

Kling Stubbins/City of  
Raleigh

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**Clarence E. Lightner  
Public Safety Center**

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Sustainability Plan

FINAL

ARUP

Kling Stubbins/City of  
Raleigh

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**Clarence E. Lightner  
Public Safety Center**

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Sustainability Plan

March 2008

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# Contents

	Page	
Executive Summary	3	
1 Introduction	8	<b>Tables</b>
1.1 Project overview	8	Table 1 – Cost of photovoltaic system after incentives
1.2 Approach	8	Table 2 - Greenhouse Gas (GHG) produced by the building's fuel source
1.3 Project Context	8	Table 3 - Plumbing fixtures
2 Energy	10	Table 4 - Water efficient fixture savings
2.1 Photovoltaics	10	Table 5 - Water savings due to rainwater harvesting
2.2 Solar hot water	13	Table 6 - Water savings due to water efficient fixtures, rainwater harvesting and greywater recycling
2.3 Ground source energy	14	Table 7 - Annual financial savings for potable water source and wastewater disposal fees
2.4 Fuel Cells	16	Table 8 - Typical embodied energy for construction materials
2.5 Microturbines	17	
3 Water	19	<b>Figures</b>
3.1 Managing water demand	20	Figure 1 - Average monthly temperature in Raleigh, NC
3.2 Water efficiency	20	Figure 2 - Average monthly precipitation in Raleigh, NC
3.3 Rainwater harvesting technologies	21	Figure 3 - Flat photovoltaic panels
3.4 Wastewater treatment technologies for re-use	24	Figure 4 - PV schematic
3.5 Condensate return	27	Figure 5 - Cumulative Cash Flow for PV system in Raleigh, NC
4 Materials	28	Figure 6 - Cumulative Cash Flow for PV system with no incentives in Raleigh, NC
4.1 Embodied Energy	28	Figure 7 - Transparent PVs – Overhead glazing (left), vertical glazing (center) and transparency options (right)
5 Healthy Design	30	Figure 8 - An active solar collecting system connected to a hot water tank
5.1 Natural Ventilation	30	Figure 9 - Ground Energy
5.2 Daylighting	31	Figure 10 - Ground source heat pump types
6 Vehicle programs	33	Figure 11 - A heat pump vapor compression refrigeration cycle
7 Summary	34	Figure 12 - Diagram showing how a fuel cell works
		Figure 13 - Capstone Microturbine
		Figure 14 - Typical water system
		Figure 15 - High performance integrated water system
		Figure 16 - Low flow fixture technologies
		Figure 17 - Rooftop rainwater harvesting treatment without disinfection

Figure 18 - Typical rainwater harvesting systems

Figure 19 - Non-potable demand vs. Rainwater supply

Figure 20 - Aquality natural greywater recycling system

Figure 21 - Non-potable demand vs. Greywater supply

Figure 22 - 100 mile and 500 mile radius from the project site

Figure 23 - Annual wind rose (left) and summer wind rose (right)

Figure 24 - Green/red light system

Figure 25 - Daylight sensors

Figure 26 - PHEV vehicle

## Executive Summary

The purpose of this report is to present the City's vision for sustainability at the Clarence E. Lightner Public Safety Center and identify the strategies and actions for the City of Raleigh to implement the sustainability goals of the proposed building. The report is structured around a sustainability framework that encompasses 13 key focus areas discussed at the Sustainability Charrette for the City on January 3<sup>rd</sup> and 4<sup>th</sup>, 2008:

- Energy
- Design with Climate
- Water
- Materials
- Waste
- Community Engagement
- Open Space
- Emergency Services
- Transportation
- Accessibility
- Sustainability Engagement
- Economic Impacts
- Health and Productivity

The focus areas have been developed using a holistic, systems-based approach that provides a comprehensive overview of resource flows and consumption across the building. For each focus area, specific goals, strategies, actions, responsible team members, maintenance issues, cost implications and supported sustainability guidelines/frameworks have been identified.

Recognizing that new technologies may emerge in the future, and that the economics of some current technologies may improve over time, it is intended that the Action Plan for Clarence E. Lightner Public Safety Center will strive to achieve progressively higher standards for sustainable design. This anticipatory approach will provide

flexibility in achieving sustainability goals through the most technologically and economically feasible means possible. The approach to incorporating sustainable technologies for design and construction and evaluating sustainability progress during building operation is discussed in the Action Plan.

Several technologies discussed in the Action Plan were selected and a cost benefit analysis was performed. The criterion for selecting these technologies were based on the impact they would have on the building and the City of Raleigh. The technologies selected were:

- Photovoltaic Panels
- Ground Source Heat Pumps
- Fuel Cells/Microturbines
- Low flow water fixtures
- Rainwater harvesting
- Greywater Recycling
- Low embodied energy materials
- Natural Ventilation
- Daylighting
- Fuel Efficient Vehicles

The Action Plan is shown on the following page. Some of the goals are aspirational and are not achievable with current technology. The complete action plan with associated responsibilities, maintenance issues, cost implications and related frameworks/guidelines is in Appendix A. A LEED checklist for the Clarence E. Lightner Public Safety Center is in Appendix B and is one of the guidelines used in the action plan.

## Clarence E. Lightner Public Safety Center

Goals	Strategies	Actions
<b>Energy</b>		
Create a building that generates more energy than it consumes	E1. Maximize the percentage of power generation from renewable sources	<ol style="list-style-type: none"> <li>1. Develop on-site cogeneration through fuel cells, microturbines or biodiesel.</li> <li>2. Use a renewable grid-connected power source (i.e., PVs) for 10% of energy supply.</li> </ol>
Design a "carbon neutral" building	E2. Support carbon neutrality by minimizing emissions	<ol style="list-style-type: none"> <li>3. Install a Building Management System (BMS) to continually monitor energy and water use by the building</li> <li>4. Install heat recovery systems, ground source heat pumps, chilled beams, solar thermal storage units, LEDs, and other energy efficient systems. Optimize natural light and ventilation.</li> <li>5. Purchase renewable energy credits from a utility provider that provides renewable energy.</li> </ol>
Develop a strategic relationship with the utility	E3. Develop a Green Power Initiative with the local utility	<ol style="list-style-type: none"> <li>6. Work with Progress Energy to source alternative renewable energy resources.</li> </ol>
<b>Design with climate</b>		
Create a positive microclimate	C1. Reduce heat islands on the project site. C2. Improve the air quality inside the building. C3. Provide water features to enhance "comfort"	<ol style="list-style-type: none"> <li>1. Shade all surfaces on site with landscapes, use high albedo materials for pavements and roof surfaces, and/or construct a vegetated roof.</li> <li>2. Provide plants that help remove indoor air pollutants and prevent sick-building illness.</li> <li>3. Install water features or other leisure areas to improve workspace comfort.</li> </ol>
Orient the building to reduce energy use and glare	C4. Maximize the beneficial effects of the sun and minimize wind impacts	<ol style="list-style-type: none"> <li>4. Design site to maximize facade area in the north south direction because these directions are easy to shade</li> <li>5. Supply natural ventilation to building occupants and monitor CO<sub>2</sub> to reduce energy use and create a healthy and productive working environment</li> </ol>
<b>Water</b>		
Minimize use of potable water and maximize reuse	W1. Reduce potable water consumption by a minimum of 30%	<ol style="list-style-type: none"> <li>1. Install a greywater recycling system.</li> <li>2. Reuse the condensate produced during dehumidification</li> <li>3. Install low flow plumbing fixtures.</li> </ol>
Minimize stormwater runoff on-site	W2. Minimize stormwater runoff by capturing 90% of rainfall on roofs and open spaces	<ol style="list-style-type: none"> <li>4. Install a rainwater harvesting on roof with retention tanks (or cisterns).</li> <li>5. Treat stormwater to greywater and/or irrigation standards</li> </ol>

Goals	Strategies	Actions
<b>Materials</b>		
Maximize use of regional and recycled materials	M1. Reuse a minimum of 20% of materials from the existing building M2. Procure 10% of materials (by cost) within 125 miles and 20% of materials within 500 miles of the site	1. Develop a plan locating existing materials and retain these materials for future use (for original purpose or another purpose). 2. Identify regionally manufactured materials (extracted or recovered if possible) during construction and building operation
Minimize the embodied energy of materials	M3. Implement a Life Cycle Analysis for all construction materials and materials during the operation of the building	3. Establish a comprehensive centralized preferential purchasing program that encourages procuring sustainable and locally sourced products.
Design with materials that promote public health	M4. Minimize the use of toxic materials during construction and operation	4. Use materials with low or no volatile organic compound (VOC) levels 5. Develop a green cleaning program
<b>Waste</b>		
Divert waste from landfills during construction	WT1. Divert a minimum of 75% of waste from landfill	1. Identify construction haulers and recyclers to handle materials
Minimize waste during building operation	WT2. Create a building recycling program which recycles paper, cardboard, glass, metal and plastic (add organic waste, if possible) WT3. Reduce waste generation during building operation by a minimum of 50% from a baseline amount (if no recycling program and purchasing policy)	2. Locate and designate collection and storage areas for recyclables. 3. Organize informational programs informing building occupants about the recycling program and recommend purchasing policies specifying easily recycled or composted products.
<b>Community Engagement</b>		
Engage the community in the design of the building	CE1. Review designs with Wake County Advisory Board and Core Advisory Board. CE2. Engage community and stakeholders CE3. Engage in PEER reviews with local architecture chapters and colleges CE4. Request feedback from building occupants	1. Contact and schedule schematic and design reviews with the Wake County Advisory Board and Core Advisory Board. 2. Host public information and comment meetings to assure community members and stakeholders values, concerns and needs are met. 3. Invite the local AIA and College of Design to review designs and provide feedback. 4. Provide a survey to all occupants regarding thermal comfort, acoustic comfort, air quality, lighting, etc.

Goals	Strategies	Actions
<b>Open Space</b>		
Create a vital public streetscape and connect Nash Square	O1. Design a mid-block crossing and entry plaza to connect to Nash Square.	1. Locate the main entrance of the building to face Nash Square and provide a crosswalk with "pedestrian crossing" signs
Design communal spaces within the building and enhance biodiversity	O2. Allocate about 0.5% of the building budget towards a public art display. O3. Design an accessible roof garden, balcony, courtyard, or atrium featuring diverse plant species	2. Provide space in the lobby or outside the building for a public art display. Engage the community through contests or monthly exhibits. 3. Design a courtyard, atrium or balcony as casual meeting areas (incorporate diversity using native and drought resistant plant species if possible)
Reduce light pollution from the building	O4. Ensure that site lighting maintains safe levels avoiding off-site lighting and night sky pollution	4. Design interior lighting to maintain direct beam illumination, exterior lighting to achieve power densities less than required in ASHRAE 90.1-2004 and complying with zoning requirements. Exterior lighting
<b>Emergency Services</b>		
Maintain a fully operational building during natural disasters	ES1. Provide a "clean" backup energy source	1. Research the possibility of biodiesel, fuel cells or microturbines for backup power generation.
Maintain operation of EOC and ECC services	ES2. Install a radio/satellite communication system	2. Research the feasibility of a backup radio/satellite communication system for EOC and ECC services.
<b>Transportation</b>		
Reduce miles traveled for design services, construction and occupants	T1. Track miles traveled for design and construction services to reduce miles traveled  T2. Track miles traveled for construction and design services and building occupants and set targets to reduce footprint over building life	1. Require contractors and design team to track miles traveled during the design and construction of the building  2. Survey building occupants to determine mode of transportation (car type) and miles traveled. Track and present carbon footprint from transportation paths.
Actively encourage alternative transit for occupants and visitors	T3. Provide covered, lit and secure bike racks T4. Provide a bus shelter outside the building T5. Provide an fuel efficient police fleet and preferred parking for alternative fuel/fuel efficient vehicles and carpoolers T6. Design the site to be "pedestrian friendly"	3. Locate and install bike covered bike racks for a minimum of 5% of the building occupants. Provide shower facilities for 0.5% of the building occupants. 4. Install a covered bus shelter at the bus stop outside the building. 5. Locate preferred parking (closest to the building entrance) for low emitting/fuel efficient vehicles for 5% of parking capacity for the building and for carpoolers (5% occupants or parking capacity). Implement a carpooling program by bulletin board or website. Provide low emission/fuel efficient vehicles to police fleet. 6. Provide secure lighting at street level, remove the curb cuts, and install "No Turn on Red" sign at intersections adjacent to the building.

Goals	Strategies	Actions
<b>Accessibility</b>		
Design to achieve equal accessibility for all (beyond ADA)	A1. Create a system of signage and wayfinding tools that meet the needs of the building	1. Provide highly visible and adequate signage which integrates with the building "context"
Balance public accessibility and security	A2. Incorporate public spaces inside a secure building.	2. Divide the building into security zones appropriate to function
<b>Sustainability Engagement</b>		
Showcase sustainability to educate the occupants, the public and the region	SE1. Design a building that makes a statement in terms of efficiency (energy, water, waste, health, etc) and aesthetics	1. Organize building tours for the public 2. Showcase energy, water and waste saving techniques with signs and interactive kiosks with intravenous monitoring of water and energy 3. Create a documentary and enter the building for awards
<b>Economic Impacts</b>		
Promote diversity within the construction/design team	EI1. Contract a minimum of 30% of the construction team as Historically Underutilized Business (HUB) firms during construction.	1. Specify minimum HUB requirements during construction.
Design the building for future flexibility	EI2. Design buildings with the intent of expansion to reduce the need for future construction	2. Analyze future programs for the building, increase ceiling height and leave open spaces.
<b>Health and Productivity</b>		
Design the building for maximum health and productivity	HP1. Provide spaces with maximum daylight and views to the outside. HP2. Allow occupants to have control of lighting and temperature. HP3. Design spaces to reduce noise intrusion and enhance privacy HP4. Promote employee health throughout the building HP5. Provide adequate ventilation in chemical storage areas.	1. Orient the building and incorporate clerestory windows, skylights, interior light shelves, louvers and blinds to increase daylight for a minimum of 75% of spaces. 2. Provide views to the outside of the building for 90% of occupants between 2.5 to 7.5 feet. 3. Determine the occupant tasks and design individual lighting controls for 90% of building occupants and controllability in multi-use spaces. 4. Design an underfloor air distribution system with to allow a minimum of 50% of the building occupants temperature control and controllability in multi-use spaces. 5. Design facades and interior to meet acoustical standard ANSI S12.60-2002 6. Determine the feasibility of a fitness facility in the building, offer reduced fees for fitness facilities located throughout the City, install scales in restrooms and provide employee health training sessions. 7. Provide partitions and dedicated exhaust systems for chemical storage areas and copy rooms.

# 1 Introduction

## 1.1 Project overview

The Clarence E. Lightner Public Safety Center is a proposed 260,000 square foot building between 15 to 18 stories tall for the Raleigh police and fire departments, emergency response (ER), traffic management and other City departments.

The City of Raleigh would like to use the building to showcase sustainable design and operation. A Sustainability Charrette was held on January 3<sup>rd</sup> and 4<sup>th</sup>, 2008, which established preliminary goals for the new building. An Action Plan (in Appendix A) was developed from the Sustainability Charrette Workshop. The action plan lists the goals of the project established at that meeting, strategies to accomplish the goals, actions and responsibilities to achieve the strategies, maintenance issues that may arise, cost implications and frameworks and guidelines to compare these actions.

Concurrent with the project goals in the action plan, the City of Raleigh has set the following additional goals:

- To build a LEED NC Gold certified building
- Reducing fossil fuel consumption by 20 % over the next five years
- To move forward on its commitment to the U.S. Mayors' Climate Protection Agreement.

These goals can be accomplished if the strategies in the action plan are followed. Many of the strategies and actions in the action plan are similar to those contained in USGBC's LEED (Leadership in Energy and Environmental Design) rating system. LEED is a voluntary, consensus-based, market-driven building rating system based on proven technologies that evaluates environmental performance from a whole building perspective over a building's life cycle, providing a definitive standard for what constitutes a "green building". It is a performance-oriented system where credits are earned for satisfying criteria designed to address specific environmental impacts inherent in the design, construction, operations and maintenance of buildings. Different levels of green building certification are awarded based on the total credits

earned. The system is designed to be both comprehensive and simple to use.<sup>1</sup> A LEED checklist is attached in Appendix B. In addition, several other frameworks/guidelines were referenced in the Action Plan, including the Cascadia Living Building Challenge (LBC) Guidelines and One Planet Living Guidelines. The Cascadia LBC is a set of 16 prerequisites (called petals) that are intended to push performance beyond the LEED guidelines. For this project, not all petals but some could be obtained. One Planet Living (OPL) is a set of 10 guiding principles, where the actual standards are determined by region. These principles may not all be achievable for this project but we suggest that they are used for reference.

Arup selected several strategies and actions established in the Action Plan for cost and benefit analysis. The strategies selected have actions that may have high capital costs but have a payback period within the technology life. In general, only marginal strategies were assessed.

## 1.2 Approach

An initial assessment was undertaken to determine the feasibility of selected strategies and actions against the local climate and site constraints. Some of the strategies and actions were then assessed in more detail using a cost - benefit technique.

Cost - benefit analysis is the comparison of an approach or technology against another (often the business as usual approach). The analysis informs decision making by evaluating the monetary value of initial and ongoing cost against expected return or benefits. The level of detail that goes into cost-benefit varies and it is commonly used to give an approximate comparison against different technologies in order to help project decision making.

Arup assessed a number of strategies for energy, water, materials and healthy design using data derived from the building conceptual plan, industry standards, project experience and local incentives. Using this data, costs and benefits were calculated and, where possible, presented.

## 1.3 Project Context

Raleigh, North Carolina is in a hot-humid climate zone with poor wind resources but favorable solar radiation. Average temperatures in Raleigh range from 30°F to 50°F in

<sup>1</sup> USGBC Leadership in Energy and Environmental Design (LEED) Core & Shell Development version 2.0 Reference Guide First Edition June 2006

the winter and from 68°F to 90°F in the summer (Figure 1). Due to warm ambient temperatures and the type of occupancy, the cooling season will be longer and more significant than the heating season.

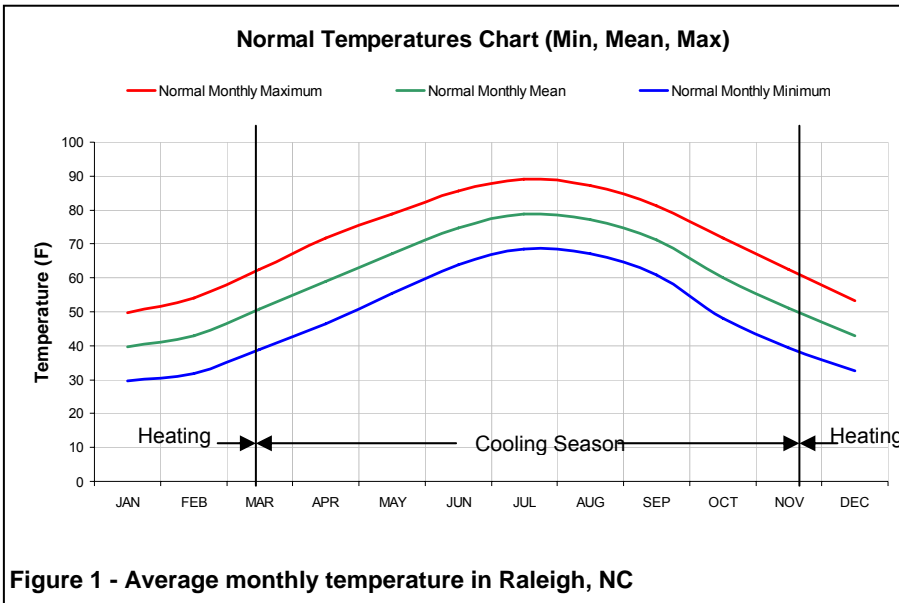


Figure 1 - Average monthly temperature in Raleigh, NC

The City is located in a region with generally consistent rainfall throughout the year totaling 43.1 inches (Figure 2). However, the region is currently experiencing a long and harsh drought. The building should therefore conserve water wherever possible. In addition, it is not just drought conditions that make water conservation worth doing - water treatment both before and after use is expensive and energy intensive.

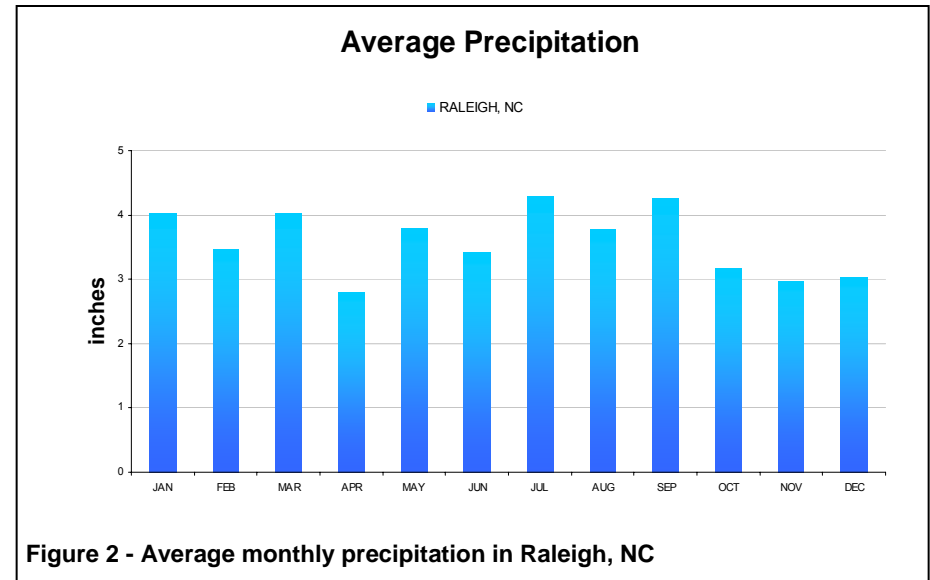


Figure 2 - Average monthly precipitation in Raleigh, NC

## 2 Energy

### 2.1 Photovoltaics

Photovoltaics cells are devices that convert solar radiation into electrical energy. The technology is similar to semi-conductors. Photovoltaics are normally sold for use as panels. These panels contain a number of photovoltaic cells pre-wired and enclosed in glass for protection.

Photovoltaic panels (PVs) (Figure 3) can be distributed on building roofs throughout the building to generate electricity. At the Clarence E. Lightner Public Safety Center the panels should preferably face south and as they are likely to be on the roof of the building, their angle should be around +/- 30 degrees. It is important that the panels do not shade one another as this reduces output. Some solar systems can rotate on one or two axes so that they face the sun directly for as much time as possible.

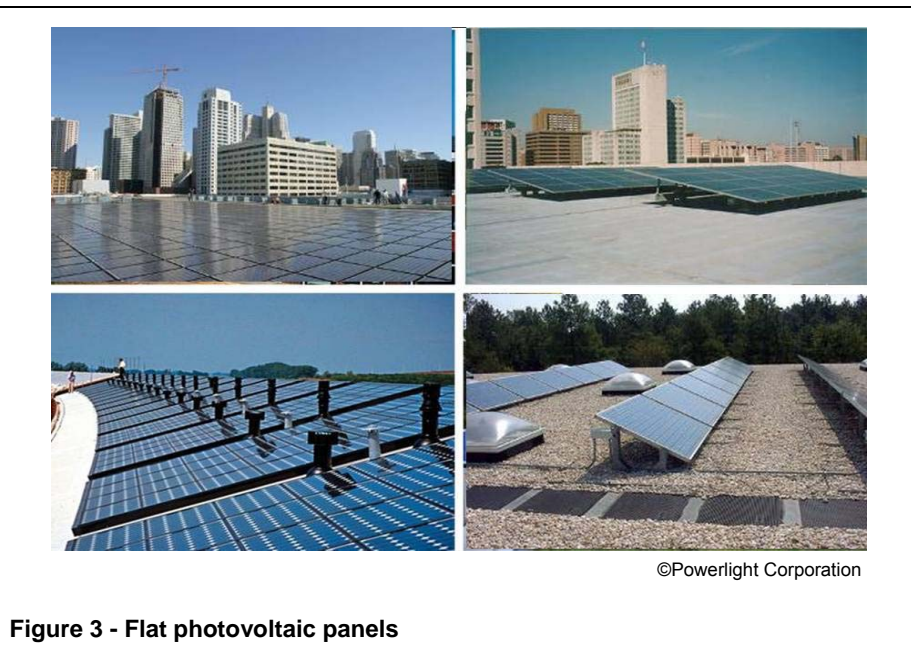


Figure 3 - Flat photovoltaic panels

These types of systems are capable of capturing more solar radiation, however a fixed system is cheaper and requires less maintenance.

As an exercise in exploring the potential of photovoltaics at the site, a target was set for covering 10% of the total roof surface area with photovoltaics. The total roof area was calculated at approximately 22,200 ft<sup>2</sup>. Using RETScreen International software ([www.etscreen.net](http://www.etscreen.net)) and weather from Raleigh-Durham International airport, North Carolina, it was determined that if approximately 10% of roof area (2,216 ft<sup>2</sup>) was covered with photovoltaic panels (a schematic is illustrated in Figure 4), the panels would be capable of producing approximately 45 MWh per year. If the City would like to purchase 4,000 ft<sup>2</sup> of photovoltaics, the panels could produce about 92 MWh per year, which is about 3% of an annual energy use estimate for the building. An energy model of the building should be used to estimate the building's energy demand accurately and conclude the amount of PV panels required. Additional panels could be added to other areas of the building with solar exposure. The amount of energy produced by the panels is scalable to the estimated values mentioned above.

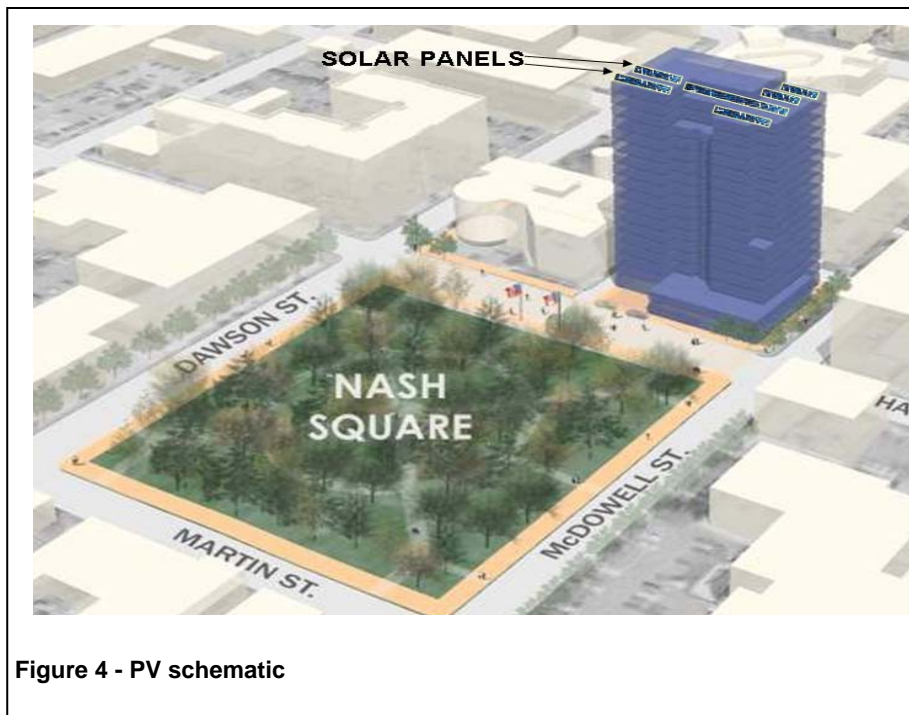


Figure 4 - PV schematic

The calculations above used 183 Canadian Solar/CS5A-195M panels rated at 17.3%. This is a good typical value. Solar panels are improving with time and it is possible

that within a few years' efficiencies greater than 20% will be common. The panels gross cost is approximately \$9 per installed Watt or \$145 per square foot including all associated infrastructure, inverters and cabling. As shown on Table 1, the cost of the photovoltaic system is substantially reduced with economies of scale, federal and state tax credits and utility rebates. North Carolina's tax incentives for alternative energy are favorable and also include loans [Energy Improvement Loan Program (EILP)] to fund photovoltaic and energy reducing measures. A 30% tax rebate is offered by the federal government, a 35% tax credit is awarded by the State and the NC GreenPower production credit, which gives \$0.18 for each kWh generated back to the grid. Progress energy gives an additional \$0.04 per kWh (approximate) generated back to the grid under a power-purchase agreement. The duration of the production credit is assumed to be 25 years. In addition, costs are predicted to decrease as investment increases and the technology becomes more readily available. The tax incentives do not apply to the City government but it may be possible to deduct from city bonds, arrange a third company agreement or organize a lease-purchase arrangement. For example, the US EPA RTP building in Durham arranged a lease purchase agreement with their local energy provider for photovoltaic lighting on the site. The annual savings was determined using a local electricity rate of \$0.06/kWh, as mentioned at the presentation on February 29<sup>th</sup>, 2008.

Initial Capital Cost of PV arrays (for 2,200 ft <sup>2</sup> of panels)	\$321,822
30% tax rebate - federal incentive*	(\$96,547)
35% North Carolina Renewable Energy Tax Credit**	(\$112,638)
<b>Net Capital Cost</b>	<b>\$112,637</b>
NC GreenPower*** Production Credit (\$0.18/kWh if sold to grid) plus Progress Energy power purchase agreement (\$0.04/kWh if sold to grid) plus electricity cost savings	
<b>Annual Savings</b>	<b>\$13,567</b>

\* Federal incentives include a 30% tax rebate

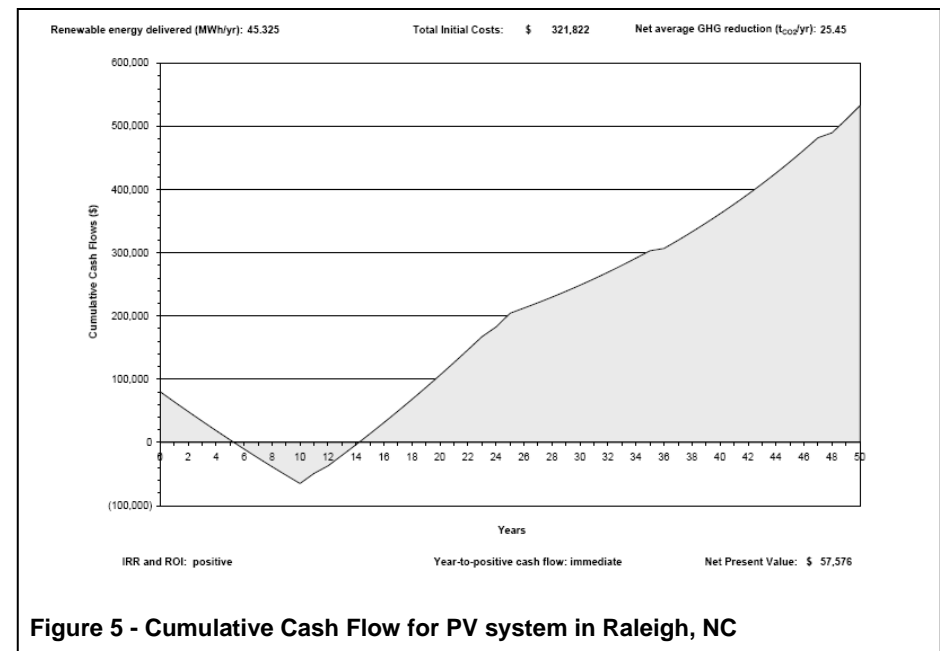
\*\*North Carolina Renewable Energy Tax Credit – “a credit of 35% of the cost of renewable energy property constructed, purchased or leased by a taxpayer and placed into service in North Carolina during the taxable year” ( tax rebate up to \$2.5 million)

\*\*\*NC Green Power Incentive – “Owners of solar-electric systems enrolled in NC GreenPower receive \$0.18/kWh from the program, plus approximately \$0.04/kWh from their utility under the power-purchase agreement, for a total production payment of about \$0.22/kWh”

**Table 1 – Cost of photovoltaic system after incentives**

North Carolina Senate Bill 3, written in August 2007, requires North Carolina to generate a minimum of 12.5% of its power from renewable resources by 2021, another reason to consider photovoltaics for the project

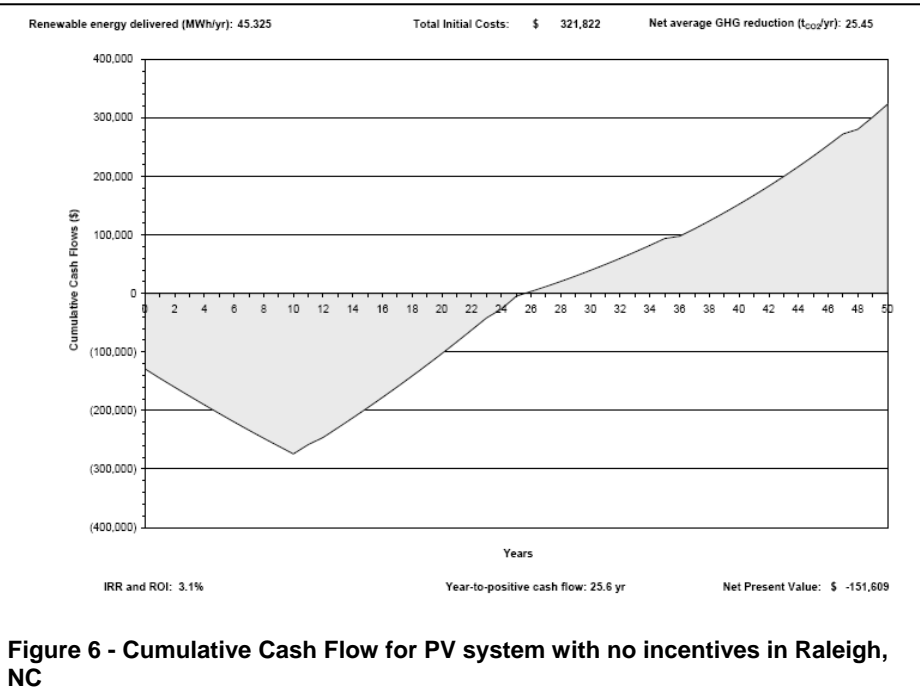
Due to the incentives, the projected payback for this photovoltaic system is approximately 9 years with immediate year-to-positive cash flow. Year-to-positive cash flow is the length of time that it takes for the owner of a project to recoup its own initial investment out of the project cash flows generated. The year-to-positive cash flow considers project cash flows following the first year as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback<sup>2</sup>. The cumulative cash flow is shown in Figure 5. The initial positive cash flow, shown in Figure 5, will occur if the City prefers to take a loan on the initial capital investment of the project. The loan used in this analysis assumed 60% debt ratio, 8% debt interest rate and a 10 year payback. The duration of the production credit is assumed to be 25 years.



**Figure 5 - Cumulative Cash Flow for PV system in Raleigh, NC**

<sup>2</sup> RetScreen

If the City does not receive tax incentives then the projected payback for this photovoltaic system is approximately 25 years, which is the typical life of the photovoltaic system. However, the increase in energy costs and the volatility/unpredictability of the energy industry makes the model more difficult to predict. Rising energy costs will likely reduce the payback time for the system. The cumulative cash flow for the same size system with no incentives (with debt repayment) is shown in Figure 6.



**Figure 6 - Cumulative Cash Flow for PV system with no incentives in Raleigh, NC**

Translucent photovoltaic panels (Figure 7) are also available which can be integrated into buildings to increase available photovoltaics or where it is not practical to fit panels to the roof or side of buildings. However, translucent panels are much less efficient, more costly and fragile.



**Figure 7 - Transparent PVs – Overhead glazing (left), vertical glazing (center) and transparency options (right)**

By installing photovoltaics, the building will be reducing its dependence on the electrical grid and reduce its associated greenhouse gas (GHG) emissions. Currently, the City of Raleigh is receiving its energy from Progress Energy. The breakdown of fuels used to produce this energy and their associated GHG emission factor in the region is in Table 2.

Fuel Source	%	GHG emission factor (tCO <sub>2</sub> /MWh)
Coal	51.0%	1.069
Nuclear	40.0%	0.000
Natural gas	4.0%	0.491
#6 oil	2.0%	1.018
Large hydro	2.0%	0
Renewables (biomass)	1.0%	0
<b>Weighted Average</b>	<b>100%</b>	-----

**Table 2 - Greenhouse Gas (GHG) produced by the building's fuel source**

The production of 45MWh of renewable energy annually should reduce GHGs by approximately 25.45 tons per year.

Automatic power cutoff of these systems needs to be included so that the utility can fix power lines during a power outage. If this system is not installed then the PV system will still be sending electricity to the grid while maintenance crews are working on the utility lines.

## Benefits

- Long life, minimal maintenance
- North Carolina offers generous incentive programs
- Visible educational benefit and advertisement for sustainability

## Constraints

- Large investment, even with incentives
- Efficiency of panels may degrade over time
- Complication of structuring purchase agreements to take tax benefits

## Maintenance

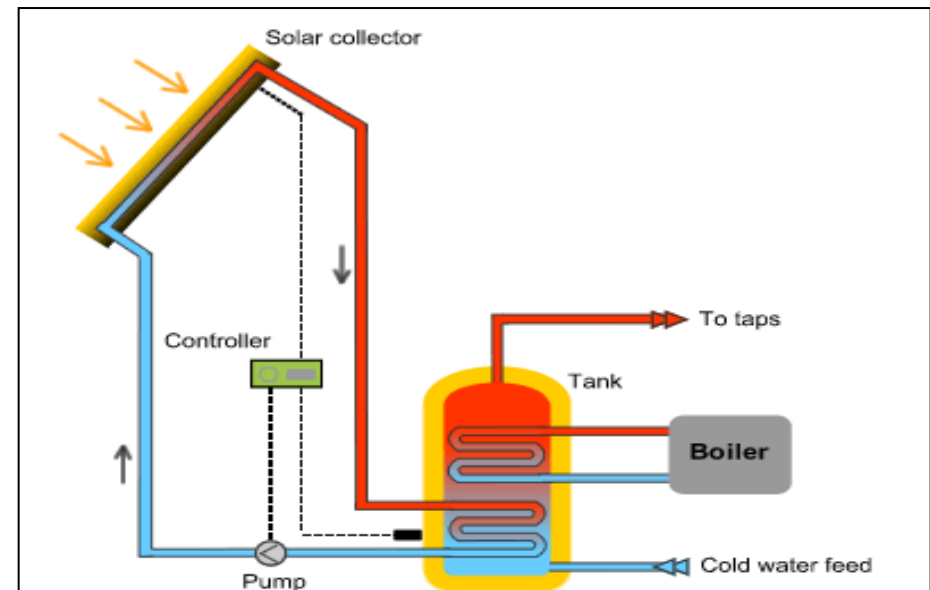
- Panels require cleaning to remove dust and pollen (panels should be cleaned during the cooler part of the day)
- Periodic inspections of electrical systems (wires and inverter) and panel supports
- Monitor the annual electricity output to see if degradation is occurring or the system capacity is decreasing (validate warranty)
- To pass UL testing, modules must be able to withstand wind gusts of 120 mph (50 lbs/ft<sup>2</sup>) and one-inch hail stones.

## 2.2 Solar hot water

Solar Hot Water technologies use a series of panels or tubes with water circulating through them which are designed and orientated to collect the sun's energy and transfer it to the water (Figure 8). The solar heated water can then be used within the building for domestic hot water (DHW) heating or to provide energy to the buildings heating system. There are a number of collector types on the market. The two most appropriate for commercial use are flat plate collectors and evacuated tubes.

The flat plate collector consists of a glazed front panel with an insulated box sitting behind this. The inside of the box is lined with a solar absorptive material. This system typically heats water to between 70°F and 180°F.

Evacuated tubes use an array of tubes that contain an inner and outer tube with a vacuum between. The inner tube is coated with an absorptive material and contains a liquid. This liquid evaporates when the sun's energy hits the tubes and transfers the heat to a header tank which contains the water being heated. The vacuum helps to ensure that this technology is highly efficient. Typically, this product heats water to between 170°F and 350°F and could operate on cloudy days.



©The Solar Trade Association

**Figure 8 - An active solar collecting system connected to a hot water tank**

The water circulated through the collectors is typically kept as a closed loop for commercial applications. This water enters a tank where a heat exchanger transfers the heat to the system water, which can then be used for DHW or for heating purposes. Typically, a gas heater is also used to top off the collector heated water when required.

The cost of solar hot water systems, including installation, range from \$50 per square foot to \$90 per square foot (less expensive than a PV) depending on the type of installation. Typical payback in this region for roof mounted solar collectors sized to

meet minimum monthly hot water demand compared to a base case system (domestic water heated by ASHRAE minimally compliant gasified water heating system with 5% recirculation) is \$27,536 annually with a 7 year payback. The payback could increase or decrease depending on the hot water demand of the building. Currently, hybrid PV/solar thermal systems are not recommended and the heat produced by the solar thermal unit directly affects the efficiency of the PV. These systems could work separately, however.

### Benefits

- A less expensive renewable technology
- Minimal maintenance
- May reduce boiler and water heater sizes

### Constraints

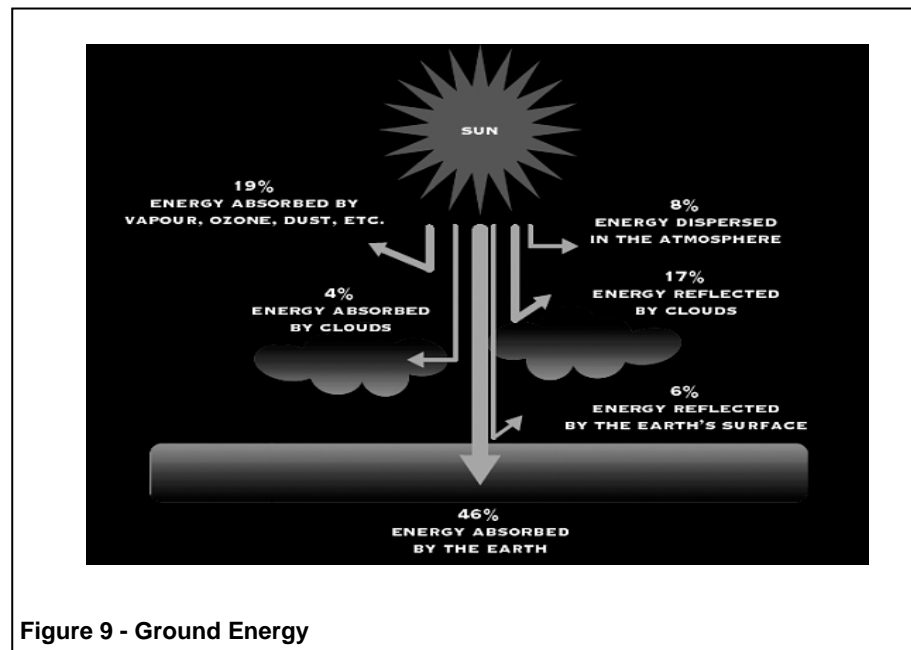
- Requires roof area (reduces photovoltaic energy output to grid)
- Cost premium

### Maintenance

- Panels require cleaning to remove dust and pollen (panels should be cleaned during the cooler part of the day)
- Hard water may corrode the systems

## 2.3 Ground source energy

A geothermal system offers the opportunity to use the Earth's natural thermal energy making the earth a "thermal battery" (Figure 9).



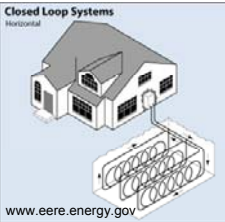
There are four types of ground source heat pump arrangements:

- Horizontal Closed Loop
- Vertical Open Loop Injection/Extraction
- Standing Column Well
- Energy Piles

These arrangements are shown in Figure 10.


In all cases, the concept is to use the earth as a heat sink and/or heat source. Compared to a conventional water cooled refrigerant circuit, the ground performs the function as the condenser and heat rejection plant.

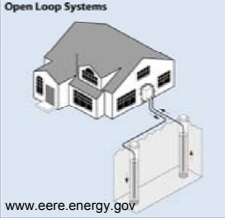
During the cooling season heat is rejected into the earth. During the heating season, heat is abstracted from the earth. Care needs to be taken to balance the cooling and heating systems. In addition, hydrology and soil type need evaluation prior to installation.



**Closed Loop Systems**  
Horizontal

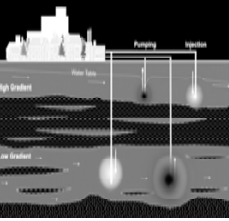
**Horizontal Closed Loop**  
These systems are used during the winter for heating. During the summer, they are used for heat rejection. They rely on the temperature of the ground being more stable than the air temperature. Horizontal closed loop systems are primarily used for residential buildings due to the need for area. Trenches are a minimum 4 feet deep. The cost of these systems is approximately \$550/kW (\$2,000/ton).

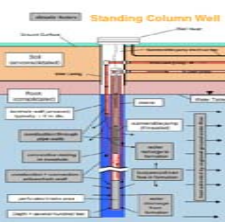





**Open Loop Systems**


**Vertical Open Loop Injection/Extraction**  
These systems use an open borehole that abstracts water from an aquifer as the heat exchange fluid. The water is circulated and returned to the well. The cost of vertical open loop systems is approximately \$300/kW (\$1,000/ton).






**Standing Column Well**  
This system is a semi-open loop system which extracts groundwater from the bottom of the well and returns it to the top. The borehole depth could be as deep as 1,500 ft. The approximate cost of a standing column well system is \$450/kW (\$1,500/ton)



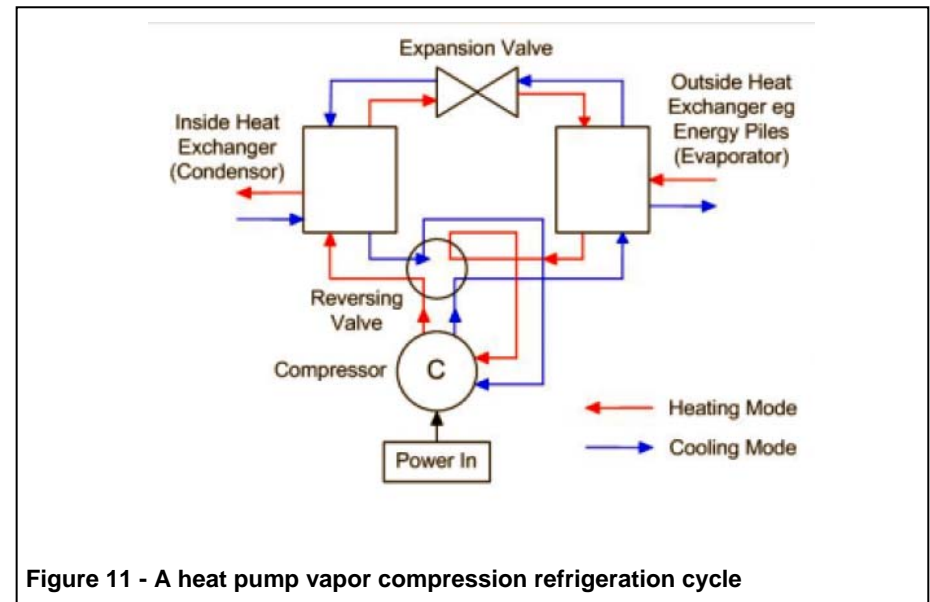


**Energy piles**  
Energy piles are similar to the closed loop boreholes except that the pipe is installed within the building substructure (piles). The cost of an energy pile is approximately \$250/kW (\$500/ton).



**Figure 10 - Ground source heat pump types**

A heat exchange unit (Figure 11) pumps a solution (water) from the ground, where it transfers its heat to a refrigerant, which moves to the compressor. In the compressor, it is pressurized to a high temperature (>180°F) and then moved to the radiator. A fan pulls air through the coils and the air absorbs heat emitted by a pressured gas. The heat is then distributed across the building. In cooling mode, the process is reversed.



**Figure 11 - A heat pump vapor compression refrigeration cycle**

As space is an issue then a Horizontal Loop system and Vertical Open Loop system are not recommended. For urban environments like the proposed Clarence E. Lightner Public Safety Center, a Standing Column Well or Energy piles are recommended. Siting boreholes under sidewalks or in the foundation of the building (energy piles) are options, however, any areas where there are utility lines should be avoided. In addition, the probability of using Nash Square (one of the remaining parks from the William Christmas Plan, circa 1792) as a ground source site is unlikely due to the disturbance caused by drilling boreholes and its significance to the State of North Carolina. A sample specification for a closed loop system is in Appendix C.

A cost benefit analysis was not determined due to the infancy of the design process. In order to determine an accurate cost and payback, the geology and hydrology of

the proposed borehole areas need to be determined, as well as an accurate energy model of the proposed and baseline building.

### Benefits

- Energy efficient method of providing cooling
- Reduces carbon dioxide emissions
- Reduces peak load charges

### Constraints

- Closed systems may have leakage in the pipes
- Uncommon in the region
- Hydrology of the region and testing the system is extremely important
- The unknown effect of raising or lowering the temperature of the surrounding ground

### Maintenance

- The system must be properly commissioned to balance the system
- Clean filters and heat exchangers in the heat pump
- Pump motors and compressors requires replacement (compressors could work up to 25 years but warranty is less)
- High Density Polyethylene (HDPE) pipes require little maintenance and have lifetimes of over 50 years
- Closed loop systems require occasional flush-out with water
- If pipes are fused, joints may break
- Meter system to check system efficiency

## 2.4 Fuel Cells

A fuel cell (illustrated in Figure 12) is an electrochemical device that produces electricity and heat. It does this by the reaction of hydrogen fuel and atmospheric oxygen to produce water without combustion. If pure hydrogen is used as a fuel then

the outputs are direct current (DC) electricity, heat and water vapor. The electrical efficiency of fuel cells is generally quoted as being 50%, however, this is a function of the fuel cell stack design and can be raised up to a theoretical maximum of 74% although this will result in increased system cost.

Fuel cells can be fed by a number of different fuel sources, including pure hydrogen, natural gas, methane, anaerobic digester gas and other hydrogen rich gases. Natural gas is the usual fuel source for most fuel cells on the market today.

Fuel cell costs remain prohibitively high in many cases when compared to other systems such as conventional combined heating and power systems (CHP). Fuel cell prices could be as much as \$4,500 per kW.

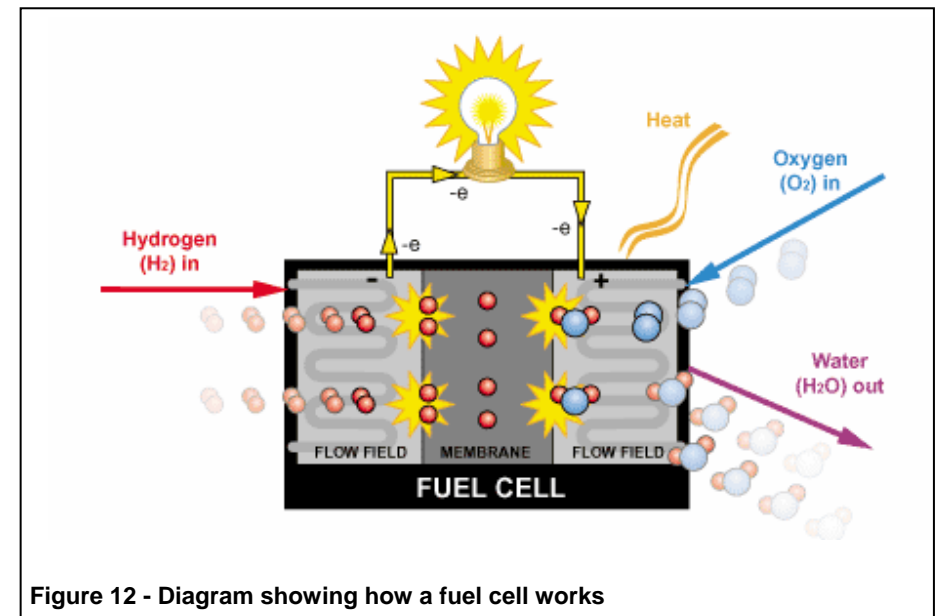


Figure 12 - Diagram showing how a fuel cell works

In order to make the best use of a fuel cell it should be used for base electrical loads and a use must be found for the heat. For a building with 24 hour loads, such as the Clarence E. Lightner Public Safety Center, it is likely that a base constant electrical load can be found and that heat could be used for domestic hot water or as part of a cooling system. In addition, fuel cells can act as an energy source in long term operation after a disaster.

## Benefits

- Fuel cells are significantly more efficient than internal combustion engines (ICE's) because, unlike heat engines, they are not limited by the Carnot Cycle
- They operate at maximum efficiency at part load whereas the efficiency of ICE generators is reduced at part load
- Their efficiency is unaffected by size
- Fuel cells can be stacked in such a way to match the specific output power needs without significant additional design work or capital requirements
- The simple nature of their design and operation, i.e. no rotating or reciprocating machinery, makes them highly reliable
- They operate quietly and can operate on a variety of fuel types
- They emit little NO<sub>x</sub> (<1ppm) and SO<sub>x</sub> (<0.01ppm)

## Constraints

- Expensive ~\$4,500 per kW
- The average fuel cell stack life is 5-10 years with some extending to 20 years and is very expensive to replace
- Installation of natural gas lines are required
- Maintenance costs for these emerging systems are generally high. An all inclusive annual maintenance contract may reduce costs
- Water input requires membrane filtration
- Natural gas input requires activated carbon treatment (activated carbon requires replacement)
- Not recommended for fluctuating energy loads
- They produce DC electricity which will require rectification for most uses

## Maintenance

- Auxiliary equipment is required to remove heat and that equipment requires regular inspections and maintenance

- Stacks require replacement every 5 – 10 years due to the carbon monoxide produced from hydrocarbons in fuel
- Reverse Osmosis (RO) system, to filter water, needs to be backwashed (if the system does not come with automatic backwash cleaning) every 1 to 3 months, depending on load
- Activated carbon used to filter the natural gas requires removal and disposal every 8 to 12 months

## 2.5 Microturbines

A microturbine, shown in Figure 13, is a small power generator that can simplistically be described as a small aircraft engine coupled with a generator. They take up roughly 50 ft<sup>2</sup> to 100 ft<sup>2</sup> of floor area and are 7 feet to 9 feet in height. Commercially available systems output 25 kW to 75kW at an efficiency of 25% to 30% and can run off of a variety of hydrocarbon based fuels. In the process of generating electricity, the turbine creates heat at approximately 40% efficiency. This heat can be reclaimed for space heating or cooling. As a result of the stand-alone ability of the design, microturbines can be used in a distributed role at the building or block level, or in a centralized facility that would supply power and heat to the district.



Figure 13 - Capstone Microturbine

www.microturbine.com

Like the fuel cell, the heat from the microturbine will have to be managed. Microturbines are cheaper than fuel cells and cost about \$1,000 to \$2,000 per kW (depending on the size).

#### Benefits

- Microturbines can be shut down during periods of low energy demand, the result being a flatter electrical demand curve that can benefit utilities and lead to decreased rate structures
- Microturbines can be used as a primary source of energy during a power outage

#### Constraints

- The engines create a significant amount of noise and would require sound attenuation if placed in the development district
- Requires a fuel source line (natural gas)

#### Maintenance

- Fuel compressors require service after 3,000-16,000 hours of operation
- Air and fuel filters should be replaced after every 8,000 hours of operation
- At 16,000 hours, the igniter, fuel injectors and thermocouples will require replacement. After 40,000 hours of operation (nearly 5 ½ years of continuous run time) the turbine will require a major overhaul that includes rotor replacement



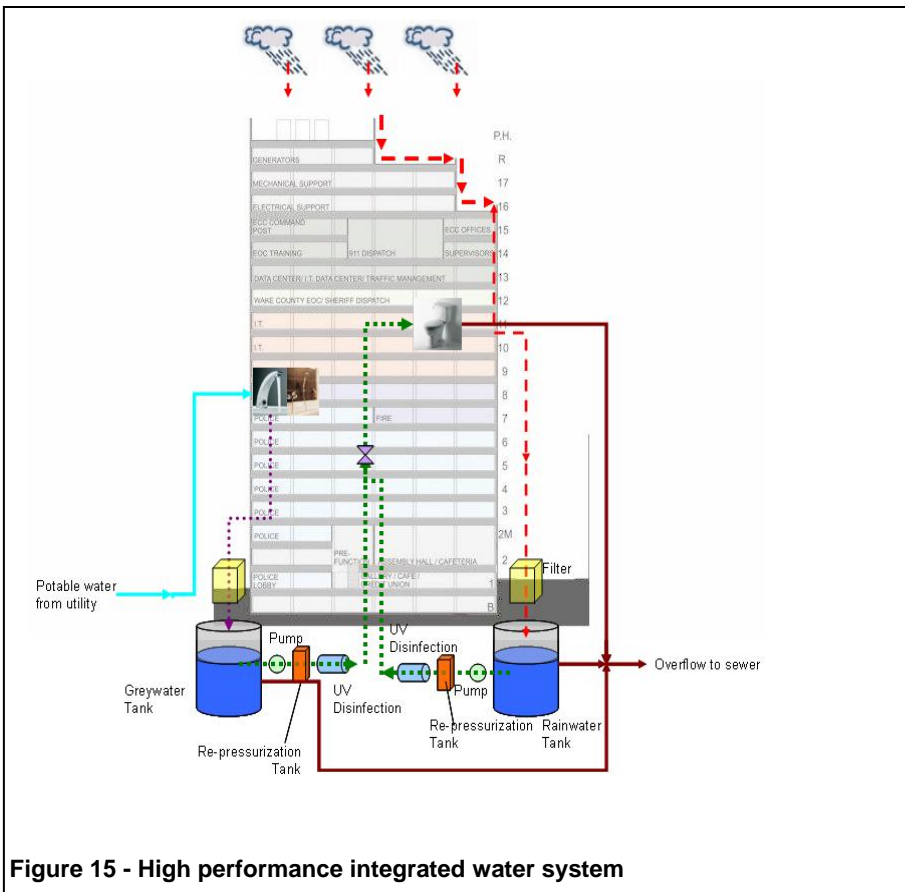


Figure 15 - High performance integrated water system

### 3.1 Managing water demand

Managing water demand is key to reducing water consumption. A well designed building can significantly reduce the water budget. The building's largest potential consumers of water are likely to be water closets, showers, faucets, maintenance and any kitchens within the building.

If there are landscaped areas, the water demand for irrigation can be almost completely eliminated through design solutions such as using indigenous species and xeriscaping. However, there will be an initial need for irrigation to help establish new planting.

Using rainwater and recycled water could reduce the requirement for potable water by up to or above 50% and this is commonly achieved by buildings which achieve LEED® certification. Anticipated non-potable water uses are:

- Water closet and urinal flushing
- Irrigation of landscaped areas (if applicable)
- Fountains
- Vehicle cleaning, maintenance and custodial uses
- Cooling water
- Fire suppression systems

### 3.2 Water efficiency

As previously noted, reducing demand is critical to water conservation. Figure 16 illustrates a series of building focused technologies which contribute to reducing demand.

A demand estimate was prepared between standard plumbing fixtures (baseline), low flow fixtures, and ultra low flow fixtures (design) for water closets, urinals, faucets and showers. The plumbing fixtures selected in the estimate are in Table 3.

Fixture Type	Standard	Low Flow	Ultra low flow
Water Closet (WC)	1.6 gpf	1.1 gpf	1.1 gpf
Urinal	1 gpf	0.5 gpf	0 gpf
Lavatory	2.5 gpm	1.8 gpm	0.5 gpm
Shower	2.5 gpm	1.8 gpm	1.8 gpm
Kitchen sink	2.5 gpm	1.8 gpm	1.8 gpm

Table 3 - Plumbing fixtures

Low flow urinal – Low flow urinals achieve proper drainage at 50% or less water use (0.1 to 0.5 gpf compared to 1 gpf). The cost of these units is about the same as a conventional urinal (~\$200).

Waterless Urinal – Zero water needed; uses biodegradable filter to treat liquid waste; cartridges need to be replaced 6,000 to 7,000 uses (every 15,000 uses for some units). The cost of these units is approximately \$40 to \$50 more and replacement cartridges, cost about \$35 every 7,000 uses (about every 3 months assuming 20 urinals are installed in the building).

Low-flow and ultra low-flow water closet – Uses 30% to 50% less water (1.1 gpf compared to 1.6 gpf). These WCs are approximately the same price of a conventional WC.

Dual flush WC’s – These WC’s can save up to 60% more water than a conventional toilet (1.6 gpf full-flush and 0.8 gpf) Dual flush WC’s are relatively the same cost as a conventional toilet.

Efficient appliances – Low flow (aerating & spray) and sensors. Some of these appliances can cut water use by greater than 50% and are marginally more expensive than conventional technology (1.8 gpm or 0.5 gpm compared to 2.5 gpm). They require battery replacement.

**Figure 16 - Low flow fixture technologies**

To calculate the potable water demand, it was assumed that the building will be occupied 365 days a year and have 1,000 occupants (50% male and 50% female). Assuming that 25% of the building occupants will be on 8 hour shifts the FTE (Full time equivalent) value was estimated to be 1,500 occupants. Table 4 compares the system types and shows the potable water savings from ultra low flow fixtures.

Scenario	Baseline Standard gal	Low Flow gal	Design Ultra Low Flow gal
Daily potable water demand	11,925	7,965	5,753
% Savings	-	33%	52%

**Table 4 - Water efficient fixture savings**

Due to the amount of building occupants and installing ultra low flow fixtures, the amount of potable water could be reduced by over 50%. Installing ultra low flow fixtures is an easy design practice with little cost implications.

Waterless urinals are permitted as per North Carolina Building Code. These units have been installed locally such as at the Horney building at UNC and abroad such as at Heathrow Airport or the Rose Bowl. The units installed at these facilities were approximately \$150 per unit and require little or no maintenance besides cartridge replacement.

**Maintenance**

- Filter changes for waterless urinals (newer technologies do not require change out)
- Water closets, lavatories and showers have the same maintenance requirements as standard fixtures
- Sensor batteries need to be replaced (>1,000 hours of use)

**3.3 Rainwater harvesting technologies**

Rainwater can be harvested from a number of different sources, including, roof areas, car parks, surrounding hardscaped areas, driveways, permeable paving and ponds. Roofs provide the best solution for rainwater harvesting as they can be easily accessed for maintenance. The total roof area of the Clarence E. Lightner Public Safety Center is approximately 22,200 square feet, which could be used for rainwater harvesting and capture.

The basic components of a rainwater harvesting system are:

- Collection/catchment surface – the collection surface from which rainfall runs off
- Filtration system
- Storage – tanks or cisterns
- Treatment system
- Delivery system – gravity-fed or pumped to the end use

### 3.3.1 Rainwater harvesting (RWH) technology

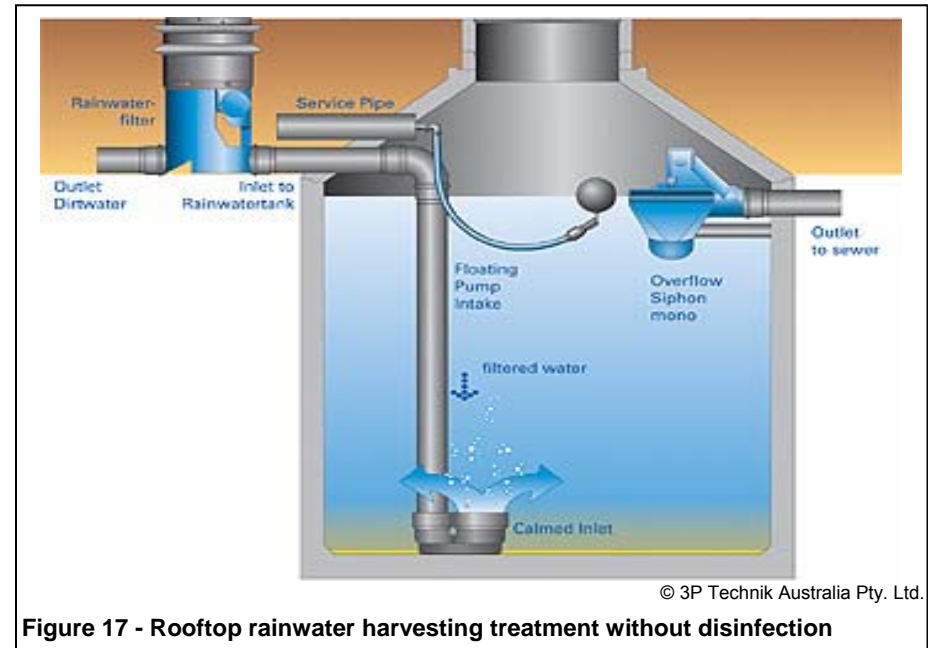
The key factors that should be considered when selecting a collection method are the quantity of rainwater and the quality of water required. When deciding on a collection method it is important to remember that it is part of an integrated system and not an individual feature. Therefore, if other features such as green roofs are to be integrated into buildings designs then this needs to be considered at the outset. Green roofs and rainwater collection systems can be integrated together but the collection system collects more water when it is installed as a single component. The ideal collecting surfaces are pitched roofs of tile or slate but other materials can be used.

There are a number of contaminants that can enter any rainwater harvesting system, from animal excretion to dust, which must be removed to ensure the safety of the system. “First flush” systems remove the initial amount of rainfall hitting the roof surface. The number of possible contaminants increases considerably if areas other than roofs are used to collect rainwater as they may be exposed and easier for animals and pollutants to enter.

Filters and separators should be added to a rainwater harvesting system either before and/or after storage. While filters allow all flow and simply remove debris, separators wash debris away by using a small amount of the harvested water.

Some form of treatment (Figure 17) is recommended for most projects, even if the intended water use is only WC and urinal flushing. The rainwater requires a filtration system to remove dirt and debris and disinfection in the form of chlorine, ozone sterilization or Ultra Violet (UV) sterilization. UV sterilization is the easiest to maintain and does not require chemicals but is more energy intensive than chlorination. Current City of Raleigh code requires treatment for rainwater harvesting if the water were to be used for non-potable uses. Treatment is required to control physical,

microbiological and chemical quality which affects the nutrient and microbial levels of the water.



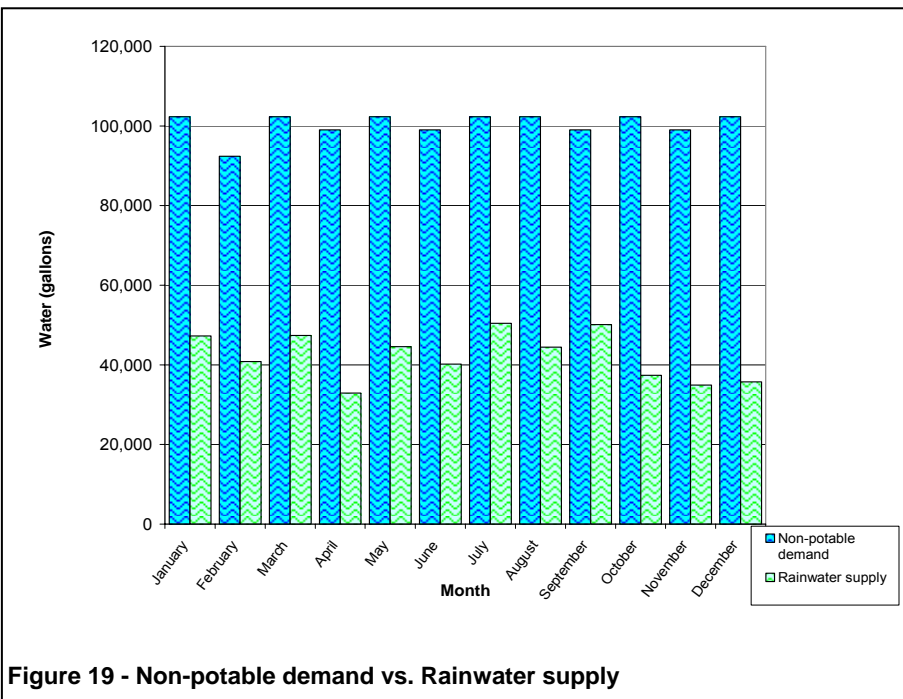
**Figure 17 - Rooftop rainwater harvesting treatment without disinfection**



**Figure 18 - Typical rainwater harvesting systems**

sterilization or Ultra Violet (UV) sterilization. UV sterilization is the easiest to maintain and does not require chemicals but is more energy intensive than chlorination. Current City of Raleigh code requires treatment for rainwater harvesting if the water were to be used for non-potable uses. Treatment is required to control physical, microbiological and chemical quality which affects the nutrient and microbial levels of the water.

During storage, the water should be hygienically stored to ensure the water does not suffer from recontamination. Exit disinfection is recommended if the water is stored in tanks for long periods of time. Figure 19 illustrates the potential amount of rainwater storage against the demand for ultra low flow water closets and urinals.



**Figure 19 - Non-potable demand vs. Rainwater supply**

Figure 19 illustrates that if rainwater harvesting was used, it would not be capable of meeting the non-potable demand and some potable water would be required. The addition of a greywater recycling system could potentially meet these requirements.

Distribution of harvested rainwater will involve pump sets and pipework that should be clearly marked as containing harvested rainwater and should not connect to other distribution systems without appropriate protection. Roof top storage tank installations could distribute water by gravity reducing the need for additional pipe but will impose a large structural load.

A demand estimate was prepared to indicate the water savings if a RWH system is installed. It was assumed that the 22,200 ft<sup>2</sup> roof area was used to collect stormwater and 85% of the rainwater throughout the year was collected (15% loss due to evaporation and “first flush”). Table 5 tabulates the water savings.

Scenario	Baseline	Design
	Typical Fixtures	Ultra low flow fixtures
	gal	gal
Daily potable water demand (faucets and showers)	11,925	5,753
Daily non-potable water demand (water closets, urinals)	6,300	3,300
Daily rainwater harvested (RWH) to meet non-potable water demand	(1,387)	(1,387)
% Total savings of potable water by RWH	12%	24%
% Savings of potable water by efficient fixtures and RWH	-	63%

**Table 5 - Water savings due to rainwater harvesting**

Table 5 shows that if the baseline potable water demand is 11,925 gallons (5,753 gallons if ultra low flow fixtures are used), which 6,300 gallons of that demand could be non-potable (3,300 gallons if ultra low flow fixtures are used) and 1,387 gallons of the non-potable water could be met by RWH, then RWH alone could produce 12% potable water savings for baseline fixtures and 24% for ultra low flow fixtures.

To meet the non-potable water demand (assuming low flow fixtures will be installed) for three days (72 hours), the rainwater storage tank or cistern would need to be

about 10,000 gallons. If the building plans to recycle its greywater (discussed in the next Section 3.4), multiple storage tanks or a 15,000 to 20,000 gallon should be used.

### 3.3.2 RWH Costs

Prices are steadily increasing for potable water and wastewater disposal, so rainwater harvesting is likely to become more economically attractive. The City of Raleigh water rates are about \$0.0021 per gallon (including base meter rate) and wastewater rates are about \$0.0019 per gallon<sup>3</sup>, and both are expected to increase annually.

Payback periods vary depending on the scale of the project, and projected water use. Payback for an RWH system in this region is typically less than 10 years. In residential situations and small scale commercial applications, rainwater harvesting systems can pay back within five years. However, this cost can reduce significantly with early design integration and use in other applications such as irrigation, water features, dust control, vehicle washing and fire extinguishing (assuming the fire suppression water is treated). An approximate capital cost is \$20,000 including pumps, treatment and piping, however, increased amounts of piping and larger cisterns and infrastructure would increase the cost. The cost of a 15,000 gallon polyethylene tank is \$11,000. For Clarence E. Lightner Public Safety Center, the cost of the system could be as much as \$80,000 to \$100,000 if a complex treatment process is required.

### Benefits

- Reduces demand on municipal water supply
- Visible educational benefit and marketing value for water conservation
- Can use existing rainwater catchment infrastructure
- Reduces cost of supplied water and wastewater disposal

### Constraints

- Water storage tanks location and size need to be considered in building layouts
- A separate non-potable water supply system needs to be provided separate from the potable water supply

- The filters and treatment require maintenance

### Maintenance

- Change filter media on a regular basis and clean the first flush filter (if applicable)
- Pumping systems require routine maintenance and inspection

## 3.4 Wastewater treatment technologies for re-use

### 3.4.1 Greywater treatment

Greywater is defined as the wastewater from all the sources in a building excluding blackwater. It includes water from sinks, baths and showers but can also include wastewater from the washing machines, kitchen sinks and dishwashers. Kitchen sink and dishwasher water are used less often because of the large amounts of food and detergents. Blackwater is effluent from water closets, urinals, waste disposal units, kitchen sinks (without filters), dishwasher and any other highly polluted effluent sources.

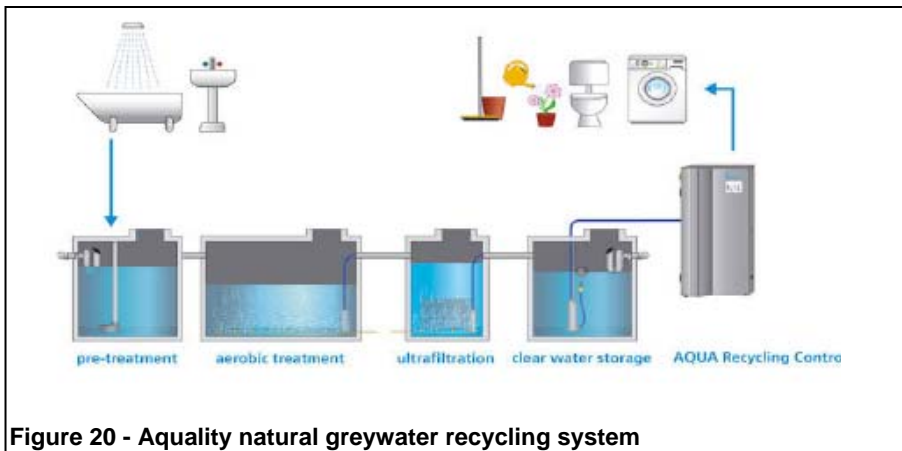
Greywater can be treated and recycled for use within a project like the Clarence E. Lightner Public Safety Center. However, rainwater capture is generally more cost-effective than the reuse of greywater in buildings. Blackwater can be treated for irrigation re-use but it is generally treated to discharge to sewer system only.

Various greywater treatment systems exist. Mechanical and chemical, anaerobic or aerobic treatments which alter the biological and chemical properties of the wastewater. The basic elements are a storage/treatment tank, filter, treatment and delivery system (integrated into building design).

The common system incorporates a tank to allow separation and pretreatment (Figure 20). This is then followed by an aerobic treatment where the effluent is filtered over a coarse medium or membrane which treats and aerates the material to a useable greywater standard. Some systems use a mechanical or chemical treatment instead or as well as the aerobic stage to guarantee the water quality to local water regulations standards. However, careful design, maintenance and specific end use can avoid the use of chemical or mechanical treatment. Another type of treatment device, reverse osmosis (RO) and microfiltration use pressure and membranes to remove small contaminants and microorganisms. RO is energy intensive but is very efficient and will be capable of filtering and removing most microorganisms.

<sup>3</sup> <http://www.efc.unc.edu>

Currently, the City of Raleigh code permits greywater use for water closet fixtures without treatment, if the greywater is used within 72 hours of discharge from sinks and showers. If this is the case, there will be no need for a treatment system and costs of the system will reduce significantly. These costs include basic filtration, pumps, storage and pumping (~\$20,000).

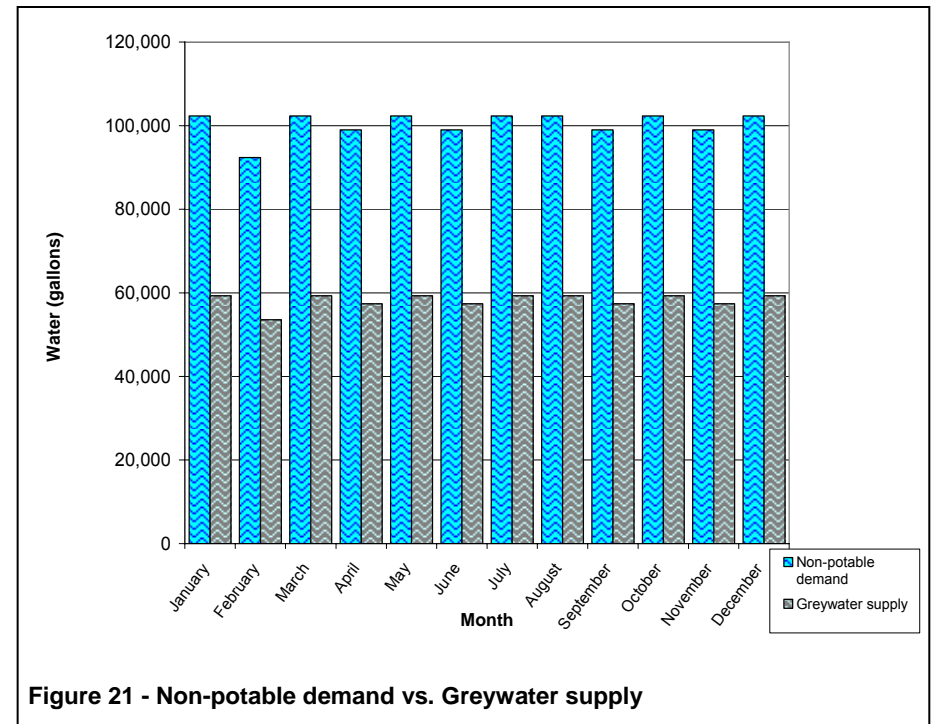


**Figure 20 - AQUALITY natural greywater recycling system**

Figure 21 illustrates the potential amount of greywater storage against the demand for ultra low flow water closets and urinals.

Rainwater capture is generally more cost-effective than greywater recycling systems. The cost of a greywater recycling system in a home could be as much as \$20,000 and a large office building with 4,000 occupants would range from \$100,000 – \$150,000.

An estimate was prepared in Table 6 to determine the potable water savings if the building chooses to recycle its greywater. The three scenarios are for typical fixtures (baseline), low flow fixtures and ultra low flow fixtures (design). The potable water savings was calculated as each new technology was implemented.



**Figure 21 - Non-potable demand vs. Greywater supply**

Scenario	Baseline Standard Flow gal	Low Flow gal	Design Ultra Low Flow gal
Daily potable water demand	11,925	7,965	5,753
% Savings of potable water use with efficient fixtures	-	33%	52%
Daily RWH	(1,387)	(1,387)	(1,387)
Daily potable water demand after RWH	10,538	6,578	4,365
% Savings of potable water use with efficient fixtures & RWH	-	45%	63%
Daily greywater produced (sinks, showers)	(4,688)	(3,375)	(1,913)
Daily potable water demand after RWH and greywater recycling	5,850	3,915	2,453
% Savings of potable water with efficient fixtures, RWH and greywater recycling	-	67%	79%

**Table 6 - Water savings due to water efficient fixtures, rainwater harvesting and greywater recycling**

The annual costs and savings associated with water costs when applying water efficient fixtures, rainwater harvesting and greywater recycling to the project is tabulated in Table 7.

Scenario	Baseline (standard) per year	Design (ultra low flow) per year
Efficient Fixtures (no GW recycling, no RWH)	\$18,300	\$9,200
\$\$ Savings	-	\$9,100
Efficient Fixtures, RWH (no greywater recycling)	\$13,900	\$6,800
\$\$ Savings	-	\$11,500
Efficient fixtures, RWH, greywater recycling	\$10,400	\$5,400
\$\$ Savings	-	\$12,900

**Table 7 - Annual financial savings for potable water source and wastewater disposal fees**

As a result of the analysis, it is shown that implementing water efficient fixtures, recycling greywater and rainwater harvesting will save \$12,900 per year in potable water costs.

The City should consider greywater recycling, especially if treatment is not required. This will reduce the costs of the system significantly. In addition, rainwater harvesting is usually considered “cleaner” than greywater recycling, therefore, the City should negotiate with local authorities for the consideration of using rooftop rainwater without treatment within 72 hours for water closets.

**Benefits**

- Reduces reliance and demand on municipal water supply
- Reduces need for municipal water treatment
- Reduces cost of supplied water

**Constraints**

- Water storage tanks location and size need to be considered in building layouts
- A separate water supply network needs to be provided separate from the potable water supply

- The system needs to be maintained by a skilled engineer
- Can be expensive

#### Maintenance

- Filtration system requires monthly maintenance cleaning/inspection
- If chlorination is used for treatment, chlorine element (gas, solid, liquid) requires refilling

### 3.5 Condensate return

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Another non-potable water source in the building is condensate from the cooling coils in the air conditioning system. A rough calculation to determine the amount of condensate that could be used as a non-potable water source was performed based on the size of the building and the region's average humidity. Approximately an average of 648 gal/day (this value changes seasonally) could be used as a non-potable source of water for water closets and urinals. This would save approximately \$500 in wastewater disposal fees. These savings would change for summer months and winter months due to the amount of humidity in the outside air.

This could also be used in the cooling tower – note that there is less condensate available when there is less cooling needed so a cooling tower is often a good match. These types of systems require little maintenance.

## 4 Materials

To make a project as sustainable as possible, the appropriate building materials need to be selected. Materials should be selected to:

- Allow flexibility in design of the project
- Be suitable for any future modification that may be necessary in the future, i.e., lowering future space configuration change costs
- Promote the increased health and welfare of building occupants
- Improve the productivity of occupants
- Save energy
- Be durable and long lasting
- Reduce future maintenance costs for the life cycle

Construction materials should be selected with consideration based on the embodied energy of the materials. A sample LEED specification detailing the contractor's responsibilities regarding recycled content is in Appendix D.

### 4.1 Embodied Energy

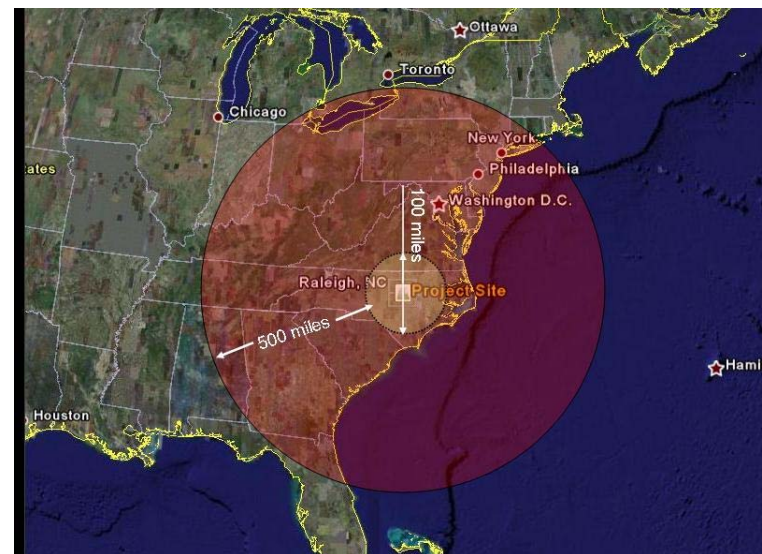
- Local Availability – transportation costs can account for 50% or more of the embodied energy of a material. Locally extracted and manufactured materials should be chosen where possible. Figure 22 illustrates the 100 mile and 500 mile radius for the site.
- Durability – materials that last longer with less maintenance use less embodied energy over their life.
- Speed of assembly – using materials that can be assembled more quickly can reduce energy required during construction.
- Recycled content

The embodied energy of typical construction materials are listed in Table 8.

Material	Embodied Energy (MJ/kg)
Aluminum (Virgin)	191
Aluminum (Recycled)	8.1
Cement	7.8
Concrete (block)	0.94
Concrete (pre-cast)	2.0
Concrete (ready mix)	1.3
Steel (virgin)	32
Steel (recycled)	10.1
Stone (imported)	6.8
Stone (local)	0.79
Timber (kiln dried)	1.6
Timber (for mouldings etc)	3.1
Timber (MDF)	11.9
Plaster board	6.4

Source: Center for building performance research, Victoria University of Wellington, New Zealand.

**Table 8 - Typical embodied energy for construction materials**



**Figure 22 - 100 mile and 500 mile radius from the project site**

#### 4.1.1 Steel vs. Concrete Building

When applying embodied energy values, thought should be given to the weight of each material required for construction. For example, a heavier weight of concrete required in a concrete structure building when compared to the weight of steel in an all steel building.

#### 4.1.2 Cement Replacements

The production of Portland cement (an essential ingredient of concrete) is very energy intensive and releases large amounts of CO<sub>2</sub> into the atmosphere. This contributes significantly to concrete's embodied energy and embodied carbon. Cement replacements such as fly ash, silica fume, ground granulated blast-furnace slag, and/or natural pozzolans can be used to replace large proportions of cement.

Fly ash, one of the most readily available cementing materials, is a waste product of thermal power generation. In high volume fly ash (HVFA) concrete, large proportions (usually 40 to 50%, sometimes up to 65%) of the Portland cement is replaced by fly ash. The proportion of materials (cement, fly ash, water, aggregates, chemical admixtures such as the air-entraining admixture, water-reducer and super plasticizer) can be optimized to produce a high-quality concrete for a wide range of applications. HVFA concrete can meet most technical specifications, even those for high-performance concrete, has environmental benefits and is similar in cost to conventional concrete.

HVFA concrete has advantages and limitations as compared to conventional Portland cement concrete. Due to the large proportion of cement being replaced by fly ash, the strength development of HVFA concrete is somewhat slower than that of conventional concrete. In spite of this, HVFA concrete can be proportioned to achieve both early-age and later-age strengths commonly required or specified for various applications.

A detailed cost benefit has not been conducted due to the early stage of the design process. However, regarding local materials, green building projects in the region were capable of using local concrete, gypsum and brick. The typical specification language for recycled materials in concrete is below:

“Cast-in-place Concrete shall contain one of the following post-industrial and/or post-consumer recycled products or a combination as specified below:

- a) Fly Ash shall be incorporated into mixtures at a minimum rate of [25%] and a maximum rate of [40%] by weight of total cement.
- b) Ground Granulated Blast-Furnace Slag shall be incorporated into the mixtures at a minimum rate of [40%] and a maximum rate of [60%] by weight of cement.
- c) Where Fly Ash (FA) and Ground Granulated Blast-Furnace Slag (GGBS) are combined, their proportions shall be such that FA + GGBS = [50% minimum, 80% maximum] of weight of cement, where individual FA or GGBS contents shall not be greater than 50% of total cementitious materials.
- d) Silica Fume shall be incorporated into mixtures at a minimum rate of [5%] and a maximum rate of [15%] by weight of cement.”

Benefits and constraints of Portland cement replacements are below:

#### Benefits

- Lowers embodied energy and CO<sub>2</sub> emissions
- Increases durability by lowering the risk of thermal cracking in large concrete elements, reducing drying shrinkage and creep, controls expansion
- Improves concrete performance due to low permeability and excellent resistance to chloride-ion penetration

#### Constraints

- Some slowing of curing time and lower early-age strength
- Reduced bleeding, which may involve slightly different finishing procedures of flat surfaces
- May change the color composition of the concrete

## 5 Healthy Design

### 5.1 Natural Ventilation

Buildings have been optimized for natural ventilation since ancient times. In an effort to save energy, modern air conditioned buildings will typically re-circulate used room air which can make buildings seem stuffy and can affect occupant comfort and some reports also indicate that this can effect productivity. Using natural ventilation increases the amount of ventilation air to 100% and does not have the same issues. It also uses no fans or heating and cooling energy.

Thoughts should be given to the massing and orientation of a building at an early stage if natural ventilation is under consideration. First, a wind study should be undertaken. The wind rose for Raleigh is shown in Figure 23. The wind resources should be identified for the peak summer months and the building orientated to take advantage of the wind direction during this period. Also, because very little cooling effectiveness will be available during the summer period, every effort should be made to minimize heat gains to the building. This may include:

- Shading
- Increased insulation
- High efficiency glazing
- Organizing the massing of the building so that high heat emitting equipment is located outside of naturally ventilated areas

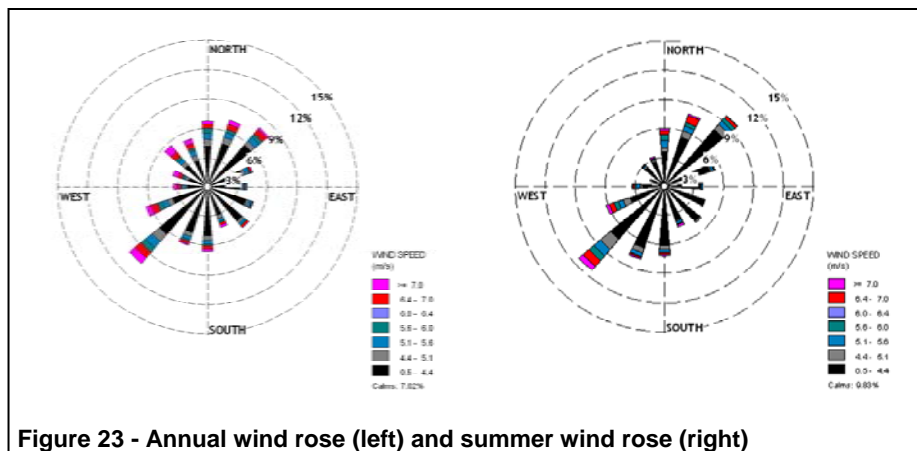


Figure 23 - Annual wind rose (left) and summer wind rose (right)

Typically, natural ventilation can be used to ventilate up to around 20 ft depth from a window. If a room has two windows, this doubles to 40 ft. The effectiveness can be increased by introducing an atrium into the space which will cause the natural ventilation to be driven by stack effect (hot air rises) instead of by the outside wind speed.

For the Clarence E. Lightner Public Safety Center, a green/red light system (Figure 24) could be designed to alert occupants when to open and close windows. This system alerts the occupants to open the windows when the temperature and humidity are within the “comfort zone”. When conditions are not within the programmed range, the mechanical system turns on and the occupants are alerted to close the windows.

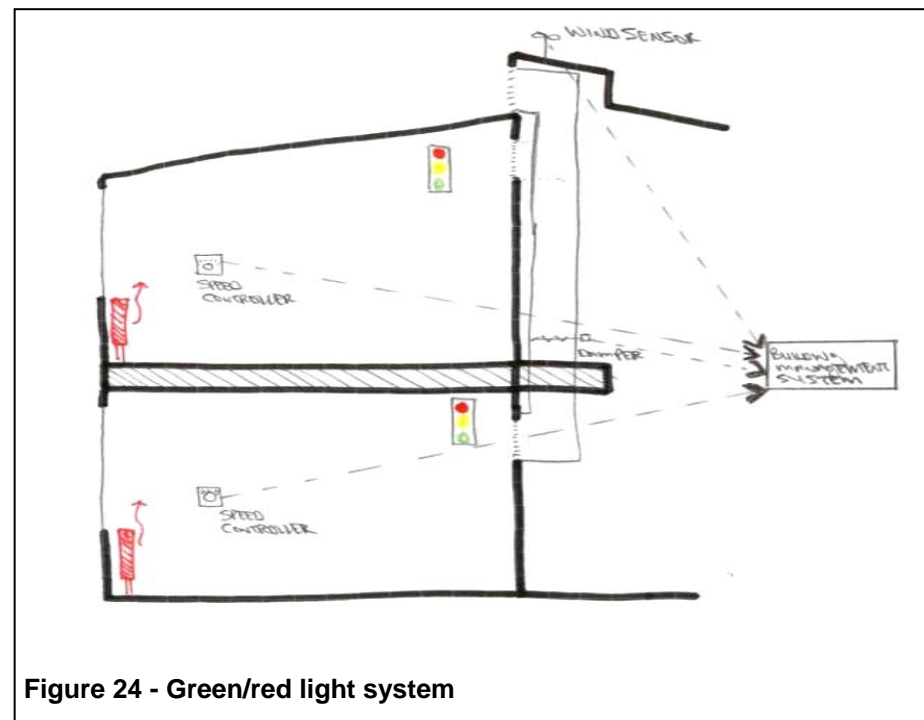


Figure 24 - Green/red light system

Compared to a base case system with no operable windows and no exterior and interior shading, a proposed system consists of operable windows with A/C lockouts

when windows are open and operable temperatures between 68°F and 78°F with a probability of 35% of the building occupants opening windows during operative range.

Typical well designed natural ventilation systems can save a building in this region approximately \$13,478 annually and have a payback of about 5 years.

### Benefits

- Energy from mechanical systems is not needed
- Eliminated artificial noise from HVAC system
- A minimum level of maintenance

### Constraints

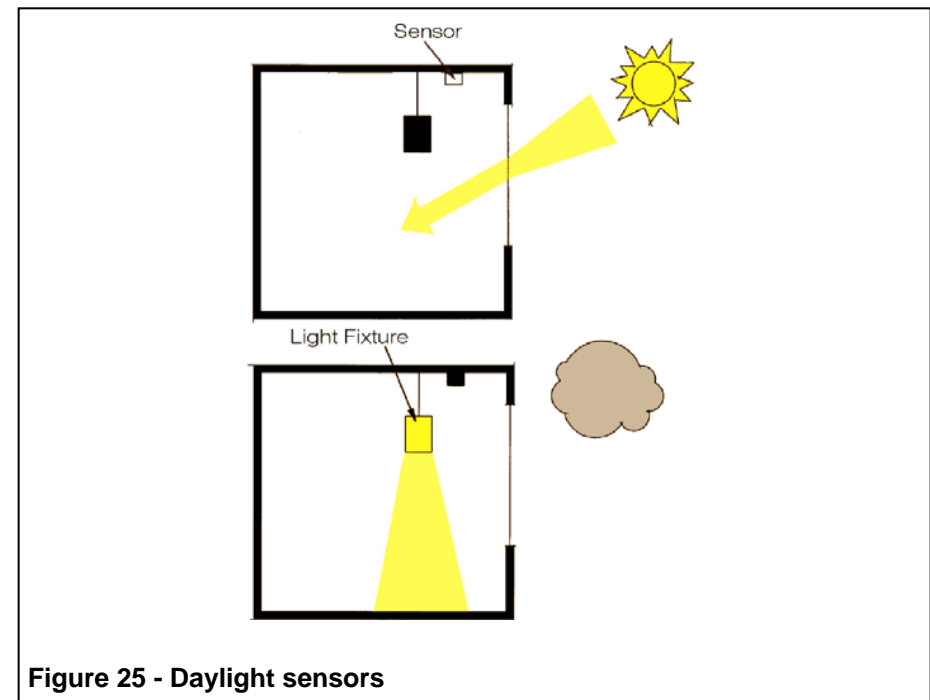
- Outdoor noise (street traffic) and air pollution could disturb occupants
- If not designed well, excessive heat loss could occur

## 5.2 Daylighting

Daylighting controls are used to reduce artificial lighting levels when adequate daylighting is available from outside the building. Smart design of the building envelope is very important to maximize the penetration of daylight and gain the most out of these controls. There are two main types of daylighting controls available in terms of the configuration of the artificial lights. The simplest is called on-off control where the lighting is circuited to enable perimeter fixtures to turn off manually or automatically when daylighting is sufficient (Figure 25). This could also be on a ballast by ballast basis where for example a three lamp ballast drops down to one lamp lit when daylighting is acceptable. The second is known as dimming control.

Lamp on-off control, also includes bi-level switching, and is a way of obtaining daylighting control with very modest cost implications. This method can utilize multi lamp fixtures with internal bi-level lamp control or separately switched lamp fixtures. Multi-level compact fluorescent lamps are also available and more appropriate to office lighting, but cannot be automatically controlled.

Dimming control works well for providing uniform lighting levels throughout most of the year. Dimming controls and ballasts are more expensive and will often double the cost of the ballast when compared to conventional systems. In contrast to the lamp on/off method, this technology is typically automatic, using photosensors at the perimeter of the internal space to control light levels.



**Figure 25 - Daylight sensors**

Compared to a base case system compliant to ASHRAE 90.1 – 2004, a proposed daylight control system contains photocell sensors and dimmable ballasts used in individual spaces. A typical well designed daylighting systems can save a building in this region approximately \$46,682 annually and have a payback of about 8 years.

Additionally light shelves can be placed inside or exterior to a building façade and are usually located on the southern orientation. Locating them inside the building will often allow for greater penetration of light. Light shelves are optimal in buildings with high floor to ceiling heights or where the glazing is at a high position in the wall. The device should be installed so that it is above head height or else it becomes a safety hazard. Installing at a height of 6'5" is a good rule of thumb. There are cases however where shelves have been installed lower than this but it depends on the building configuration and ensuring safety for building occupants. The light shelves require direct sun to be effective and care has to be given to the type of glazing being used. If the glazing above the light shelf is heavily tinted, this could eliminate up to 70% to 80% of the natural light before it enters the room making the light shelf ineffective. The reflected light that comes from using these devices is typically good quality as it

is diffuse and illuminates the ceiling. Many factors dictate how much light is available and how deep into the room it penetrates – such as location, sun altitude, window size, etc. but depths of 20 ft could be considered typical for standard window sizes. In order to use this technology to its full potential and maximize energy savings, it is best used in tandem with photo sensors linked to the artificial lighting in the building. The ballasts on this artificial lighting should also be capable of dimming as the daylight penetration from the light shelf increases.

To determine the effectiveness of daylight sensors and light shelves, a solar analysis should be performed, studying the solar radiation of the site, the geometry of the sun and position of the building at the site, the proposed shading devices and the light transmittance of the proposed glazing.

#### Benefits

- Significant energy savings available from reduced artificial lighting levels
- Gives a more constant illuminations level
- Will give occupants more control over their lights along with more varied lighting levels
- Occupants appreciate natural lighting more than artificial lighting
- Light shelves can act as shading devices to the windows below them
- Less heat output from artificial lights will reduce cooling load

#### Constraints

- Higher costs - particularly for a dimmable system
- Glare and solar gain should be addressed

#### Maintenance

- Photocell sensors require regular cleaning

## 6 Vehicle programs

The City of Raleigh has developed the plug-in hybrid electric vehicle (PHEV) program to reduce fossil fuel consumption and emissions from the City. The City plans to achieve this through<sup>4</sup>:

- Further expansion of the City's alternative fuel vehicles (AFVs). The current number is 334
- Use of alternative fuels such as bio-diesel in the Capital Area Transit buses
- Use of remote facilities to reduce miles traveled by City staff.



**Figure 26 - PHEV vehicle**

The City could showcase the program by switching its entire police fleet to alternative vehicles (already in progress).

<sup>4</sup>[http://www.raleighnc.gov/portal/server.pt/gateway/PTARGS\\_0\\_2\\_306\\_210\\_0\\_43/http/pt03/DIG\\_Web\\_Content/news/public/News-PubAff-Raleigh\\_Begins\\_Pilot\\_Of\\_-20071120-13044568.html](http://www.raleighnc.gov/portal/server.pt/gateway/PTARGS_0_2_306_210_0_43/http/pt03/DIG_Web_Content/news/public/News-PubAff-Raleigh_Begins_Pilot_Of_-20071120-13044568.html)

## 7 Summary

The Action Plan should guide the City of Raleigh during the design of the Clarence E. Lightner Public Safety Center to create a sustainable example in the growing city. The technologies analyzed from the Action Plan will help achieve the City's goals. The solar radiation of the region encourages photovoltaic installation. A major constraint of the project includes the capital cost, however, the rising prices in energy, the little maintenance required and the sustainable feature aspect should help in the decision process. It is recommended that the City invest in photovoltaic panels to reduce energy consumption on the electricity provider and showcase sustainability in Raleigh. In addition, depending on the hot water demand of the building, solar water units can be installed, eliminating the need for a large boiler. Hot water demand could also be met by the heat from a Fuel Cell or microturbine, if installed. Ground source energy is another viable energy reduction option, although placement of the wells and types of materials must be considered.

The water savings from water efficient fixtures is fairly clear. Installing ultra low flow fixtures will decrease the City's potable water demand on the utility, as well as, establish savings in potable demand and wastewater discharge. Greywater recycling and rainwater harvesting is expensive if thorough treatment is required, however, the City will reduce nearly 79% of potable water demand on the utility by implementing these technologies. In a City that is having drought issues, water savings of this magnitude would be beneficial for the entire region.

The City should take advantage of local material manufacturers during the project, including concrete, steel, gypsum board, brick and wood. All of the construction materials should be specified to maximize the recycled content. The contractor should be made aware of all of the diversion requirements, as well as, supply of local and healthy building materials.

To improve environmental quality in the building, as well as reduce energy, daylighting and natural ventilation should be considered. These systems provide approximately an 8 year payback and 5 year payback, respectively, as well as introduce light and fresh air to building occupants, reducing "sick building" syndrome.

The technologies mentioned in the report and other local goals such as the plug-in hybrid electric vehicle (PHEV) program and LED cities (not mentioned in the report) will all help to make Raleigh one of the most sustainable cities in the Southeast. If the City of Raleigh actively pursues the items in the Action Plan and those technologies

investigated in this report, the Clarence E. Lightner Public Safety Center could be the most sustainable building in the City.

Appendix A

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**Action Plan**

**Clarence E. Lightner Public Safety Center**

Goals	Strategies	Actions	Responsibility	Maintenance	Cost Implications	Supported Framework*
<b>Energy</b>						
Create a building that generates more energy than it consumes	E1. Maximize the percentage of power generation from renewable sources	<ol style="list-style-type: none"> <li>Develop on-site cogeneration through fuel cells, microturbines or biodiesel.</li> <li>Use a renewable grid-connected power source (i.e., PVs) for 10% of energy supply.</li> </ol>	<p>Owner/Design Team</p> <p>Design Team</p>	<ol style="list-style-type: none"> <li>Fuel cell: Stacks should be changed every 10 years, water and natural gas needs to be treated</li> <li>PVs require cleaning, electric equipment inspections, &amp; monitor energy output</li> </ol>	<ol style="list-style-type: none"> <li>Fuel Cell: ~\$4,500/kW Microturbine: ~1,000 - \$2,000/kW PV: ~\$9/W (installed)</li> </ol>	<p>LEED EAp2: Minimum Energy Performance &amp; EAc1: Optimize Energy Performance; LBCp4: Net Zero Energy EAc2: On-site renewable energy</p>
Design a "carbon neutral" building	E2. Support carbon neutrality by minimizing emissions	<ol style="list-style-type: none"> <li>Install a Building Management System (BMS) to continually monitor energy and water use by the building</li> <li>Install heat recovery systems, ground source heat pumps, chilled beams, solar thermal storage units, LEDs, and other energy efficient systems. Optimize natural light and ventilation.</li> <li>Purchase renewable energy credits from a utility provider that provides renewable energy.</li> </ol>	<p>Design Team</p> <p>Design Team</p> <p>Owner</p>	<ol style="list-style-type: none"> <li>Complete systems require monitoring. Meters have design lives of 10 to 20 years</li> <li>GSHP: Clean the filters and exchanger in the heat pump, pump motor and compressors requires replacement (compressors could work up to 25 years but warranty is less). High Density Polyethylene (HDPE) pipes require little maintenance and have lifetimes of over 50 years, if pipes are fused, joints may break (not often if done correctly), &amp; meter system to check system efficiency</li> <li>N/A</li> </ol>	<ol style="list-style-type: none"> <li>Maintenance: \$0.07/ft<sup>2</sup> to \$0.11/ft<sup>2</sup> annually</li> <li>\$500/ton - \$2,000/ton</li> <li>\$4 per block of 100 kWh for small energy user; \$2.50 per block of 100 kWh for &gt;10,000 kWh</li> </ol>	<p>LBCp4: Net Zero Energy; OPL 1: Zero Carbon</p> <p>LEED EAp2: Minimum Energy Performance &amp; EAc1: Optimize Energy Performance</p> <p>LEED EAc6: Green Power</p>
Develop a strategic relationship with the utility	E3. Develop a Green Power Initiative with the local utility	<ol style="list-style-type: none"> <li>Work with Progress Energy to source alternative renewable energy resources.</li> </ol>	Owner	<ol style="list-style-type: none"> <li>N/A</li> </ol>	<ol style="list-style-type: none"> <li>N/A</li> </ol>	<p>LEED EAc6: Green Power; OPL 1: Zero Carbon</p>
<b>Design with climate</b>						
Create a positive microclimate	<p>C1. Reduce heat islands on the project site.</p> <p>C2. Improve the air quality inside the building.</p> <p>C3. Provide water features to enhance "comfort"</p>	<ol style="list-style-type: none"> <li>Shade all surfaces on site with landscapes, use high albedo materials for pavements and roof surfaces, and/or construct a vegetated roof.</li> <li>Provide plants that help remove indoor air pollutants and prevent sick-building illness.</li> <li>Install water features or other leisure areas to improve workspace comfort.</li> </ol>	<p>Architect</p> <p>Architect/Owner</p> <p>Architect</p>	<ol style="list-style-type: none"> <li>Less maintenance than dark roof (UV damage)</li> <li>Plants require watering</li> <li>Water features require pump cleaning and water testing (pH)</li> </ol>	<ol style="list-style-type: none"> <li>N/A</li> <li>N/A</li> <li>Size dependant</li> </ol>	<p>LEED SSc7.1: Heat Island Effect, Non-roof &amp; SSc7.2 : Heat Island Effect, Roof</p> <p>LBCp15: Beauty and Spirit</p> <p>LBCp15: Beauty and Spirit</p>
Orient the building to reduce energy use and glare	C4. Maximize the beneficial effects of the sun and minimize wind impacts	<ol style="list-style-type: none"> <li>Design site to maximize facade area in the north south direction because these directions are easy to shade</li> <li>Supply natural ventilation to building occupants and monitor CO2 to reduce energy use and create a healthy and productive working environment</li> </ol>	<p>Architect/Design Team</p> <p>Design Team</p>	<ol style="list-style-type: none"> <li>Occupant shading devices in south, east and west façade</li> <li>Annual calibration the sensors is required to ensure that acceptable air quality is maintained</li> </ol>	<ol style="list-style-type: none"> <li>No cost</li> <li>NV savings: \$13,500/yr CO2 sensor: ~\$250 each</li> </ol>	<p>LEED EAp2: Minimum Energy Performance &amp; EAc1: Optimize Energy Performance;</p> <p>LEED EQp1: Minimum IAQ Performance, EQc1: Outdoor Air Delivery Monitoring; LBCp14: Healthy Air Ventilation</p>
<b>Water</b>						
Minimize use of potable water and maximize reuse	W1. Reduce potable water consumption by a minimum of 30%	<ol style="list-style-type: none"> <li>Install a greywater recycling system.</li> <li>Reuse the condensate produced during dehumidification.</li> <li>Install low flow plumbing fixtures.</li> </ol>	<p>Design Team</p> <p>Design Team</p>	<ol style="list-style-type: none"> <li>Filtration system requires monthly maintenance cleaning/inspection</li> <li>Basic HVAC inspection and possible replacement of coils</li> <li>Waterless urinals require cartridge replacement</li> </ol>	<ol style="list-style-type: none"> <li>~\$80,000 (~\$20,00 if no disinfection)</li> <li>Minimal cost</li> <li>~\$50/unit more than traditional urinal</li> </ol>	<p>LEED WEc3.1 &amp; 3.2: Water Use Reduction, 30% Reduction; LBCp10: Net Zero Water; OPL 6: Sustainable Water</p>
Minimize stormwater runoff on-site	W2. Minimize stormwater runoff by capturing 90% of rainfall on roofs and open spaces	<ol style="list-style-type: none"> <li>Install a rainwater harvesting on roof with retention tanks (or cisterns).</li> <li>Treat stormwater to greywater and/or irrigation standards</li> </ol>	<p>Design Team</p> <p>Design Team</p>	<ol style="list-style-type: none"> <li>Change filter media on a regular basis and clean the first flush filter (if applicable)</li> </ol>	<ol style="list-style-type: none"> <li>~\$20,000 (~\$80,000 if treatment and disinfection is required)</li> </ol>	<p>LEED WEc1.1, WEc1.2, WEc2; LBCp10 &amp; LBCp11</p> <p>LEED SSc6.1: Stormwater Design, Quantity Control &amp; SSc6.2: Stormwater Design, Quality Control; LBCp11: Sustainable Water Discharge</p>

Goals	Strategies	Actions	Responsibility	Maintenance	Cost Implications	Supported Framework*
<b>Materials</b>						
Maximize use of regional and recycled materials	M1. Reuse a minimum of 20% of materials from the existing building M2. Procure 10% of materials (by cost) within 125 miles and 20% of materials within 500 miles of the site	1. Develop a plan locating existing materials and retain these materials for future use (for original purpose or another purpose). 2. Identify regionally manufactured materials (extracted or recovered if possible) during construction and building operation	Design Team/Construction Manager  Owner/Architect/Design Team	1. Storage areas are required during construction and reused materials may require cleaning (water use) 2. N/A	1. Cost savings depending on quality of materials 2. Varies with material type	LEED MRc1: Building Reuse, Maintain 75% of Existing Walls, Floors & Roof & MRc3: Building Reuse, Maintain 50% of Interior Non-Structural Elements; LBCp9: Leadership in Construction Waste; OPL 4: Local and sustainable materials LEED MRc5.1 & 5.2: Regional Materials, 20% Extracted, Processed & Manufactured Regionally; LBCp8: Appropriate Materials/Services Radius
Minimize the embodied energy of materials	M3. Implement a Life Cycle Analysis for all construction materials and materials during the operation of the building	3. Establish a comprehensive centralized preferential purchasing program that encourages procuring sustainable and locally sourced products.	Owner/Construction Manager/Architect	3. N/A	3. Administration cost	LBCp7: Responsible Industry & LBCp8: Appropriate Materials/Services Radius
Design with materials that promote public health	M4. Minimize the use of toxic materials during construction and operation	4. Use materials with low or no volatile organic compound (VOC) levels  5. Develop a green cleaning program	Construction Manager/Owner  Owner	4. Same as conventional materials 5. Less maintenance than conventional materials (less harmful) and training of cleaning staff	4. Same price as conventional materials 5. Minimal additional cost	LEED EQc4.1-4.4: Low-Emitting Materials: Adhesives, Sealants, Paints, Coatings, Carpet Systems, & Composite Wood & Agrifiber; LBCp5: Materials Red List LBCp5: Materials Red List
<b>Waste</b>						
Divert waste from landfills during construction	WT1. Divert a minimum of 75% of waste from landfill	1. Identify construction haulers and recyclers to handle materials	Construction Manager	1. Receipt collection and chain of custody necessary if salvaging will be done off-site (staging areas if on-site)	1. Cost savings	LEED MRc2.1 & 2.2: Construction Waste Management, Divert 75% From Disposal ; LBCp9: Leadership in Construction Waste; OPL 2: Zero Waste
Minimize waste during building operation	WT2. Create a building recycling program which recycles paper, cardboard, glass, metal and plastic (add organic waste, if possible) WT3. Reduce waste generation during building operation by a minimum of 50% from a baseline amount (if no recycling program and purchasing policy)	2. Locate and designate collection and storage areas for recyclables. 3. Organize informational programs informing building occupants about the recycling program and recommend purchasing policies specifying easily recycled or composted products.	Owner Owner	2. Requires storage space and maintenance, and pickup of recyclables 3. Organizing a building waste management team for events and awareness	2. Administrative cost 3. N/A	LEED MRp1: Storage & Collection of Recyclables; OPL 2: Zero Waste
<b>Community Engagement</b>						
Engage the community in the design of the building	CE1. Review designs with Wake County Advisory Board and Core Advisory Board. CE2. Engage community and stakeholders CE3. Engage in PEER reviews with local architecture chapters and colleges  CE4. Request feedback from building occupants	1. Contact and schedule schematic and design reviews with the Wake County Advisory Board and Core Advisory Board. 2. Host public information and comment meetings to assure community members and stakeholders values, concerns and needs are met. 3. Invite the local AIA and College of Design to review designs and provide feedback. 4. Provide a survey to all occupants regarding thermal comfort, acoustic comfort, air quality, lighting, etc.	Owner/Design Team Owner/Design Team Owner/Design Team Owner	1. N/A 2. N/A 3. N/A 4. Staff member or outside consultant to survey building occupants	1. N/A 2. N/A 3. N/A 4. <\$10,000 if outside consultant	LEED EQc7.2: Thermal Comfort, Verification

Goals	Strategies	Actions	Responsibility	Maintenance	Cost Implications	Supported Framework*
<b>Open Space</b>						
Create a vital public streetscape and connect Nash Square	O1. Design a mid-block crossing and entry plaza to connect to Nash Square.	1. Locate the main entrance of the building to face Nash Square and provide a crosswalk with "pedestrian crossing" signs	Architect	1. To be determined with City	1. Cost unknown	
Design communal spaces within the building and enhance biodiversity	O2. Allocate about 0.5% of the building budget towards a public art display. O3. Design an accessible roof garden, balcony, courtyard, or atrium featuring diverse plant species	2. Provide space in the lobby or outside the building for a public art display. Engage the community through contests or monthly exhibits. 3. Design a courtyard, atrium or balcony as casual meeting areas (incorporate diversity using native and drought resistant plant species if possible)	Owner/Architect  Architect	2. Maintenance of space  3. Landscape maintenance and irrigation (if necessary)	2. Administrative cost  3. Administrative cost for maintenance	LBCp15: Beauty and Spirit; OPL 8: Culture and Heritage  LEED SSc5.1: Site Development, Protect and Restore Habitat & SSc5.2: Site Development, Maximize Open Space ; LBCp3: Habitat Exchange; OPL 7: Natural Wildlife and Habitats
Reduce light pollution from the building	O4. Ensure that site lighting maintains safe levels avoiding off-site lighting and night sky pollution	4. Design interior lighting to maintain direct beam illumination, exterior lighting to achieve power densities less than required in ASHRAE 90.1-2004 and complying with zoning requirements. Exterior lighting	Design Team	4. Maintaining fixtures and changing light bulbs (will be reduced with LED or fluorescents)	4. Motion sensor: ~\$30-50/unit	LEED SSc8: Light Pollution Reduction
<b>Emergency Services</b>						
Maintain a fully operational building during natural disasters	ES1. Provide a "clean" backup energy source	1. Research the possibility of biodiesel, fuel cells or microturbines for backup power generation.	Owner/Design Team	1. See Energy focus area	1. See energy focus area	
Maintain operation of EOC and ECC services	ES2. Install a radio/satellite communication system	2. Research the feasibility of a backup radio/satellite communication system for EOC and ECC services.	Owner/Design Team	2. Unknown	2. Unknown	
<b>Transportation</b>						
Reduce miles traveled for design services, construction and occupants	T1. Track miles traveled for construction, design services and building occupants and set targets to reduce footprint over building life	1. Survey building occupants to determine mode of transportation (car type) and miles traveled. Track and present carbon footprint from transportation paths. 2. Provide low emission/fuel efficient vehicles to police fleet.	Owner  Owner	1. Building staff may be required to administer and collect survey (availability on City website is an option) 2. Vehicles require same maintenance as current police fleet.	1. Administrative cost (if outside consultant then additional costs) 2. ~\$20,000/vehicle (not including grant deductions)	OPL 3: Sustainable Transport
Actively encourage alternative transit for occupants and visitors	T2. Provide covered, lit and secure bike racks T3. Provide a bus shelter outside the building T4. Provide an fuel efficient police fleet and preferred parking for alternative fuel/fuel efficient vehicles and carpools T5. Design the site to be "pedestrian friendly"	3. Locate and install bike covered bike racks for a minimum of 5% of the building occupants. Provide shower facilities for 0.5% of the building occupants. 4. Install a covered bus shelter at the bus stop outside the building. 5. Locate preferred parking (closest to the building entrance) for low emitting/fuel efficient vehicles for 5% of parking capacity for the building and for carpools (5% occupants or parking capacity). Implement a carpooling program by bulletin board or website. Provide low emission/fuel efficient vehicles to police fleet. 6. Provide secure lighting at street level, remove the curb cuts, and install "No Turn on Red" sign at intersections adjacent to the building.	Architect  Architect  Design team/Owner	3. N/A 4. N/A 5. N/A 6. N/A	3. Minimal cost per unit 4. Minimal cost 5. N/A 6. N/A	LEED SSc4.2: Alternative Transportation, Bicycle Storage & Changing Rooms  LEED SSc4.1: Alternative Transportation, Public Transportation LEED SSc4.3: Alternative Transportation, Low Emitting & Fuel Efficient Vehicles & LEED SSc4.4: Alternative Transportation, Parking Capacity
<b>Accessibility</b>						
Design to achieve equal accessibility for all (beyond ADA)	A1. Create a system of signage and wayfinding tools that meet the needs of the building	1. Provide highly visible and adequate signage which integrates with the building "context"	Architect	1. N/A	1. N/A	
Balance public accessibility and security	A2. Incorporate public spaces inside a secure building.	2. Divide the building into security zones appropriate to function	Design Team	2. N/A	2. N/A	

Goals	Strategies	Actions	Responsibility	Maintenance	Cost Implications	Supported Framework*
<b>Sustainability Engagement</b>						
Showcase sustainability to educate the occupants, the public and the region	SE1. Design a building that makes a statement in terms of efficiency (energy, water, waste, health, etc) and aesthetics	1. Organize building tours for the public	Owner	1. Train and have a person on staff to give scheduled and inprompto building tours	1. Labor cost	LBCp16: Inspiration and Education LBCp16: Inspiration and Education
		2. Showcase energy, water and waste saving techniques with signs and interactive kiosks with intravenous monitoring of water and energy	Architect/Owner	2. Meters need to be replaced (depends on quality)	2. Kiosk: \$250 - 500	
		3. Create a documentary and enter the building for awards	Owner	3. Record in the construction phase and in the design phase if capable.	3. Local film students could produce (minimal cost)	LBCp16: Inspiration and Education
<b>Economic Impacts</b>						
Promote diversity within the construction/design team	EI1. Contract a minimum of 30% of the construction team as Historically Underutilized Business (HUB) firms during construction.	1. Specify minimum HUB requirements during construction.	Owner	1. N/A	1. N/A	
Design the building for future flexibility	EI2. Design buildings with the intent of expansion to reduce the need for future construction	2. Analyze future programs for the building, increase ceiling height and leave open spaces.	Owner/Architect/Design Team	2. N/A	2. N/A	
<b>Health and Productivity</b>						
Design the building for maximum health and productivity	HP1. Provide spaces with maximum daylight and views to the outside. HP2. Allow occupants to have control of lighting and temperature. HP3. Design spaces to reduce noise intrusion and enhance privacy HP4. Promote employee health throughout the building HP5. Provide adequate ventilation in chemical storage areas.	1. Orient the building and incorporate clerestory windows, skylights, interior light shelves, louvers and blinds to increase daylight for a minimum of 75% of spaces.	Architect	1. N/A	1. N/A	LEED EQc8.1: Daylight & Views, Daylight 75% of Spaces
		2. Provide views to the outside of the building for 90% of occupants between 2.5 to 7.5 feet.	Architect	2. N/A	2. N/A	LEED EQc8.2: Daylight & Views, Views for 90% of Spaces
		3. Determine the occupant tasks and design individual lighting controls for 90% of building occupants and controllability in multi-use spaces.	Architect/Design Team	3. Bulbs require changing.	3. \$20-100/occupant	LEED EQc6.1: Controllability of Systems: Lighting
		4. Design an underfloor air distribution system with to allow a minimum of 50% of the building occupants temperature control and controllability in multi-use spaces.	Design Team	4. Periodic vacuuming and maintenance staff will need to know how to reset the controls.	4. \$3-\$4/sf	LEED EQc6.2: Controllability of Systems: Thermal Comfort
		5. Design facades and interior to meet acoustical standard ANSI S12.60-2002	Architect/Design Team	5. N/A	5. Based on availability of materials.	OPL 10: Health and Happiness
		6. Determine the feasibility of a fitness facility in the building, offer reduced fees for fitness facilities located throughout the City, install scales in restrooms and provide employee health training sessions.	Owner	6. Monthly maintenace of fitness equipment.	6. Could be negotiated with health care company	
		7. Provide partitions and dedicated exhaust systems for chemical storage areas and copy rooms.	Design Team	7. N/A	7. N/A	LEED EQc5: Indoor Chemical & Pollutant Source Control; LBCp13: Healthy Air/Control

**Notes:**

LEED is the USGBC's Leadership in Energy and Environmental Design Guidelines

LBC is Cascadia's Living Building Challenge Guidelines

OPL is One Planet Living Guidelines

\* Some LBC and OPL requirements are above those targeted

Appendix B

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**LEED Checklist**



LEED-NC

**LEED-NC Version 2.2 Registered Project Checklist**

Clarence E. Lightner Public Safety Center  
Raleigh, NC

Costs*	
N/A	No Cost
Low	Less than \$10K
Medium	\$10K-50K
High	\$50K +

\*change from business as usual.

Yes ? No

10	2	2	Sustainable Sites	Design / Construction	14 Points	Responsible Party	Comment	Cost
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Y			Prereq 1 <b>Construction Activity Pollution Prevention</b>	C	Required	CM		Low
1			Credit 1 <b>Site Selection</b>	D	1	Owner	Building meets credit requirements	N/A
1			Credit 2 <b>Development Density &amp; Community Connectivity</b>	D	1	Owner	<b>Option 2:</b> Ten Basic services within site area	N/A
		1	Credit 3 <b>Brownfield Redevelopment</b>	D	1	Owner	Not on a brownfield. Can be achieved if asbestos abatement and remediation is required	Low
1			Credit 4.1 <b>Alternative Transportation, Public Transportation Access</b>	D	1	Owner	Achieved with bus route	N/A
1			Credit 4.2 <b>Alternative Transportation, Bicycle Storage &amp; Changing Rooms</b>	D	1	Architect	Provide bike racks and showers. Based on full time occupants and visitors	Low
1			Credit 4.3 <b>Alternative Transportation, Low-Emitting and Fuel-Efficient Vehicles</b>	D	1	Owner/Architect	<b>Option 1:</b> Fuel Efficient vehicles to 3% of building occupants and preferred parking for these vehicles (police fleet may be capable of meeting credit requirements) or <b>Option 2:</b> Preferred parking for 5% of vehicle parking capacity.	Med
	1		Credit 4.4 <b>Alternative Transportation, Parking Capacity</b>	D	1	Owner	Option 1 or Option 2? Carpooling program needs to be established.	N/A
		1	Credit 5.1 <b>Site Development, Protect or Restore Habitat</b>	C	1	Landscape Architect/Architect	50% of of the site area (excluding footprint) with native or adapted vegetation.	High
	1		Credit 5.2 <b>Site Development, Maximize Open Space</b>	D	1	Landscape Architect/Architect	Vegetated areas, pedestrian oriented hardscapes	N/A
1			Credit 6.1 <b>Stormwater Design, Quantity Control</b>	D	1	Civil Engineer	<b>Option 2:</b> 25% decrease in volume of stormwater runoff for 2-yr, 24 hour storm. Can be achieved with rainwater harvesting or stormwater retention/detention	Low
1			Credit 6.2 <b>Stormwater Design, Quality Control</b>	D	1	Civil Engineer	Rainwater harvesting or Best Management Practices (BMPs)	Med
1			Credit 7.1 <b>Heat Island Effect, Non-Roof</b>	C	1	Landscape Architect/Civil Engineer	<b>Option 1:</b> High SRI paving materials or open grid system or <b>Option 2:</b> Cover 50% of parking	Med
1			Credit 7.2 <b>Heat Island Effect, Roof</b>	D	1	Architect	High SRI roof material	Low
1			Credit 8 <b>Light Pollution Reduction</b>	D	1	Lighting consultant	Decrease light pollution	Low

Yes ? No

5			Water Efficiency	Design / Construction	5 Points	Responsible Party	Option	Cost
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1			Credit 1.1	<b>Water Efficient Landscaping</b> , Reduce by 50%	D	1 Landscape Architect	If there is irrigation then this can be achieved with native/adaptive vegetation or rainwater harvesting	Low	
1			Credit 1.2	<b>Water Efficient Landscaping</b> , No Potable Use or No Irrigation	D	1 Landscape Architect	Rainwater harvesting? Native and adaptive planting.	High	
1			Credit 2	<b>Innovative Wastewater Technologies</b>	D	1 Plumbing Engineer/Civil Engineer	Low flow plumbing fixtures, greywater recycling and rainwater harvesting.	High	
1			Credit 3.1	<b>Water Use Reduction</b> , 20% Reduction	D	1 Plumbing Engineer	Low flow plumbing fixtures	Low	
1			Credit 3.2	<b>Water Use Reduction</b> , 30% Reduction	D	1 Plumbing Engineer	Low flow plumbing fixtures	Low	
Yes	?	No							

<b>9</b>	<b>6</b>	<b>2</b>	<b>Energy &amp; Atmosphere</b>	<b>Design / Construction</b>	<b>17 Points</b>	<b>Responsible Party</b>	<b>Option</b>	<b>Cost</b>
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Y			Prereq 1	<b>Fundamental Commissioning of the Building Energy Systems</b>	C	Required Commissioning Agent	Hire commissioning services	N/A
Y			Prereq 2	<b>Minimum Energy Performance</b>	D	Required Mechanical Engineer	14% above ASHRAE 90.1-2004 Appendix G	N/A
Y			Prereq 3	<b>Fundamental Refrigerant Management</b>	D	Required Mechanical Engineer	No CFCs	N/A

\*Note for EAc1: All LEED for New Construction projects registered after June 26<sup>th</sup>, 2007 are required to achieve at least two (2) points under EAc1.

4	4	2	Credit 1	<b>Optimize Energy Performance</b>	D	1 to 10 Mechanical Engineer	Minimum 14% improvement above ASHRAE-90.1-2004 (2 points). 3.5% per point up to 42% (10 points)	Low-Med	
1	2		Credit 2	<b>On-Site Renewable Energy</b>	D	1 to 3 Electrical Engineer	PVs. 2.5% (1 point), 7.5% (2 points), 12.5% (3 points)	High	
1			Credit 3	<b>Enhanced Commissioning</b>	C	1 Commissioning Agent	TBD	Low-Med (0.5 - 2% of construction costs)	
1			Credit 4	<b>Enhanced Refrigerant Management</b>	D	1 Mechanical Engineer	No refrigerants or low global warming potential HCFCs	Low	
1			Credit 5	<b>Measurement &amp; Verification</b>	C	1 Mechanical Engineer	M&V options - metering and monitoring building systems	Low-Med (1% of construction costs)	
1			Credit 6	<b>Green Power</b>	C	1 Owner	Purchase 35% of buildings electricity from renewable energy sources.	Low	
Yes	?	No							

<b>5</b>	<b>7</b>	<b>1</b>	<b>Materials &amp; Resources</b>	<b>Design / Construction</b>	<b>13 Points</b>	<b>Responsible Party</b>	<b>Option</b>	<b>Cost</b>
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Y			Prereq 1	<b>Storage &amp; Collection of Recyclables</b>	D	Required Architect/Owner	-	N/A
	1		Credit 1.1	<b>Building Reuse</b> , Maintain 75% of Existing Walls, Floors & Roof	C	1 Architect/Construction Manager	Inventory necessary	N/A
		1	Credit 1.2	<b>Building Reuse</b> , Maintain 100% of Existing Walls, Floors & Roof	C	1 Architect/Construction Manager	Inventory necessary	N/A
	1		Credit 1.3	<b>Building Reuse</b> , Maintain 50% of Interior Non-Structural Elements	C	1 Architect/Construction Manager	Inventory necessary	N/A
1			Credit 2.1	<b>Construction Waste Management</b> , Divert 50% from Disposal	C	1 Construction Manager	Is achievable in this region	Low
1			Credit 2.2	<b>Construction Waste Management</b> , Divert 75% from Disposal	C	1 Construction Manager	Is achievable in this region	Low

1	Credit 3.1	<b>Materials Reuse, 5%</b>	C	1 Construciton Manager	Specify salvaged, refurbished or reused materials	Low-Med
1	Credit 3.2	<b>Materials Reuse, 10%</b>	C	1 Construciton Manager	Specify salvaged, refurbished or reused materials	Low-Med
1	Credit 4.1	<b>Recycled Content, 10%</b> (post-consumer + ½ pre-consumer)	C	1 Construciton Manager/Architect	Specify materials with recycled content	Low
1	Credit 4.2	<b>Recycled Content, 20%</b> (post-consumer + ½ pre-consumer)	C	1 Construciton Manager/Architect	Specify materials with recycled content	Low
1	Credit 5.1	<b>Regional Materials, 10%</b> Extracted, Processed & Manufactured Regionally	C	1 Construciton Manager/Architect	Specify local materials	Low
1	Credit 5.2	<b>Regional Materials, 20%</b> Extracted, Processed & Manufactured Regionally	C	1 Construciton Manager/Architect	Specify local materials	Low
1	Credit 6	<b>Rapidly Renewable Materials</b>	C	1 Construciton Manager/Architect	Specify products such as bamboo, wool, cotton insulation, agrifiber, linoleum, wheatboard, strawboard or cork	Low
1	Credit 7	<b>Certified Wood</b>	C	1 Construciton Manager/Architect	Specify FSC certified wood	Low

Yes ? No

13	2	Indoor Environmental Quality	Design / Construction	15 Points	Responsible Party	Option	Cost
Y		Prereq 1	<b>Minimum IAQ Performance</b>	D	Required Mechanical Engineer	Meet ASHRAE 62.1-2004	Low
Y		Prereq 2	<b>Environmental Tobacco Smoke (ETS) Control</b>	D	Required Owner	No smoking in the building	Low
1		Credit 1	<b>Outdoor Air Delivery Monitoring</b>	D	1 Mechanical Engineer	CO2 sensors and outdoor air monitoring	Low
1		Credit 2	<b>Increased Ventilation</b>	D	1 Mechanical Engineer	30% above ASHRAE 62.1-2004. Humidity may be an issue.	Med
1		Credit 3.1	<b>Construction IAQ Management Plan, During Construction</b>	C	1 Construction Manager	IAQ plan	Low
1		Credit 3.2	<b>Construction IAQ Management Plan, Before Occupancy</b>	C	1 Construction Manager	Building flushout	Low
1		Credit 4.1	<b>Low-Emitting Materials, Adhesives &amp; Sealants</b>	C	1 Construciton Manager/Architect	Low VOC materials; specify	Low
1		Credit 4.2	<b>Low-Emitting Materials, Paints &amp; Coatings</b>	C	1 Construciton Manager/Architect	Low VOC materials; specify	Low
1		Credit 4.3	<b>Low-Emitting Materials, Carpet Systems</b>	C	1 Construciton Manager/Architect	Low VOC materials; specify	Low
1		Credit 4.4	<b>Low-Emitting Materials, Composite Wood &amp; Agrifiber Products</b>	C	1 Construciton Manager/Architect	Urea/formaldehyde-free composite wood; specify	Med (difficult to locate)
1		Credit 5	<b>Indoor Chemical &amp; Pollutant Source Control</b>	D	1 Mechanical Engineer/Architect	Roll-off carpets; ventilation in chemical storage areas; MERV 13 filters	Low
1		Credit 6.1	<b>Controllability of Systems, Lighting</b>	D	1 Lighting Consultant/Electrical Engineer	Individual occupant control of lighting	Low
1		Credit 6.2	<b>Controllability of Systems, Thermal Comfort</b>	D	1 Mechanical Engineer	Occupant control of temperature (under floor venting)	Med
1		Credit 7.1	<b>Thermal Comfort, Design</b>	D	1 Mechanical Engineer	Design to ASHRAE 55-2004	Low
1		Credit 7.2	<b>Thermal Comfort, Verification</b>	D	1 Owner	Survey occupants	N/A
1		Credit 8.1	<b>Daylight &amp; Views, Daylight 75% of Spaces</b>	D	1 Architect	Daylight in non-secure areas	N/A (glazing costs)
1		Credit 8.2	<b>Daylight &amp; Views, Views for 90% of Spaces</b>	D	1 Architect	Views in non-secure area	N/A (glazing costs)

Yes ? No

5 2			Innovation & Design Process	Design / Construction	5 Points	Responsible Party	Option	Cost
1			Credit 1.1 <b>Innovation in Design:</b> Exemplary Performance WEc3 (40%)	D	1	Plumbing Engineer	If greywater recycling or rainwater harvesting	Med
1			Credit 1.2 <b>Innovation in Design:</b> Exemplary Performance SSc7.1 (all parking under cover)	D	1	Architect	Cover parking	Low-Med
1			Credit 1.3 <b>Innovation in Design:</b> Green Cleaning Initiative	D	1	Owner	Initiate a green cleaning program	N/A
1			Credit 1.4 <b>Innovation in Design:</b> Building Education Elements (tours, displays, documentary)	D	1	Owner	Have a person on-staff for building tours	Low-Med
	1		Credit 1.4 <b>Innovation in Design:</b> Life Cycle analysis	D	1	Owner	A comprehensive centralized preferential purchasing program	Low
	1		Credit 1.4 <b>Innovation in Design:</b> Community Engagement	D	1	Owner	Invite the local AIA and College of Design to review designs and provide feedback.	N/A
1			Credit 2 <b>LEED® Accredited Professional</b>	D	1	Design Team		

Yes ? No

47 19			<b>Project Totals (pre-certification estimates)</b>	<b>69 Points</b>				
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Certified 26-32 points Silver 33-38 points Gold 39-51 points Platinum 52-69 points

Appendix C

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**Sample closed loop  
GSHP specification**

SECTION 15600

GROUND COUPLED VERTICAL CLOSED LOOP SYSTEM

PART 1 - GENERAL

1.1 DESCRIPTION OF WORK

- A. The work to be done by the Contractor shall consist of furnishing and delivering to the job site all material and equipment and furnishing all labor necessary for the complete installation of forty-one new vertical bores.
- B. The work to be done shall also include all necessary test drillings, and tests on completed vertical bores, which will verify to the Owner and the Engineer that each new vertical bore will meet the minimum guaranteed capacity. The new bores shall meet all requirements as set forth in the following detailed specifications.

1.2 RELATED WORK

- A. Section 15050 - Basic Mechanical Materials and Methods
- B. Section 15100 - Valves
- C. Section 15120 - HVAC Piping Specialties
- D. Section 15140 - Pipe Supports and Anchors
- E. Section 15240 - Mechanical Sound and Vibration Control

1.3 SUBMITTALS

- A. Submit product data under provisions of Section 01300.

- B. Submit product data for manufactured components and assemblies required for this project.
- C. Submit complete product shop drawings showing all installation details.
- D. Vertical Bore Logs and Construction Drawings of Vertical Bores: The Contractor shall keep a log of the geologic materials encountered in the drilling of the Vertical Bores and shall furnish three typewritten copies of such log to the Engineer on completion of the Vertical Bores. The Contractor shall also furnish three copies of a drawing for the Vertical Bores showing the depth and exact construction Vertical Bore and giving all dimensions regarding lengths and diameters of bore holes, pipe diameter, grouting material and other pertinent details and dimensions.

1.4 COORDINATION

- A. Coordinate power connection requirements with electrical contractor.
- B. Coordinate all drilling work with Kresge Foundation taking into account location of the vertical bores in relation to the parking lot.

1.5 REFERENCE STANDARDS

- A. IGSPHA – International Ground Source Heat Pump Association
- B. ISO 13256 – Ground Water Heat Pumps
- C. Michigan State Department of Environmental Quality

1.6 REGULATORY REQUIREMENTS

- A. Contractor is responsible to secure all permits required for the work.
- B. Coordinate with requirements of Troy City Building Department.

PART 2 - MATERIALS

2.1 VERTICAL BORES

- A. General
  - 1. The work to be done by the Contractor shall consist of furnishing and delivering to the job site all material and equipment and furnishing all labor necessary for the complete installation of bore holes.
  - 2. Vertical bores are indicated on the civil design drawings however final boreholes configurations will be recommended and submitted by the drilling contractor for engineering review and approval.
  - 3. The new Vertical bores shall be located as shown on the drawings. The exact location of the bore shall be finally coordinated in the field by the Owner, Engineer and Drilling Contractor.
  - 4. It is expected that the Vertical bores will be approximately 400 feet deep below existing grade and the horizontal subheaders shall be installed a MINIMUM of 6 feet bellow grade in trench (to eliminate the need for glycol in the system). However, the exact depth will be determined by the driller and the Engineer in the field. A unit price per foot for bore depth shall be supplied on the form of proposal.
- B. Vertical Bore installation, Backfill and Grouting
  - 1. Vertical bores shall be drilled to sufficient depths to ensure that the entire length of U-tube is inserted.

- This may require the bore to be drilled several feet deeper than the U-tube length.
- 2. All U-tube joints shall be visually inspected for integrity as specified by the pipe manufacturer (alignment of joints, proper bead roll-back) before insertion into the bore hole.
- 3. The bore hole annulus shall be backfilled or grouted to ensure there are no air voids. In consolidated formations, this will require the bore annulus to be filled from the bottom to the top with a "tremie" tube.
- 4. The upper 20 ft of every bore annulus shall be grouted with a material having a permeability of  $1 \times 10^{-7}$  cm/s or less to inhibit surface water penetration into the formation.

C. Horizontal Sub-header and Header Installation

- 1. U-tubes are to be thermally fused to the horizontal supply and return headers (or sub-headers) in the trench, which are to be connected to isolation valves. The assembly is to be filled with water and purged at a flow rate that ensures that the velocity in all sections of piping exceeds 2 ft. per second (fps).
- 2. Horizontal piping must be buried at least 6ft below the finished grade level.

D. Ground Loop Purging and Flushing

- 1. After purging, the U-tube and headers assemblies should be pressurized to 60 psig at the isolation valves and maintain pressure for a period of one hour. Pressurization sheets/test results should be submitted for engineer's and Commissioning Agent review.
- 2. After pressure testing, the headers should be backfilled with sand or rock-free natural fill.

PART 3 - EXECUTION

3.1 GENERAL

A. Vertical Bore Construction Method

1. The Vertical Bore shall be constructed in accordance with local AHJ.
2. IGSPHA – International Ground Source Heat Pump Association
3. ISO 13256 – Ground Water Heat Pumps
4. Michigan State Department of Environmental Quality
5. Coordinate with requirements of Troy City Building Department.

B. Drilling Equipment

1. The drilling equipment used for the work must be adequate in all respects to insure expeditious completion of the work. If the drilling equipment proves to be inadequate or not in proper repair for the execution of work repairs shall be made immediately or more adequate equipment be furnished by the Contractor.

C. Vertical Alignment and Plumbness

1. The Vertical Bore shall be constructed round, true to line and shall not depart from the vertical more than 4 inches per each 100 feet. If doubt exists as to the departure from the vertical, the Contractor may be required by the Engineer to furnish equipment to test the plumbness of the Vertical Bore at no extra cost. No Vertical Bore will be accepted if the straightness or vertical alignment is unsatisfactory.

D. Vertical Bore Development

1. It will be the Contractor's responsibility to assure the sufficient development has been done to insure that the Vertical Bore will be debris free, as specified, throughout the warranty period.

E. Vertical Bore Purging and Flushing

1. The Vertical Bores shall be purged and flushed before put in normal operation.

F. Protection of Vertical Bore

1. At all times during the progress of the work, the Contractor shall protect the Vertical Bore in such a manner as to effectively prevent the entrance of foreign matter into it.

G. Abandonment of Vertical Bore

1. In the event that the Contractor shall fail to complete the Vertical Bore to the depth required or should he abandon the Vertical Bore for any reason, he shall, abandon the Vertical Bore per Michigan State and Troy local codes. No payment will be made for any Vertical Bore abandoned by the Contractor for any reason.

H. Contractor's Responsibility

1. The Contractor shall be responsible for performing all of the work in strict accordance with these specifications. If evidence indicates that the Vertical Bore is not constructed in accordance with the specifications to the satisfaction of the Engineer, the Engineer may order that proper changes be made by the Contractor or, in the event that proper changes cannot be made, the Engineer may order the Contractor to abandon the Vertical Bore, without additional cost, and to drill a new Vertical Bore.

**END OF SECTION 15060**

Appendix D

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**Sample LEED  
specification**

SECTION 01352

LEED GOALS AND REQUIREMENTS

PART 1 - GENERAL

1.1 SUMMARY

- A. This Section includes general requirements and procedures for compliance with certain U.S. Green Building Council's (USGBC) LEED prerequisites and credits needed for the Project to obtain LEED certification.
  - 1. Attached is a LEED scorecard that identifies the # required LEED points.
  - 2. OWNER will file for LEED certification, but Contractor is responsible for providing Owner with required documentation to achieve LEED certification.
  - 3. Project must comply with requirements of USGBC LEED Green Building Rating System version 2.2
- B. Related Sections include the following:
  - 1. Divisions 1 through 16 Sections for LEED requirements specific to the Work of each of those Sections. These requirements may or may not include reference to LEED.

1.2 DEFINITIONS

- A. Certificates of Chain-of-Custody: Certificates signed by manufacturers certifying that wood used to make products was obtained from forests certified by an FSC-accredited certification body to comply with FSC 1.2, "Principles and Criteria." Certificates shall include evidence that mill is certified for chain-of-custody by an FSC-accredited certification body.
- B. LEED: Leadership in Energy & Environmental Design.

- C. Rapidly Renewable Materials: Materials made from agricultural products that are typically harvested within a ten-year or shorter cycle. Rapidly renewable materials include products made from bamboo, cotton, flax, jute, straw, sunflower seed hulls, vegetable oils, or wool.
- D. Regionally Manufactured Materials: Materials that are manufactured within a radius of 500 miles (800 km) from the Project location. Manufacturing refers to the final assembly of components into the building product that is installed at the Project site (does not include on-site).
- E. Regionally Extracted, Harvested, or Recovered Materials: Materials that are extracted, harvested, or recovered and manufactured within a radius of 500 miles (800 km) from the Project site.
- F. Recycled Content: The percentage by weight of constituents that have been recovered or otherwise diverted from the solid waste stream, either during the manufacturing process (pre-consumer), or after consumer use (post-consumer).
  - 1. Spills and scraps from the original manufacturing process that are combined with other constituents after a minimal amount of reprocessing for use in further production of the same product are not recycled materials.
  - 2. Discarded materials from one manufacturing process that are used as constituents in another manufacturing process are pre-consumer recycled materials.

1.3 SUBMITTALS

- A. Submit additional LEED submittal requirements included in other sections of the Specifications.
- B. LEED submittals are in addition to other submittals. If submitted item is identical to that submitted to comply with other requirements, submit duplicate copies as a separate submittal to verify compliance with indicated LEED requirements.

## APPENDIX D

- C. Project Materials Cost Data: Provide statement indicating total cost for building materials used for Project. Division 2 through 10: exclude costs for mechanical, electrical and plumbing equipment and do not include labor or equipment costs.
- D. LEED Action Plans: Provide preliminary submittals within 30 days of date established for the Notice to Proceed indicating how the following requirements will be met.
  - 1. Credit MR 2.1 and 2.2: Waste management plan complying with Division 1 Section "Construction Waste Management."
  - 2. Credit MR 4.1 and 4.2: List of proposed materials with recycled content.
    - a. Indicate cost, post-consumer recycled content, and pre-consumer recycled content for each product having recycled content.
  - 3. Credit MR 5.1: List of proposed regionally manufactured materials and regionally extracted, harvested, or recovered materials.
    - a. Identify each regionally manufactured material, its source, and cost.
    - b. Identify each regionally extracted, harvested or recovered material, its source, and cost.
  - 4. Credit EQ 3.1: Construction indoor air quality management plan, refer to Section 01500 TEMPORARY FACILITIES AND CONTROLS for additional requirements.
- E. LEED Progress Reports: Concurrent with each Application for Payment, submit reports comparing actual construction and purchasing activities with LEED action plans for the following:
  - 1. Credit MR 2.1: Waste reduction progress reports complying with Division 1 Section "Construction Waste Management."
  - 2. Credit MR 4.1 and 4.2: Recycled content.
  - 3. Credit MR 5.1: Regionally manufactured materials and regionally extracted, harvested, or recovered materials.
  - 4. Credit MR 6: Rapidly renewable building materials.
  - 5. Credit EQ 3.1: Construction indoor air quality management plan.
- 6. Credits EQ 4.1, 4.2, 4.3, 4.4: Low-emitting materials complying with requirements of Section 01352 LEED Requirements.
- F. LEED Documentation Submittals:
  - 1. Credit SS 7.2: Product Data for roofing materials indicating compliance with LEED Credit requirements for use roofing having an SRI equal or greater than 78 for low-sloped roofs ( $\leq 2:12$ ) or 29 for steep-sloped roofs ( $\geq 2:12$ ) when tested in accordance with ASTM E1980, ASTM E903, ASTM E1918 and ASTM C1549
  - 2. Credit SS 8.0: Product Data for interior and exterior lighting fixtures that stop direct-beam illumination from leaving the building site per LEED which requires: "The angle of maximum candela from each interior luminaire as located in the building shall intersect opaque building interior surfaces and not exit out through the windows or all non-emergency interior lighting shall be automatically controlled to turn off during non-business hours. Provide manual override capability for after hours use. Only light areas as required for safety and comfort. Do not exceed 80% of the lighting power densities for exterior areas and 50% for building facades and landscape features as defined in ASHRAE/IESNA Standard 90.1-2004, Exterior Lighting Section, without amendments. Exterior lighting shall be classified as LZ3, defined in IESNA RP-33, and follow all of the requirements for that specific zone."
  - 3. Credit WE 3.1 and 3.2: Product Data for plumbing fixtures indicating water consumption.
  - 4. Prerequisite EA 3.0: Product Data for new HVAC equipment indicating absence of CFC refrigerants.
  - 5. Credit EA 4.0: Product Data for new HVAC equipment indicating absence of HCFC refrigerants, and for clean-agent fire-extinguishing systems indicating absence of HCFC and Halon.
  - 6. Credit EA 5.0: Product Data and wiring diagrams for sensors and data collection system used to provide continuous metering of building energy and water consumption performance over time.
  - 7. Credit MR 2.1 and 2.2: Comply with Division 1 Section "Construction Waste Management."

8. Credit MR 4.1 and 4.2: Product Data and certification letter indicating percentages by weight of post-consumer and pre-consumer recycled content for products having recycled content. Include statement indicating costs for each product having recycled content.
9. Credit MR 5.1: Product Data indicating location of material manufacturer for regionally manufactured materials.
  - a. Include statement indicating cost and distance from manufacturer to Project for each regionally manufactured material.
  - b. Include statement indicating cost and distance from point of extraction, harvest, or recovery to Project for each raw material used in regionally manufactured materials.
10. Credit MR 6: Product Data indicating percentages by weight of each rapidly renewable material. Include statement indicating costs for each rapidly renewable material.
11. Credit MR 7: Product Data indicating type, manufacturer and COC certification number for FSC certified wood.
12. Credit EQ 1.0: Product Data and Shop Drawings for carbon dioxide monitoring system.
13. Credit EQ 3.1: Refer to Section 01500 TEMPORARY FACILITIES AND CONTROLS for submittal requirements.
14. Credit EQ 4.1:
  - a. Product Data and material safety data sheets (MSDSs) for adhesives and sealants used on the interior of the building indicating VOC content of each product used. Indicate VOC content in g/L calculated according to 40 CFR 59, Subpart D (EPA method 24). Per LEED, "The VOC content of adhesives and sealants used must be less than the current VOC content limits of South Coast Air Quality Management District (SCAQMD) Rule #1168."
  - b. If weighted average is required for compliance indicated quantity used of each material.
15. 13. Credit EQ 4.2:
  - a. Product Data and material safety data sheets (MSDSs) for paints and coatings used on the

- interior of the building indicating chemical composition and VOC content of each product used. Indicate VOC content in g/L calculated according to 40 CFR 59, Subpart D (EPA method 24). VOC emissions from paints and coatings must not exceed the VOC and chemical component limits of Green Seal's Standard GS-11 requirements.
  - b. If weighted average is required for compliance indicated quantity used of each material.
16. Credit EQ 4.3:
  - a. Product Data for carpet products indicating VOC content of each product used. Carpet systems must meet or exceed the requirements of Carpet and Rug Institute's Green Label Plus Program.
  - b. If weighted average is required for compliance indicated quantity used of each material.
17. Credit EQ 4.4: Product Data for composite wood and agrifiber products indicating that products contain no urea-formaldehyde resin.
  - a. Include statement indicating adhesives and binders used for each product.
18. Credit EQ 7: Product Data and Shop Drawings for sensors and control system used to monitor and control room temperature and humidity.

PART 2 - PRODUCTS

2.1 RECYCLED CONTENT OF MATERIALS

- A. Credits MR 4.1 and MR 4.2: Provide building materials with recycled content such that post-consumer recycled content constitutes a minimum of 10 percent of the cost of materials used for the Project or such that post-consumer recycled content plus one-half of pre-consumer recycled content constitutes a minimum of 20 percent of the cost of materials used for the Project.
  1. The cost of post-consumer recycled content of an item shall be determined by dividing the weight of post-consumer recycled content in the item by the total weight of the item and multiplying by the cost of the item.

2. The cost of post-consumer recycled content plus one-half of pre-consumer recycled content of an item shall be determined by dividing the weight of post-consumer recycled content plus one-half of pre-consumer recycled content in the item by the total weight of the item and multiplying by the cost of the item.
3. Do not include mechanical, electrical or plumbing components in the calculation.
4. Recycled content of materials shall be defined according to the International Organization for Standardization document, ISO 14021 "Environmental labels and declarations – Self-declared environmental claims (Type II environmental labeling)".

## 2.2 REGIONAL MATERIALS

- A. Credit MR 5.1: Provide 10 percent of building materials (by cost) that are regionally extracted, processed and manufactured materials.

## 2.3 RENEWABLE MATERIALS

- A. Credit MR 6: Provide 2.5 percent of building materials (by cost) that are rapidly renewable materials.

## 2.4 CERTIFIED MATERIALS

- A. Credit MR 7: Provide 50% of wood-based materials for wood building components that are certified in accordance with the Forest Stewardship Council's (FSC) Principles and Criteria.

## 2.5 LOW-EMITTING MATERIALS

- A. Credit EQ 4.1: For interior applications all adhesives and sealants shall comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA method 24):
  1. Wood Glues: 30 g/L.
  2. Metal to Metal Adhesives: 30 g/L.
  3. Adhesives for Porous Materials (Except Wood): 50 g/L.

4. Subfloor Adhesives: 50 g/L.
5. Plastic Foam Adhesives: 50 g/L.
6. Carpet Adhesives: 50 g/L.
7. Carpet Pad Adhesives: 50 g/L.
8. VCT and Asphalt Tile Adhesives: 50 g/L.
9. Cove Base Adhesives: 50 g/L.
10. Gypsum Board and Panel Adhesives: 50 g/L.
11. Rubber Floor Adhesives: 60 g/L.
12. Ceramic Tile Adhesives: 65 g/L.
13. Multipurpose Construction Adhesives: 70 g/L.
14. Fiberglass Adhesives: 80 g/L.
15. Structural Glazing Adhesives: 100 g/L.
16. Wood Flooring Adhesive: 100 g/L.
17. Contact Adhesive: 250 g/L.
18. Plastic Cement Welding Compounds: 350 g/L.
19. ABS Welding Compounds: 400 g/L.
20. CPVC Welding Compounds: 490 g/L.
21. PVC Welding Compounds: 510 g/L.
22. Adhesive Primer for Plastic: 650 g/L.
23. Sealants: 250 g/L.
24. Sealant Primers for Nonporous Substrates: 250 g/L.
25. Sealant Primers for Porous Substrates: 775 g/L.

- B. Credit EQ 4.2: For interior applications, (on site only), all paints and coatings shall comply with the following limits for VOC content when calculated according to 40 CFR 59, Subpart D (EPA method 24) and the following chemical restrictions:
  1. Flat Paints and Coatings: VOC not more than 50 g/L.
  2. Non-Flat Paints and Coatings: VOC not more than 150 g/L.
  3. Anti-Corrosive Coatings: VOC not more than 250 g/L.
  4. Varnishes and Sanding Sealers: VOC not more than 350 g/L.
  5. Stains: VOC not more than 250 g/L.
  6. Aromatic Compounds: Paints and coatings shall not contain more than 1.0 percent by weight total aromatic compounds (hydrocarbon compounds containing one or more benzene rings).
  7. Restricted Components: Paints and coatings shall not contain any of the following:
    - a. Acrolein.

- b. Acrylonitrile.
- c. Antimony.
- d. Benzene.
- e. Butyl benzyl phthalate.
- f. Cadmium.
- g. Di (2-ethylhexyl) phthalate.
- h. Di-n-butyl phthalate.
- i. Di-n-octyl phthalate.
- j. 1,2-dichlorobenzene.
- k. Diethyl phthalate.
- l. Dimethyl phthalate.
- m. Ethylbenzene.
- n. Formaldehyde.
- o. Hexavalent chromium.
- p. Isophorone.
- q. Lead.
- r. Mercury.
- s. Methyl ethyl ketone.
- t. Methyl isobutyl ketone.
- u. Methylene chloride.
- v. Naphthalene.
- w. Toluene (methylbenzene).
- x. 1,1,1-trichloroethane.
- y. Vinyl chloride.

- C. Credit EQ 4.1: All carpet adhesive shall meet the requirements of EQ Credit 4.1: VOC limit of 50 g/L.
- D. Credit EQ 4.4: Do not use composite wood and agrifiber products that contain urea-formaldehyde resin.

**PART 3 - EXECUTION**

**3.1 CONSTRUCTION WASTE MANAGEMENT**

- A. Credit MR 2.1: Comply with Division 1 Section "Construction Waste Management."

**3.2 CONSTRUCTION INDOOR AIR QUALITY MANAGEMENT**

- A. Credit EQ 3.1: Refer to Section 01500 TEMPORARY FACILITIES AND CONTROLS for requirements.

**END OF SECTION**