Green Power: Photovoltaic Rooftop Panels
Doyle Conservation Center

The Trustees of Reservations
464 Abbott Avenue
Leominster, MA 01453

Final Report Prepared by James Younger, AIA
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MASSACHUSETTS
TECHNOLOGY
COLLABORATIVE

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2. Project Abstract

The Trustees of Reservations was granted a Green Building Design and Construction Assistance Grant with the Massachusetts Technology Collaborative Renewable Energy Trust. Our original intent was to cover 4,700 square feet of the building complex with an amorphous shingle and a standing seam solar roofing product manufactured by Uni-Solar. Each shingle module is rated for 17 watts with a total peal output of 26.1 kw dc. This coverage of solar shingles represented approximately 32,000 kWh year; or approximately 28% of the building's average annual energy consumption.

The Trustees of Reservations was attracted by the idea of using the amorphous solar shingles to demonstrate how the solar shingle product could be successfully integrated into the fabric of the building. As construction documents were completed, our engineering team ARUP advised by Global Resource Options; a Vermont based alternative technology company, in concert with the architect HKT architects, determined that there were a number of reasons an integral amorphous solar shingle did not present the appropriate solution for the Doyle Conservation Center.

The reasons were as follows:

1 *Cost and Efficiency*

While the initial grant request was for $361,515, the redesign of the photovoltaic system resulted in a reduction in the grant request to $329,870.55. A comparison of the 32kWh year Uni-Solar system originally proposed versus the 33.8kWh year Sanyo system installed indicates that while the costs for the two system were nearly the same, the Sanyo crystalline panels generates nearly three times as much power per square foot of area. Calculations estimate that the Uni-Solar system would generate 6.8 watts per square foot while the Sanyo system generates 18.5 watts per square foot. Amorphous technology is newer than crystalline technology. It is unclear how much power degradation occurs or what an expected useful life would be using amorphous technology; thus, The Trustees supported the switch to crystalline technology.

2 *Aesthetics*

Originally part of the surface area to be covered by the amorphous solar shingles was the existing colonial house, currently clad in wooden shingles. While The Trustees favored the installation of a new technology juxtaposed against a traditional New England roofing material, one of our major supporters was not as intrigued. The loss of this solar shingle surface area on the existing building would have significantly reduced our opportunity to produce more than 25% of the building's electrical energy.

3 *Installation*

> The final design of the Doyle Conservation Center included an open office space with a clerestory roof above. This roof was composed of a sandwich of structural insulated panels infilling the top chords of a Douglas fir laminated truss. Installation of amorphous shingles is best suited for applications where there is an attic or plenum space to run the necessary conductor wires. In the case of the Doyle Conservation Center, installation of amorphous shingles would have required over 2,500 holes in the roof deck to feed wiring to connectors and there would have needed to be a design and construction of some kind of tray below the ceiling. A tray below the ceiling would be required to house all this wiring since the ceiling is an exposed fir ceiling; acting as the outer layer of the structural insulated sandwich.

For these reasons, we installed 144 Sanyo HIP 190 PV modules covering 1,831 square feet of the uppermost west and east clerestory and lower west gable roofs. A panelized rack system supports the photovoltaic modules on top of the asphalt roof surface. All wiring between modules occurs above the roof, behind the modules. Arrays are 73 feet long by 8.75 feet wide on both of the high roofs and 73 feet long by 4.4 feet wide on the low west roof. There are 12 SMA Sunny Boy 2500U Inverters located in the basement to convert power for building consumption.

The 144 Sanyo HIP 190 panels capacity is 190watts x 144 = 27.4 kw-dc. Using 1226 hours of solar availability in Leominster the solar output of this photovoltaic configuration represents approximately 33,800 kWh year, approximately 30% of the building’s average annual energy consumption.

The Trustees applied 30% of the available funds to increase the buildings energy efficiency. Funds to compliment the photovoltaic shingles include ground-coupled heat pumps, high efficiency lighting and controls, high performance windows, a high performance building envelope, and CO2 Monitoring.

Doyle Conservation Center
Project Narrative

The Doyle Conservation Center embodies the conservation beliefs of The Trustees of Reservations and was approached as an environmentally conscious project. We adopted the U.S. Building Council's Leadership in Energy and Environmental Design (LEED) Guidelines to help us create an energy-efficient, low-impact building that enhances the landscape and employs green construction techniques. Construction of the Doyle Conservation Center (DCC) began in May 2003 and was completed in July 2004. It is registered for gold standard certification in the LEED program (www.usgbc.org), gold award is expected summer of 2005.

A grant from the Massachusetts Technology Collaborative Renewable Energy Trust (www.masstech.org) provided a unique opportunity to demonstrate the importance and practicality of sustainable design. Photovoltaic panels, high-efficiency lighting and controls, an energy recovery "heat wheel" ventilation system, high performance windows, a high performance building envelope, geothermal wells and carbon dioxide monitoring systems are all part of the building's sustainable design. From top to bottom, the Doyle Conservation Center is a case study for green construction. To learn more about the building's sustainable features go to www.thetrustees.org/pages/783_green_construction.cfm .

Green Materials

Desks from sunflower husks, bamboo and cork flooring, recycled fiber carpet and paneling, and "zero waste" solid surfaces are some of the sustainable and rapidly renewable products used in the Doyle Conservation Center (DCC). They include:

Desktops — Dakota Burl Composite

The desktops in DCC were locally crafted from a composite made of sunflower hulls and other agricultural production by-products. Rather than entering the waste stream, hulls from sunflower seed production are bound with wheat and natural resins and pressed to form Dakota Burl (www.environblocomposites.com/Dakota.php). The material resembles traditional burled woods (veneers made from growths on trees, called burls) in more than appearance: Dakota Burl works like real wood, too. A local furniture maker encased the desktops in Douglas fir to match the buildings interior frame.

Sink counters — AVONITE

The AVONITE (www.avonitesurfaces.com/products/recycled.asp) sink counters installed in the DCC is considered a "zero waste" product. Not only is it made entirely of reclaimed materials, but the polyester powder byproduct from AVONITE manufacturing is sent to other companies to reuse in their products. Through this recycling, the manufacturer prevents nearly 300,000 pounds of waste from entering landfills each year. The environmental benefits don't stop there: Avonite saves 100,000 gallons of water each year through recycling, and destroys 95% of the Volatile Organic Compounds (VOCs) created during the manufacturing process, preventing the off-gassing of toxic fumes.

Bamboo flooring

All the "hardwood" floors in DCC are made from bamboo, (www.bamboohardwoods.com) which is much more environmentally friendly than real hardwood floors. Because bamboo is a grass, it has an extensive underground root system and can be harvested in a sustainable manner every three to five years. Bamboo flooring has a higher fiber density than wood, and resists wear well. It is sandable, repairable, and even comes pre-finished. This bamboo was grown in the Hunan Province in south-central China, where bamboo has been harvested in a sustainable manner for centuries.

Cork flooring

The flooring in DCC's offices is made of cork--a natural, sustainable product harvested from the bark of the cork oak, Quercus suber, which grows in the sunny Mediterranean. A cork oak can be first harvested at 25 years old, when the virgin bark is carefully cut from the tree. From this point, the tree can be "stripped" of its cork every nine years for about 200 years. An 80-year-old cork tree can produce more than 500 pounds of cork. Cork flooring (www.naturalcork.com) is made from the byproduct of cork used for wine bottle stoppers. It is durable, fire resistant, provides thermal and acoustic insulation and is soft on the feet.

Carpet — Eco Solution Q

The carpeting in DCC was created from recycled fibers. And if the supplier of this carpet gets its way, all carpet will one day be created from recycled materials, and will be recycled at the end of its useful life. Shaw Fibers, makers of the Eco Solution Q (www.ecosolutions.com) carpet in the DCC, has a goal to keep carpet from ending up in the landfill. With the highest amount of recycled content available in any carpet today (25% reclaimed fiber), this carpet can be completely recycled to create more carpet fiber. It is the first step toward a "cradle to cradle" product life cycle where everything is reused.

Acoustic Tile Fabric

Not only do the acoustic tiles serve to reduce the noise level in DCC, they are also covered in fabric made from 100% recycled materials. This particular fabric is a blend of recycled polyester, nearly half of which comes from post-consumer sources. The manufacturer of the fabric, Maharam (www.maharam.com/maharam.html), offers a wide variety of textiles that are produced with a reduced environmental impact. By using natural or recycled materials, limiting the toxic Volatile Organic Compounds (VOCs) emitted by its products, and manufacturing in an environmentally sensitive manner, companies like Maharam can achieve environmental certification and recognition, and we can hear ourselves think without breathing VOCs.

Siding — Werzalit

It might look like wooden clapboard siding from the front, and medium density fiberboard from the side, but Werzalit (www.wags-system.com) is better than either of those products. Unlike natural wood siding, this product will not warp, buckle, blister, flake or peel. And unlike the urea formaldehyde in MDF, there are no nasty toxins in Werzalit. Werzalit is made of hardwood particles which primarily come from hardwood timber harvesting for the furniture market. It comes with a baked-on finish that will not need painting for 10-15 years.

Photovoltaic Cells

Photovoltaic (PV) cells are devices that convert sunlight directly into electricity. The name comes from the words photo (light) and voltaic (electricity). The 144 PV panels (www.globalresourceoptions.com) on the roof of DCC provide about 25% of the building's overall electrical energy usage. Rather than using expensive batteries to store solar energy, the system is connected to the electric grid so any unused energy can be sold back to the power company. This "net-metering" means that whenever the PV cells produce more energy than is being used in the building, our electric meter runs backwards and our electricity bill goes down.

Composting Toilets

Composting toilets (www.clivusne.com) means no wasted water--toilets flush with a thin layer of foam and waste is composted on site

Site Selection & Landscaping

DCC's building site was a previously disturbed area (backyard of exiting house used as The Trustees of Reservations offices). DCC was designed with a small building footprint to maximize open space and parking lots are the minimum size required by city zoning. DCC's landscaping was designed with native vegetation—there are no manicured lawns and therefore no need for irrigation. DCC has a gray water recycling system that will ultimately water flower beds and a bioswale constructed for stormwater treatment and management.

Indoor Environmental Quality

In DCC, 90% of building receives daylight, with views to the outdoors. The ventilation system that utilizes fresh air from controllable windows and paints and materials were chosen that minimize the “off gassing” of toxins. There is no smoking allowed in the building

Geothermal Heating & Cooling

DCC is heated and cooled mechanically using geothermal heat pumps. The geothermal system consists of two 1,500 ft. deep wells adjacent to the building which supply ground water to 19 heat pumps throughout the building. At a constant temperature of approximately 50°F all year, the ground water in the deep wells provides an efficient media to transfer heat away from the building during the summer when the building is being cooled. During the winter, heat is transferred from this 50°F groundwater to create warm air for heating. Water entering the building during the winter at 50°F, leaves the building at 42°F--eight degrees cooler. Water entering the building during the summer at 50°F leaves the building at 58°F—eight degrees higher. While it appears rather magical, this transfer of energy uses an evaporator and a compressor to “pump” heat from lower temperatures to higher temperatures, just like a household refrigerator. The size of DCC’s 1,500 ft. deep wells is directly proportional to the amount of air to be heated or cooled in the building. The constant 50°F temperature of the water makes it a highly efficient media for transferring energy. Regardless of the season the temperature difference between 50°F water during the summer and winter seasons and the inside air temperatures desired for thermal comfort is much less than the temperature differential of outside air, this leads to higher efficiency and lower energy use. In fact, DCC is 60% more energy efficient than a modern building of its same approximate 18,000 square foot size. This energy efficiency is attributable to not only the geothermal heat pump system but also the use of triple-glazed windows, a tight building envelope, and energy recovery ventilators which use a heat wheel to recover heat from exhausted air.

So how you can get 70°F air out of 50°F water? Read on.

The transfer of heat energy works using an evaporator and a compressor, the cycle is the same as the principles of refrigeration. The idea behind a refrigerator is very simple: It uses the evaporation of a liquid to absorb heat. You probably know that when you put water on your skin it makes you feel cool. As the water evaporates, it absorbs heat, creating that cool feeling. Rubbing alcohol feels even cooler because it evaporates at a lower temperature. The liquid, or refrigerant, used in a refrigerator evaporates at an extremely low temperature, so it can create freezing temperatures inside the refrigerator. If you place your refrigerator's refrigerant on your skin (definitely NOT a good idea), it will freeze your skin as it evaporates. The heat pump has four major components--all four components are housed in each of the individual heat pump units; a compressor, a refrigerant-to-air fin tube coil heat exchanger, expansion valve, and a refrigerant-to-water heat exchanger. When heat is required, high temperature refrigerant vapor is pumped from the compressor to the refrigerant-to-air fin tube coil heat exchanger. The high pressure refrigerant vapor condenses to a liquid as it passes through the coil, the coil is heated and this heat is transferred to the ducted air which is drawn over the coil by a fan. Liquid refrigerant then passes through the expansion valve into the refrigerant-to-water heat exchanger. As the low pressure refrigerant moves through this refrigerant-to-water heat exchanger, it evaporates to become a low temperature vapor, absorbing heat from the circulating 50°F well water. The refrigerant then flows as a low pressure gas to the compressor where the cycle begins again. Like a refrigerator the compressor/evaporator cycle does require electricity to change refrigerant from high temperature to low temperature. For more information visit http://physics.csustan.edu/Marvin/HowThingsWork/Phase_Trans/Change_State.htm.

TOURS

For an in depth tour of the Doyle Conservation Center please contact Jackie Allain, jallain@ttor.org, 978-840-4446 x1923

Founded in 1891, The Trustees of Reservations is the nation's oldest regional nonprofit conservation organization. Supported by more than 40,000 members, The Trustees protects Massachusetts' natural and historic resources for everyone to enjoy. From working farms to historic homesteads, barrier beaches to mountain vistas, The Trustees owns, manages and interprets nearly 25,000 acres on 95 reservations, most of which are free to all. For more information contact The Trustees of Reservations at www.TheTrustees.org or 978/921-1944.

HVAC BASIS OF DESIGN – DOYLE CENTER

1. KEY DESIGN ISSUES

The HVAC system selection and design has been influenced by the following assumptions, aims and issues:

- To provide a suitable and comfortable environment in the Doyle Center.
- To minimize energy consumption and life-cycle costs
- To provide systems which are compatible with the architectural goals of the project.
- To provide reliable, cost-effective, and energy efficient systems.

2. DESIGN CRITERIA

2.1 Internal Design Criteria

Space	**Temperature**		**Humidity**		**Internal Loads**			**Fresh air**	**Noise**
	Summer	**Winter**	**Summer**	**Winter ***	**Occupancy**	**Lights**	**Equip.**	**per person**	**level**
						W/SF	W/SF		
Office Space	75	68	60	20	1 person	1.1	1.0	20 CFM	NC35
					per 150 SF	W/SF	W/SF		
Conference Rooms and Public Meeting Room	75	68	60	20	1 person	1.1	0.5	20 CFM	NC25
					per 30 SF	W/SF	W/SF		
Lobbies and Circulation	75	68	60	20	1 person	1.1	0	15 CFM	NC35
					per 150 SF	W/SF	W/SF		
Utility Spaces	No control	60	No Control	No Control	NA	NA	NA	0.05 CFM/SF	NC 45

*** -** no building humidification system is provided. Minimum humidity will be maintained by latent heat gains in space, and enthalpy heat recovery.

2.2 External Design Criteria

The building is located in Leominster, Worcester County, Massachusetts. Massachusetts' State Building Code classifies Worcester County as part of Climate Zone 14a, and requires thermal design criteria, as follows:

Winter Design Conditions:

- Heating Design Temperature: -1 °F
- Heating Degree Days (Base 50): 3448

Summer Design Conditions:

- Cooling Design Dry Bulb: 86 °F
- Cooling Design Wet bulb: 73 °F
- Cooling Degree Days (Base 65): 507

For other data, we use the nearest location listed in ASHRAE Fundamentals 2001. The nearest location for Leominster is Worcester, Massachusetts.

- Location: Worcester, Massachusetts
- Latitude: 42.27°
- Longitude: 71.88°
- Elevation: 1010 ft. above sea level
- Mean coincident wet bulb 69°F (ASHRAE 1%)
- Daily Temperature Range (cooling): 16.6 °F

2.3 Codes, Standards and References

All systems will be designed in accordance with the following codes and standards. The latest locally or applicable version will apply except where stated.

MSBC	Massachusetts State Building code
NFPA	National Fire Protection Association
ASHRAE	American Society for Heating, Refrigeration and Air Conditioning Engineers
UL	Underwriter's Laboratories
OSHA	Occupational Safety and Health Act
ANSI	American National Standards Institute
ASTM	American Society of Testing Materials
ASME	American Society of Mechanical Engineers
BOCA	Building Officials and Code Administrators International

3. AIR CONDITIONING SYSTEMS

3.1 Overview

The building has been designed to employ a simple, low energy mechanical system.

The base building system uses water-source heat pumps for conditioning and air distribution. The heat pumps reject/collect heat through two open loop ground wells, located on the site, in a ground-source heat pump arrangement.

A dedicated out door air system provides ventilation air to each heat pump, through an energy recovery unit located in the basement.

The building is designed to operate in a “mixed-mode” so that natural ventilation can be employed when conditions are appropriate.

3.2 Mixed Mode Ventilation Concept

The “holy grail” of energy efficient build design is to create a naturally ventilated building – one that conditions itself. Unfortunately the realities of our harsh New England climate make this impractical. In this climate it is a daunting challenge to provide acceptable environmental conditions for a professional office year round, without the use of mechanical heating and cooling.

There is, however, a large portion of the year, where outdoor conditions are such that a natural conditioning strategy will provide the proper indoor environment.

A “mixed-mode” building takes advantage of this changing of seasons. In peak winter with outdoor temps less than 60 deg F, the windows are closed, and the mechanical system provides heating. In peak summer, when outdoor temperature are 75 deg F or higher, the windows are closed, and the mechanical system provides cooling. But when outdoor conditions are right, the mechanical systems are turned off, while windows and vents are used to provide temperature control and ventilation.

3.3 Office Space

The spaces are conditioned via distributed heat pumps, typically located in the ceiling of the spaces being served. Each unit is equipped with individual supply and return ductwork, connected to ceiling supply and return grilles. A room thermostat allows some occupant control of each unit.

Fresh air is delivered directly to each heat pump, through the dedicated outside air system, described below.

At perimeter zones, we will avoid an envelope heating system, by providing high levels of insulation, and high performance triple glazing. This allows us to avoid fin-tube radiation, or similar, at the building perimeter.

CO2 Sensors are located in each zone to insure that adequate fresh air is provided.

3.4 Public Meeting Space

The public meeting space includes operable partitions, which can divide it into three separate rooms. Each of the three rooms is equipped with a 100% outside air HVAC system. In each space, an energy recovery unit, with enthalpy heat wheel, provides ventilation supply air to a water-source heat pump, located adjacent, which conditions and distributes the air. Supply air is distributed to the individual spaces at the ceiling. Return air is also collected at the ceiling, where it is exhausted through the energy recovery unit. Each room is equipped with a CO2 monitor, to insure adequate fresh air.

3.5 Existing Building Systems

A new heat pump will be installed in the red house, with its own thermostat. Ventilation in the Red House is by window and infiltration.

4. VENTILATION SYSTEMS

4.1 Dedicated Outdoor air system

Fresh air is supplied to the building through a dedicated outdoor air system. A large energy recovery unit with heat wheel is located in the basement of the Doyle Center. This unit supplies tempered outdoor air throughout the building to the various distributed heat pumps. Exhaust air from the building is drawn through an exhaust ducting system to the energy recovery unit, where it is used to pre-condition the fresh intake air, before being exhausted to the outdoors.

4.2 Toilet Rooms

Toilet Rooms use the Clivus Multrum Composting Toilet System. This system incorporates a toilet exhaust system into the toilets themselves. All toilet exhaust equipment will be included as part of the Clivus installation.

4.3 Mechanical Rooms and Elevator Motor Rooms

Plant room ventilation will be provided to meet code requirements. Mechanical rooms will be naturally ventilated whenever possible. Where the temperature is expected to exceed 85°F then mechanical ventilation will be provided.

4.4 Equipment Rooms

Equipment rooms and electrical/communications closets will be exhausted to maintain temperatures within the operating requirements of the equipment they contain. Transfer air will be drawn from surrounding air-conditioned areas. Where heat gain is particularly high, cooling will be introduced.

4.5 Copier Rooms

Copier Rooms are provided with independent exhaust systems, to remove potentially harmful fumes generated by the equipment.

5. CENTRAL HEATING AND COOLING SYSTEMS

5.1 Plant Load Estimate

Based on past experience, typical cooling and heating loads for a building of this type, and rough calculations based on the current building form and massing, the total heating and cooling load for the Doyle Center have been estimated as follows.

• Total Heating Required With Outside Air:	510 MBH
• Total Cooling Required With Outside Air:	35 Tons

5.2 Ground Source Heat Pump System

A ground coupled heat pump system will be used for the Doyle Center. Many options exist for ground coupling, as is apparent from the attached illustration. (Figure 1).

The most attractive options would appear to be a horizontal closed loop, ,or a vertical open loop system (similar to double well open loop shown in figure 1).

The horizontal closed loop would require approximately 90,000 SF of horizontal tubing (at 6’ on center spacing); equivalent to approximately 15,000 linear feet of buried pipe. The vertical open loop would typically require a total well depth of about 3,000 feet, or 2 wells of 1500 ft depth each.

Vertical injection wells have been selected based on budget. These wells, with well head pumps, provide condenser water to the heat pump loop, where it is used by the individual heat pumps for either heat rejection or source, depending on mode of operation.

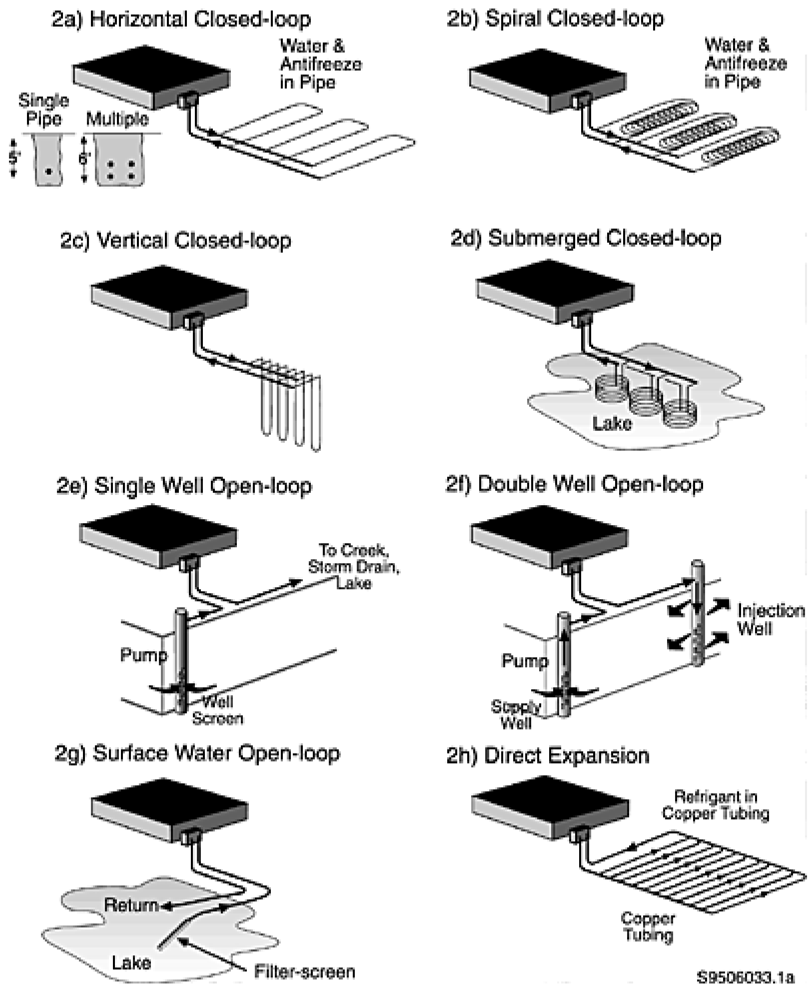


Figure 1 - GSHP Options (From DOE)

6. SUSTAINABLE DESIGN ISSUES

6.1 Optimization of Building Construction

As the building is a “green” building, efforts have been directed towards minimum energy usage and environmentally friendly systems. The design team has considered the following issues:

- Benefits of internal and external thermal mass
- Optimizing R values of the building envelope
- Optimization of glazing performance
- Designing appropriate sun shades
- Optimizing building form for “mixed mode” performance

The aim has been to determine a balance between natural daylight, summer cooling load, winter heat loss and passive solar gains.

In order to carry out the above analysis we have used an in-house developed program (ROOM) which can model in detail the construction and environment of a space. To comply with Code, final heating and cooling loads were calculated using a commercial program (Trace) which employs the ASHRAE calculation routines. Additional life cycle cost analysis has been performed using DOE 2.1 and Trace energy modeling software.

6.2 Indoor Environmental Quality

With reference to the MEP systems, improved indoor environmental quality is achieved through allowing occupants to have control of their environment and providing a fresh air supply.

This is being achieved through the following design strategies employed for the Doyle Center:

- Operable Windows
- Mixed Mode Ventilation System
- A thermostat in each area for control of the heating/cooling system
- Occupant control over lighting
- Filtered and pre-treated fresh air supply to each room
- CO_2 and occupancy sensors to maintain a good quality environment

7. FACILITY CONTROL SYSTEM

In order to minimize energy use and facilitate planned maintenance the building is equipped with a DDC automation system.

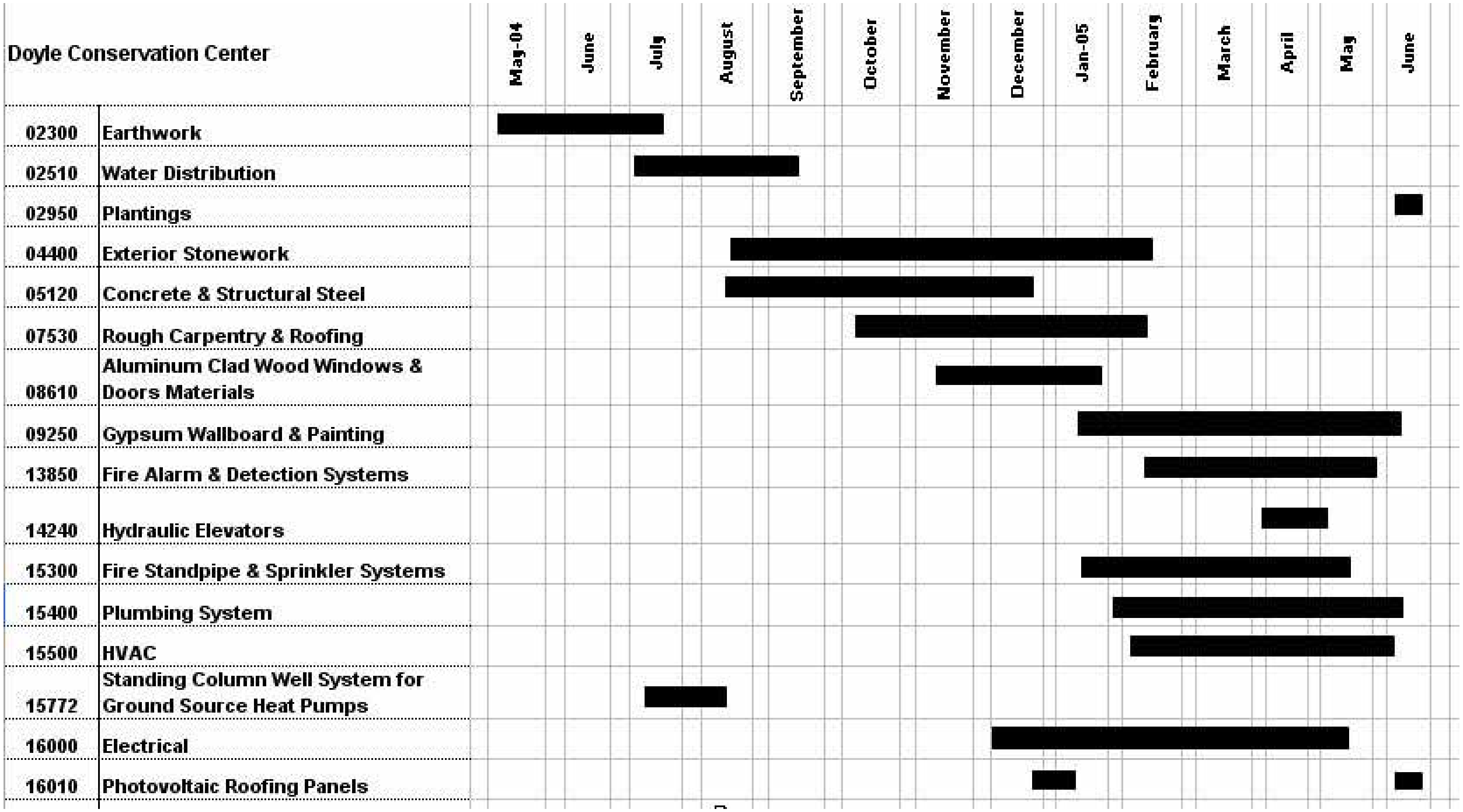
Construction Lessons

Mullaney Corporation, our General Contractor and Construction Manager worked under AIA contract A121/CMc Standard Form of Agreement between Owner and Construction Manager, where the Construction Manager is also the Constructor. This contract established a guaranteed maximum price (gmp) and in the case of this particular project the gmp worked in the owners favor protecting the inflation of costs due to an extended construction schedule of 12 months rather than 10 months. (construction schedule on next page).

If the owner is expecting to satisfy the goals of the LEED program make sure that all these goals are communicated at every job meeting, there should be a “mantra” internally realized by architects, engineer, contractors, sub-contractors, and the owner alike. Once construction starts, the schedule is driven by the contractors desire to finish in accordance with his/her contract – time is money. If the green goals are not communicated and clearly defined in the scope of work, many green related items may be in jeopardy.

For example, LEED credit 7.0, Certified Wood allows 1 point for certified lumber. Early in the construction process we lost this point since this goal was not clearly articulated in the scope of work. To add certified lumber during construction would have meant additional cost because of a delay in the sequencing of construction.

On the other hand, a number of renewable goals are easily implemented without adverse effect to the construction schedule. The photovoltaic system supplied and installed by Global resources arrived on site without delay. After the roof was installed, the rack system was installed and the Sanyo panels were installed. Electricians wired the panels and once the basement partitions were built to showcase the Sunny Boy inverters, the system was installed and commissioned. There was a delay in building the basement partitions but this was not the fault of the PV contractor. The PV contractor was anxious to finish because he only had 10% of the project left to do and he wanted to get paid. We are currently investigating a possible ground fault on the roof that is affecting the PV collection system; at least one Sunny Boy inverter is giving faulty readings. The work is being coordinated by the general contractor and we expect to see a solution soon.


Doyle Conservation Center
May-04
June
July
August
September
October
November
December
Jan-05
February
March
April
May
June
02300 Earthwork
02510 Water Distribution
02950 Plantings
04400 Exterior Stonework
05120 Concrete & Structural Steel
07530 Rough Carpentry & Roofing
08610 Aluminum Clad Wood Windows & Doors Materials
09250 Gypsum Wallboard & Painting
13850 Fire Alarm & Detection Systems
14240 Hydraulic Elevators
15300 Fire Standpipe & Sprinkler Systems
15400 Plumbing System
15500 HVAC
15772 Standing Column Well System for Ground Source Heat Pumps
16000 Electrical
16010 Photovoltaic Roofing Panels

Lessons from Design through Construction

Communication: The key to any project is communication and in the case of green construction as with other projects it is vitally important that clear responsibilities be verbalized and written into the contract. The owner is the link to communication with the entire team since he/she holds the lines of contractual communication. The architect works for the owner, the contractor works for the owner, and the architect does not work for the contractor or vice versa.

One architect told me that it was the journey that defined the success of a project, while the journey may be where critical decisions are made, the right decisions cannot be made if there are not clear lines of communication and clear objectives. The introduction of any new elements like photovoltaic, geothermal systems, and other increased energy efficiency green technologies requires a journey of education.

Even after a year, the project is not finished, it has been an educational journey and as we have learned more about the technology and the building we inhabit we have asked the right questions which have produced a better building product. Brad Jones, engineer for Sebesta Blomberg, has served as our commissioning agent. He has a genuine interest in his work and an affinity for The Trustees of Reservations and the great conservation work we catalyze. We were lucky to find Brad, he has been a champion of understanding building systems, promoting communication and most importantly education.

Commissioning is an important part of the process and it should be part of the design process as well as the construction process. Had we included commissioning from the beginning, during the design phase, I believe there may have been a better overlap of accountability, allowing checks and balances of various design and construction issues.

The geothermal system an important lesson learned.
The Doyle Conservation Center is heated and cooled using the heat energy absorbed or extracted from two 1,500 deep ground source wells. The principles of water to air heat exchange are simple and require some basic components, a water source (two 1,500 deep wells), a pump (two 5 hp Gould inline pumps located at approximately 200 feet below grade) to move water from this water source and back to the source, a heat exchanger (19 distributed water furnace heat pumps throughout the building), and a distribution system for tempered air (ducted air with energy recovery ventilators – heat wheels).

The original design team headed by David Perry Architects included ARUP engineering and the geothermal experts Water Energy Systems of Atkinson New Hampshire. Early design discussions explored many energy efficient methodologies including geothermal systems. As the design evolved and the design team changed hands, David Perry Architects assigned the contract to HKT Architects in Somerville, many of the original team members vanished including the geothermal consultants. A careful examination of the geothermal specification revealed that the well design was the responsibility of the contractor, not the geothermal consultants; this responsibility was never questioned until a problem arose.

While the system was activated in the summer of 2004, a number of issues developed around the delivery of cool conditioned air, it became apparent that much of the geothermal water distribution system was full of air not water. ARUP engineers directed the contractor to replace the original 2 hp well pumps located 150 feet below grade in the two wells with new 5 hp pumps, ARUP agreed that they had undersized the pumps but they were quick to assume that the contractor should have reviewed this design and corrected the problem.

Just before Christmas of 2004, the well pumps were replaced, during installation the well pumps began to run dry, sucking air – also known as cavitating. The HVAC sub-contractor Affiliated Mechanical was unable to start the well pumps successfully without causing cavitation to occur. Emergency propane fired heaters were brought onto the site to safeguard against losing the building and city water was fed through garden hoses on the building to fill the two wells. Amazingly, a symbol of the simplicity and power of geothermal technology, the building was able to maintain heat with city water and temporary propane heaters were no longer needed. The wells were monitored frequently, while static water levels in the wells were at about 80 feet below grade, levels in the city water fed wells were frequently overflowing the top of the well pipe.

ARUP consulted Water Energy Systems to review the situation and recommended a number of fixes including the installation of a pressure sustaining valve to maintain water pressure in the water loop inside the building and a software program addition to the variable frequency drives (VFD’s) allowing the drives to be started slowly, ramping up after the wells themselves, producing no more than 2 to 3 gallons of water per minute, were able to keep up with the well pumps.

While the system was stable through the winter and heat imbalances were remedied through water balancing of the heat pump units as well as blowing down unit strainers and cleaning filters, TTOR continued to run water to supplement the wells, we were afraid of the alternatives and we did not want to risk losing the building.

In March, confident that the cold winter was behind us, we turned off the water and have since been running the building successfully starting and stopping the wells as the building switches between a mechanical and natural venting mode.

So, the inquisitive person asks, where did all the water go? Well, we believe that since the static water level is known to be 80 feet below grade and we observed many days where water, assisted by the city water in the wells, flowed out of the well; we were filling the void in the aquifer. So much for water conservation but we know it won't be long before we make up the loss with the success of our foam flush composting toilets which use less than 3ounces of water per flush. You need to flush one foam flush toilet 65 times to equal the consumption of one modern toilet.

The lesson here is to ask lots of questions and make sure that there are plenty of structured meetings with all the players around the table to review each others answers. TTOR did not know Water Energy Systems was not on retainer; TTOR did not have the benefit of a commissioning agent at the table for many of these meetings. Had a commissioning agent reviewed the specifications and drawings carefully he/she might have found reason to highlight a number of questions. I want to reiterate, there is nothing magical about geothermal technology it works well, the problems we had were not inherent in new technologies they were the result of poor communication and poor engineering performance and review by the team.

Other lessons include:

Make sure building materials are protected when stored and prepped for use on site. A little prep work and care earlier will provide the best indoor air quality down the road.

Protect floors and other surfaces, if you conduct water tests of any equipment do this before absorbent wall surfaces are affected, you don't want to create a mold problem.

Construction Waste Planning – You'll not only need to post large signs on all the dumpsters depicting which dumpster is for wood, metal, and other recyclable byproducts, you'll need to hold daily job meetings with those laborers responsible for clean-up. The education process is important, folks who are used to doing a certain task one way will change their modus operandi but not without a constant reminder.

Planning, planning, planning – Whenever innovative methodologies are employeed make sure all those folks affected are involved or infiormed, especially regulatory agencies. Or eleven hour involvement of DEP resulted in the unfortunate addition of an unplanned 2,000 gallon tight tank. Local authorities did not know how to qualify the building of a new 18,000 facility in an area of town where there is an active sewer moratorium. While the use of composting toilets and the change of use from a residence to office use indicated a substantial decrease in sewage use, DEP was unforgiving. After three days of heavy use during the opening of the DCC, useage including a caterered dinner for over 200 people, the 2,000 gallon tight tank was emptied and found to contain only 12 gallons of effluent!

As an early adopter, TTOR paid the architect 2-4% more for full architectural services because of the green premium. I wouldn't expect there to be such a premium on green design fees today since many more architects and industry leaders have competed green training.

Green construction premiums were in excess of 10%.

While DCC was originally going to be constructed of timber locally harvested from our own forests, we could not find an expedient way to integrate the structural analysis of these framing members, give yourself plenty of time to think through the project objectives and goals.

In the case of green products, the manufacturing community may be green and be endorsed by LEED or it may be green and be without LEED certification, research methodically. We think the werzalit siding material used on the exterior of the DCC should be LEED registered but the manufacturer has not undergone LEED review.

Energy Savings

Below is a summary of projected energy usage for the Doyle Conservation Center, monthly electric bills confirm that kwh usage is approximately 132,000 kwh per year. PV metering has not been available for one full year but we expect to reach at least 30,000 kwh.

Doyle Conservation Center

	Design Base		**LEED Base**	
	kwh	therms	kwh	therms
Heating	2,002		7,821	792
Cooling	17,257		28,307	
Lights	42,709		29,320	
Receptacles	57,494		57,494	
Fans/pumps	21,079		19,068	
Total	140,541		142,010	
Solar	33,800			
Net	106,741		142,010	
less receptacles	49,247		84,516	
Cost	$5,417		$9,297	$1,188
Total Cost	$5,417		$10,485	

LEED Base represents the same building design to meet ASHRAE 90.1 1999 - model energy code

kwh cost 11 cents

therms at $1.50

Info taken from 2/24/04 memo, Chris Schaffner ARUP engineer

Energy savings equate to approximately $5,000 per year based on an energy model comparing the Doyle Conservation Center to another building of same size built to comply with ASHRAE 90.1 1999 LEED energy codes – these savings are significant.

The straight payback for the ground source heat pump system based on this comparison of design versus LEED base case would be 12 years and less if the comparison were made using a less energy efficient model like the current Massachusetts energy code. This payback is based on the cost of the wells ($60,000 - $30,000 each) since the wells are the only significant additional piece of equipment needed. Straight payback does not account for the additional cost increase in energy consumption and the payback also assumes that PV cells contribute to the energy savings.

The energy efficient envelope consists of R-11 batt insulation in the walls, R-30 batt insulation in the roof and 8" Insulated Structural Insulated Panels (SIP) at the high clerestory roof. All batt insulation is manufactured by Certainteed.

Structural Insulated panels are made by Winter Panel, Brattleboro Vermont. SIP is R-30 or 3.75 per inch. Rigid insulation at foundation is R-10, made by STRYOFOAM

The building also contains an air barrier installed by, Premier Caulking, registered with the Air Barrier Association of America. The self-adhering air and vapor barrier was Perm-A-Barrier by WR Grace along with Grace Vycor Self Adhering Membrane flashing Tape. Windows, manufactured by Pella are also triple insulated with one of the insulating barriers being argon gas.

In general, The Trustees of Reservations has been very pleased with the energy efficiency of the building, time will tell the success of energy savings. If we could do anything differently we would have taken a harder look at the use of radiant heating solutions as moving air creates noise and discomfort because of the mechanical movement necessary.

Visit us on a day when the air temperatures and relative humidity outside are comfortable, on those days you can hear a pin drop in the building as the building goes into natural ventilation mode. On days when the building goes into natural ventilation mode, the building energy system sends an email to the occupants advising them to open their windows