member to take over an equal share of the work. This not only helps cover all research holes but will ensure that the team does not fall into the age old tradition of one or two people doing all of work and the rest of the team not doing anything. Also as the project progresses and anything comes up missing, then the team will be able to more clearly pin point any short comings in the research and who to contact to resolve them.

Cons:

There are only two negative aspects or to this team structure. The first has to do with the unnecessary need for having two sub groups. The initial idea of having two sub groups composed of three team members seemed to be a god idea at first; however, the project team is too small to effectively utilize smaller sub groups. Also as the project has progressed and individual team members began taking on specific research responsibilities the need for 2 separate sub groups within the project team has become unnecessary. As the project has moved forward each team member is just going about their business doing their own research and then reporting back their findings to the whole project team.

One other risk which has the potential of surfacing is the risk of one team member failing to do enough research in a specific area by the time the team's deadlines are met. If this were to happen it would then require all of the other team members to pick up the slack. However, one way that this could be prevented would be to set up specific deliverable deadline within the team structure to use as a self-check, to ensure that all team members are performing there assigned tasks and will meet the deadlines set by the "Customer".

<u>Communication</u>

Pros:

The Idea of creating and using an ftp server, or drop box to store and share files was an excellence way for each team member to submit and update one document which could be shared by all. This helps reduce the occurrence of multiple people having different versions of the same document and then having to sift through each version to get new information to put into a master copy. By using the Drop Box the group can make their own updates to one and only one master document that can be accessed anywhere, by anyone on the team. This actually makes the forward progress of the project much smoother because we all know where everything is and that whatever is in the drop box is the most up-to-date version.

Cons:

One bad aspect to using the specific drop box program is that it has to be installed on the computer you wish to use it on in order to access the files. This creates an issue if the main computer which a team member like my self uses is a computer in 410. Since we do not have administrative rights to the computers, Drop box cannot be installed on them. This could create a serious logistical problem if a group member did not have a laptop that they could bring into the office with them. The group probably would have been better off either using Google docs or an ftp server which can be accessed by the computers in the offices.

One other thing that has been lacking in regards to communication is that there has not been a lot of communication between group members on work being done. It seems at times that group members were getting together outside of scheduled meeting times to work on certain key aspects of the project without informing the rest of the group. This may result in the feeling of being left out of the loop by certain group members.

Project Progress

Pros:
Setting up the hypothetical model early, showed as significant leap forward in the progress of the project. From a collaborative group perspective, expedient and early setup of this model could be considered the half-way point of the analysis portion of the project. This is because now that the model is setup, all what needs to be done is to plug in the raw data provided by each individual team member. This early setup will also help to accelerate the progress of each individual in their research by giving each team member a specific set of criteria to focus their research on. The hypothetical model will also help act as a guide to rate the actual progress of the team as a whole. As information is found it will be plugged into the model and then we can use that as a way of determining the level project completeness.

Cons:
The only negative aspect in regards to the team's progress is the lack of knowledge regarding each individual's progress on their individual research topic. It would be better if the team were to start setting internal group deadlines and time hacks for certain parts of the project so the group as a is more prepared to present material when meeting with the "Customer". In addition it seems that a lot of the initial work being accomplished is only being done by the same group members. More of an effort needs to be made to involve all group members in the initial phases of the project, even if

it requires the tasking of specific jobs to group members in addition to their specific research requirements.

Overall Assessment

With the exception of a few minor issues the project seems to be progressing at an efficient rate. The team as a whole is functioning very well. However, a more accurate sense of the team's progress will only be known once spring break comes to a close and all data for the hypothetical model needs to be collected.

Quentin Tourancheau
Mid-term Management Report

Team Structure

Initially, 2 sub groups, but every team member has 1 LEED category. The materialization of the subgroups was inexistent; each one was working on a specific part getting expertise and accountability, avoiding overlapping.
Risk: because of lot of accountability, if people don't meet requirements and deliverables, the whole team progress will be delayed. But it hasn't happened yet.

Communication

Communication has been generally fine, being a small team has facilitated it.
We use direct communication (co-locating in the office), meetings, emails, DropBox.
So far it worked well; I don't feel like missing information from the project.
The submission of deliverables has not been an issue because individuals have been aware of those responsibilities and deadlines

Currently we have set Wednesday evenings (after our weekly meeting with the project advisor) to meet altogether, but it hasn't been really productive because everyone is tired from the day. I recommend changing the day of the meeting.

Project Progress

I think we're on time so far, maybe on the edge of being late, because we didn't put that much of internal deadlines. I believe the second half of the semester will require more work for the gathering of data and finishing the model and the report.The initial background preparation for the model has been good set up by the advisor has been good, but I think further setting smaller and more frequent deliverables for the model (from the team itself) is appropriate for getting this project completed on time. One negative aspect in regards to the team's progress is the lack of knowledge regarding each individual's progress on their individual research topic

Having a team member who is LEED certified has also proved to be very useful, because he has a whole wealth of information that is relevant to the project and helpful to those of us who don't have the necessary background and experience.

Overall Assessment

It seems that the dynamics of the team are good; the sharing out of the work among the members looks fair. The definition and the characteristics of the project appear clearer. Everyone was getting to know each other and their way of working. The first half was essentially based on compiling data and information. I am excited to use hose information as inputs in our model. I realize the impact of the upper management (role embodied by Professor Vanek) which guides us and gives us the necessary resources. I believe the team will become more united as we share our expertise and as we work together to make the model work.

Thomas Virgin

Mid-term Management Report

Team Structure

The team was split into two subgroups and each person was given the responsibility of one of the 5 LEED categories. The two larger sub-groups became obsolete after each person was responsible for a particular LEED category. I think that this group breakdown structure was the most efficient use of people. This structure also helps to provide accountability for each person's deliverables. One downfall to this structure is that it is difficult to maintain short term accountability. This hasn't been a problem thus far, but as the project gets closer to the deadline, we will need to be more cognizant of each other's deliverables.

Communication

The group's communication has been adequate. I feel that there can be an improvement in this area. As it stands we have several ways of communicating, email, digital drop box, and a Google group account. Using email has been the most efficient way of sharing information. However, there are numerous emails and now regularity to them. I think if we utilized the Google group more often, we would be more efficient and less email obtrusive.

At present we have our meeting with our advisor, Professor Vanek, set up for Wednesdays afternoon and our group meeting without Professor Vanek immediately following. This seemed like a good idea at first, but has proven to be not as effective as we had hoped. I think everyone is ready to go after the first meet and doesn't want to hang around for another meeting starting at 6 PM. We are switching our meeting without Professor Vanek to Thursdays, which should improve our meetings.

Project Progress

I believe that our team is on schedule to complete all deliverables on time. However, like most projects, we are heavily end loaded. We will have a lot of work ahead of us to finish on time with high quality work. We have most of our research data complete and are working on the model for the project. As the model progresses, each team member should be moving forward with their respective portions of the project report and presentation.

Overall Assessment

For the first half of the semester everything has moved forward in the right direction. Although it feels like progress is slow. I think everyone was getting to know each other and figure out each other's preferred working styles. There was also a learning curve for everyone to figure out what the project is designed to achieve. There is still a plethora of work ahead of us, but I'm excited to review our results and examine our conclusions. With the help and guidance of Professor Vanek, I believe that our group now fully understands what is expected of us and our project and progressing accordingly.

Final Management Report

Team Structure

In the beginning of the semester the team was split into two subgroups and each person was given the responsibility of one of the 5 LEED categories. The two larger sub-groups became obsolete after each person was responsible for a particular LEED category. During the final stages of the project the team sub-groups pulled back together to compile project information and deliverables. This structure also helps to provide accountability for each person's deliverables; nevertheless it was based on the assumption that each member manage to produce his/her contribution on time. We did not have to face any issue of this type because everybody was able to deliver on time. Thomas Virgin did a great job informally in directing as a leader figure for the team and compiling the report. It was also good that we planned ahead and had two people working on the model because that was the most complicated part of the project. The authority of the leader could have been more used in order to accelerate the process, but it seems that the pace we worked at satisfied the all team.

Communication

Since the midterm management report, we began setting hard dates for the submission of various deliverables, and pre-assigning a team-member to be in charge of ensuring that the deliverable in question was ready for submission. Making the change to have meetings on Thursday evenings made a significant difference in getting the project done on time. We sometimes sat together for several hours in the one of our offices to get project deliverables done. During these meetings, we could quickly relay any questions we had for the group or individuals and request for any additional data from a specific team member. When we did not need to meet for long, we made sure to review our deadlines and responsibilities at the end of the meetings. It was convenient to have out weekly team meeting after our meeting with Vanek, but we were usually tired and not interested in much more work

Communication over e-mail was very productive. Members of the team would respond quickly to their e-mails (at least within 12 hours). It was difficult near the end when we had to compile all our parts for the report and presentation. Dropbox was helpful in sharing documents, but when we had to work on the same document at the same time, it would be difficult for us to save our progress. We found a way to work around this by designating times we would work on files in the Dropbox folder or at least send an e-mail to each other when one of us would be working on the "final" draft. Overall the communication within the team was excellent, it was pleasant to work all together

Project Progress

The deadlines we created together after our Wednesday meetings with the project advisor helped in setting realistic goals and milestones for ourselves. There was a rush at the end to finish the powerpoint and practice for the presentation due to some technical difficulties with Dropbox as mentioned above, but that did not affect our presentation greatly because people practiced on their own to prepare for the presentation. Some members were slightly late in delivering their parts to the team (but no more than 24 hours) so this delayed some of the time it took to compile all of our work. Even with some of those delays, we were able to complete the presentation and the project report material on time and in an organized fashion.

Overall Assessment

It seemed the audience from the presentation were pleased with our work and satisfied with the level of depth we went into researching our green technologies. Everyone was able to take away something from that presentation and the Tompkins County Planning Committee and those affiliated with Cornell University will be able to learn something from our final report.

It is evident from this that the team was cohesive enough to understand the importance of the feedback, and to imbibe them so as to ensure further effectiveness on the team's part. The camaraderie and team dynamic that was developed from the beginning of the semester grew even more, and individual feelings/sentiments were not allowed to affect this project.

This project was successful through all of the team members hard work and diligence along with professor Francis Vanek's guidance and expertise!

Anson Lin

Final management report

Team Structure

From the changes we made since the mid-term management report there was concern about some team members not finishing their work, but that did not become an issue. At times, some members fell behind due to their busy schedules, but they still finished their parts in the end. Thomas Virgin did a great job in directing as a leader figure for the team and compiling the report. It was also good that we planned ahead and had two people working on the model because that was the most complicated part of the project. Quentin Tourancheau was able to learn how to create drop-down menus during the project to finish the excel model even though he did know before. It was great to see exceptional effort from the team in taking responsibility for their parts of the project.

Communication

Making the change to have meetings on Thursday evenings made a significant difference in getting the project done on time. We sometimes sat together for several hours in the one of our offices to get project deliverables done. During these meetings, we could quickly relay any questions we had for the group or individuals and request for any additional data from a specific team member. When we did not need to meet for long, we made sure to review our deadlines and responsibilities at the end of the meetings.

Communication over e-mail was very productive. Members of the team would respond quickly to their e-mails (at least within 12 hours). It was difficult near the end when we had to compile all our parts for the report and presentation. Dropbox was helpful in sharing documents, but when we had to work on the same document at the same time, it would be difficult for us to save our progress. We found a way to work around this by designating times we would work on files in the Dropbox folder or at least send an e-mail to each other when one of us would be working on the “final” draft.

Project Progress

The deadlines we created together after our Wednesday meetings with the project advisor helped in setting realistic goals and milestones for ourselves. There was a rush at the end to finish the powerpoint and practice for the presentation due to some technical difficulties with Dropbox as mentioned above, but that did not affect our presentation greatly because people practiced on their own to prepare for the presentation. Some members were slightly late in delivering their parts to the team (but no more than 24 hours) so this delayed some of the time it took to compile all of our work. Even with some of those delays, we were able to complete the presentation and the project report material on time and in an organized fashion.

Overall Assessment

It seemed the audience from the presentation were pleased with our work and satisfied with the level of depth we went into researching our green technologies. Everyone was able to take away something from that presentation and the Tompkins County Planning Committee and those affiliated with Cornell University will be able to learn something from our final report.

In the end, I believe we managed to get through some of the obstacles of diverse cultural backgrounds and different work habits of the team members. At times, some of our communication styles clashed, but we were able to work around them. I think the diversity also helped contribute to the quality of our work since we asked each other questions to make sure we were not missing anything. Overall, this team did very well in delivering stellar work at a good pace and within the limited time they had.

Enrique Martinez

Final management report

I feel very lucky to have been part of this team. Being on this team was a real pleasure. Throughout my entire academic career I never had such a flawless experience working in a group, and I hope it wasn't a coincidence that it happened during my last semester at Cornell. I will try to keep this evaluation brief because there is no need to say much. Ever since we were able to determine a concise and concrete goal for the project the team worked in perfect synchrony. The personal tasks that were assigned to each member were described on my midterm evaluation. Everyone came through beyond what was expected of them. Additionally, Quentin and I took care of designing and building the model, and presenting the results along with recommendations. Thomas took care of the water efficiency part of the model. TJ was responsible for compiling the final report, and both Fona and Anson were very helpful in putting the presentation together and handling administrative tasks through the semester. In my opinion, everyone performed their tasks excellently and on time, and I believe the final result speaks for itself.

Fona Osunloye

Final management report

Team Structure:

The end of the semester didn't see much change to the team structure. We continued to work, with at least each member being responsible for their assigned section, and having to ensure that all the other team members were up-to-speed about the progress of their respective sections. I had previously stated that this arrangement was risky due to the likelihood of failure for the entire project if any one team member failed to deliver on their section. Fortunately for the entire team, that was not the case, and did not affect any of our activities.

Communication:

The team was able to improve upon this facet of group dynamics by the end of the semester which I believed helped play a major role in the quality of our final deliverables. Per our midterm management report, we began setting hard dates for the submission of various deliverables, and pre-assigning a team-member to be in charge of ensuring that the deliverable in question was ready for submission.

Meetings:

Going of the recommended fixes in the last management report, the team decided to revisit our team meeting schedule, and choose another time/day/date to meet that was most convenient for the entire team. What had been going on for most of the earlier part of the semester was that the team would try and meet immediately following its meeting with project supervisor, but proved unwise as these meetings ended up being very informal and lacking direction for the most part.

Overall Assessment:

All in all, I am proud of the progress that the team made, from the beginning of the semester, and the improvements that I noticed following the midterm management reports. It is evident from this that the team was cohesive enough to understand the importance of the feedback, and to imbibe them so as to ensure further effectiveness on the team's part. The camaraderie and team dynamic that was developed from the beginning of the semester grew even more, and individual feelings/sentiments were not allowed to affect this project.

Thomas Ruggieri

Final management report

Team Structure

Pros:

When looking back at the team structure nothing really changed since the initial restructuring of the team. Each team member was given a specific technology basis to research. And by the end of the project more than enough data was gathered to produce and effective savings model. In addition to that on beneficial change that occurred as the team structure further developed was that the initial subgroup structure was eventually dissolved in to small teams of two or specific individuals who were responsible for a specific technology base.

One of the major concerns that develop throughout the project was in regards to individuals meeting specific research and write up deadline which were set by the team. However each team member was able to produce the research that was needed at the necessary hour in order to finish the model on time. However, one way that this could be prevented would be to set up specific deliverable deadline within the team structure to use as a self-check, to ensure that all team members are performing their assigned tasks and will meet the deadlines set by the "Customer".

Communication

Pros:

Using Drop Box was an essential and necessary tool at the team's disposal. Though there were some doubts about its incapability with the office computers it was soon realized that all of the documents could be downloaded from the website onto a computer. The only drawback to this method is that the document would have to be re upload after changed were made. One other improvement that was made during the second half of the project was that communication between team members improved and the team stared to set up actual meetings outside of the schedule ones on Wednesday.

Cons:

One bad aspect to using the drop box program was that only one person could work on a specific document at a time. This ended up causing some delays and hick ups during the developmental stages of the PowerPoint and write up. This however was solved by scheduling out chunks of time in with each team member would work on their part of the master copy

Project Progress

Pros:

Throughout the semester there was a constant flow of positive progress on the project. Work and research was being done on a constant basis which in turn lead the project moved forward with only minimal delays.

Cons:

There were after occasions in which specific items in either the model, write up of power point were missing as the deadline came dangerously close. However these gaps were quickly filling to complete the work need to produce the deliverable on time.

Overall Assessment

With the exception of a few minor issues and set back which were resolve quickly, the project seemed to be progress at an efficient rate. The team as a whole functioned very well.

Quentin Tourancheau

Final management report

Team Structure

The structure we created for this project worked out well. The accountability of each member was high and we were relying on the good work of everybody. No one really fell behind schedule; the minor delays were sporadic and did not affect dramatically the overall progress of the project.
TJ turned out (as expected) to be a good informal leader. The Excel model required the work of 2 people who did get along well in order to deliver a practical tool.

Communication

Since the midterm management report, we began setting hard dates for the submission of various deliverables, and pre-assigning a team-member to be in charge of ensuring that the deliverable in question was ready for submission. Making the change to have meetings on Thursday evenings made a significant difference in getting the project done on time. Working all together in the same room increased significantly the productivity of the team and helped us finishing on time some deliverables.

Indirect communication via emails was good, and the commitment of every team member made it valuable. The use of Dropbox was helpful to share documents; however it doesn’t allow simultaneous work on the same document, therefore we had to be rigorous on how and when we work on a document particularly at the end to finalize the different deliverables.

Overall Assessment

The presentation seemed to have pleased the audience on the form and content. I think this project was a success; the level of depth is interesting and would represent a solid base for following projects.

I was surprised how well the team got along, there were exceptionally rare disputes and it went fine through discussion. The commitment, the interest and the harmony made this project a success.

Thomas Virgin

Final management report

Team Structure

In the beginning of the semester the team was split into two subgroups and each person was given the responsibility of one of the 5 LEED categories. The two larger sub-groups became obsolete after each person was responsible for a particular LEED category. During the final stages of the project the team sub-groups pulled back together to compile project information and deliverables. I think that this group breakdown structure was the most efficient use of people. This structure also helps to provide accountability for each person's deliverables. One downfall to this structure is that it is difficult to maintain short term accountability. This never really became a problem as everyone stayed on top of the deliverables that were due. Overall, I would say the structure worked well, but could have used a more formal team leader. Due to the nature of the program everyone wanted to be the leader or manager and as a group we decided that no team leader would be a better option.

Communication

The group's communication improved through the final stages of the project. As a whole we were more readily available for each other. As it stands we have several ways of communicating, email, digital drop box, and a Google group account. Using email remained the most efficient way of communicating, short of face-to-face time. As a group we used our digital drop box account much more efficiently, which helped to reduce some of the unnecessary emailing. I feel that our group had little to no problems communicating with each other.

After switching our team meeting without Professor Vanek to Thursday's we were able to accomplish much more work. It was convenient to have out weekly team meeting after our meeting with Vanek, but we were usually tired and not interested in much more work. After switching to Thursdays our meetings became much more productive and more conducive to progress. I think this switch was a critical change for the better for our teams work and communication.

Project Progress

I think our team did a great job finalizing all project deliverables. Everything was finished on-time given the large time constraints that each team member had. I feel like out team presentation was a great success and provided Tompkins County with pertinent information for their future development plans. The final report is getting the finishing touches on it and final revisions made and I am positive it will be equally informative and eye-catching.

Overall Assessment

I think this project was extremely successful through all of the team members hard work and diligence along with professor Francis Vanek's guidance and expertise!