

**33 Emerson Ave. , Gloucester, Mass.**

Gloucester, Massachusetts

Feasibility Study of Renewable Energy  
and Energy Efficiency Options

Prepared by:

M-MRT  
&  
Richard W. Griffin, Architect

November 7, 2003

Funded by the Green Buildings Initiative  
of the Renewable Energy Trust.



MASSACHUSETTS  
TECHNOLOGY  
COLLABORATIVE

This report was prepared by M-MRT in the course of performing work sponsored by the Renewable Energy Trust (RET), as administered by the Massachusetts Technology Collaborative (MTC), pursuant to grant number GB-FS-03-29. The opinions expressed in this report do not necessarily reflect those of MTC or the Commonwealth of Massachusetts, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it.

Further, MTC, the Commonwealth of Massachusetts, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods or other information contained, described, disclosed, or referred to in this report. MTC, the Commonwealth of Massachusetts, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage directly or indirectly resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

### **Other Acknowledgements**

**Architect:**        **Richard Griffin, AIA**  
37 Turner St., Salem, Mass. 01970  
(978) 740- 9979 ph  
(978) 740- 2352 fx  
[grifarch@aol.com](mailto:grifarch@aol.com) e-mail  
Richard Griffin, AIA  
Paul R. Lessard, RA  
Craig Herrmann

**MEP Engineer:** **Building Facilities Engineering Co.**  
100 Cummings Center, RM 229C, Beverly, Mass. 01915  
(978) 927-7882 x17 ph  
(978) 927-0239 fx  
Joel Gordon, PE

**Structural  
Engineer:**        **Ockmulgee Associates**  
317 High St., Ipswich, Mass.  
(978) 356-0636 ph  
Wayne King, PE

**Solar & Wind  
Power  
Engineer &  
Consultants:**

**Solar Tech**

31 Acorn Lane, South China, ME 04358

(207) 445-2663 ph

[solartechinc@yahoo.com](mailto:solartechinc@yahoo.com) e-mail

Robert Hussey, PE

**Daylighting  
Engineer:**

**Rising Sun**

40 Sunset Rd.#1, Basalt, Colorado 81621

(970) 927-8051 ph

(970) 927-3635 fx

[aaron@reslight.com](mailto:aaron@reslight.com) e-mail

Aaron Humphrey, LC

**LEED**

**Consultant:**

**Andrew St. John, "LEED Certified" Architect**

Essex, Mass.

(978) 768-6156 ph

[astjohn@m-g.com](mailto:astjohn@m-g.com) e-mail

Andrew St. John, AIA

**Site Engineer:**

**Gateway Consultants**

Gloucester, Mass. 01930

(781) 334-4434 ph

(781) 334-0007 fx

John Judd, PE

## **Study Abstract**

This study includes the reports of our subcontractors. They have suggested numerous alternative energy systems that are intended to save fossil fuel as well actually produce energy from a renewable source. The following is a simple list of their ideas. In our report summary we have identified those that we would like to incorporate into our own building.

Ground Source Heat Pump that puts fluid through pipes deep in the ground.

The 48-52 deg F ground temperature is maintained year round. The HVAC system utilizes that steady temperature to add heat as well as subtract heat from the building.

Efficient Electrical Lighting & automatic switching to save electrical energy and, therefore, fossil fuels and client money.

Wind Power Generator to provide a 'renewable' source of electrical energy to feed the electrical 'grid'.

Exterior fixed Shading Panels to reduce glare & heat gain. Interior fixed panels also bounce reflected light off the ceiling to so that it will penetrate deeper into the space to reduce the need for electrical lighting.

Solar Photovoltaic/ Hot Water Panels to heat Domestic Hot Water and to demonstrate how a renewable source of electrical energy can be sent back into the grid.

Green Roof planted to add insulation, improve views outside balconies, & control rain runoff to adjacent wetlands.

Computer Building Systems Modeling to understand the relative values of adding and subtracting various 'energy saving' systems to the building as a whole. This is recommended by Mass. Electric for the future & will be based on current data gathered.

Skylights to naturally illuminate 3<sup>rd</sup> floor offices and corridor.

The architectural design as a whole is a terraced building which faces most of it's windows east & west. The terraces are outdoor spaces for prime office space and have a view over a tidal canal-like estuary and wide expanses of grassy marsh wetland. Few windows face south as that side will take direct Sun at the time of the day when the Sun has it's strongest effect.

Photovoltaic Panels & mounting racks add approximately 4 lbs/sf roof load. Roof Garden materials will weigh approximately 13 lbs./sf when wet. We intend to add added structure at all roofs to cover any arrangement of Green Roof or PV Panel placement. The added cost to accommodate added roof loads is marginal, but, it will cost something. We estimate that incremental cost below.

### **Key Words:**

Photovoltaic	Green Building	Insulation
Solar	Energy	Groundsource
Wind	LEEDS	Heat Pump
Grid	KWh	Run-Off
Green Roof	Renewable	Daylighting

## Table of Contents

Subject	Page
1. SUMMARY OF STUDY	6
2. ARCHITECTURAL DESIGN	8
3. WIND & SOLAR POWER STUDY	9
4. DAYLIGHTING & ELECTRICAL LIGHTING STUDY	17
5. MECHANICAL ENGINEERING (Heating, Ventilation, Air Cond.)	33
6. GREEN ROOF STUDY	37
7. WETLAND WATER RUN-OFF CONTROL	41
8. "LEEDS" POINTS	43
Appendix	
A Building Plans	

## 1. Summary of Study

The goal of our architectural design work at 33 Emerson Ave. is to design a High Performance Building. We are creating a 'big-box' commercial office structure that will use less energy than a similar Code compliant structure. We are also creating a building that will be more pleasant to work in. The building is not intended to be a typical structure with unrelated, energy producing, demonstration project add-ons. This is intended to be an integrated system that gathers renewable energy at the site and uses less fossil fuels. The costs to incorporate the various advanced components will be higher than the typical office building. **The extra 'incremental' costs to go beyond the typical office building and design a comprehensive, progressively 'Green', building are listed below.** At this point in the design we are incorporating the below listed suggestions provided to us by our study subcontractors. Final decisions on implementing these features will be based on budgetary and cost/benefit concerns.

1. \$ 800,000 Ground Source Heat pump for HVAC system
  2. \$ 45,000 Efficient Electrical Lighting & 'Daylighting' switching
  3. \$ 140,000 50 KWh Windmill Electrical Generator
  4. \$ 120,000 Passive Shading Panels for Interior & Exterior
  5. \$ 500,000 Solar Panels with combined Photovoltaic and Domestic Hot Water piping.
  6. \$ 160,000 8,000 s.f. of planted 'Green Roof'
  7. \$ 20,000 Building Systems Computer Modeling
  8. \$ 100,000 Skylights at 3<sup>rd</sup> Floor (with lightshaft penetrations)
  9. \$ 80,000 Building Structure increased costs due to extra loads of Green Roof & Solar Panel load & wind stresses.
- \$1,965,000 Total Extra 'Incremental' Costs

(Note: These preliminary figures may change significantly as final construction details are developed & bid to contractors for pricing.

After speaking with Mass Electric it is clear that computer modeling will be necessary to properly balance the amount of each energy saving component installed. The computer model will tell us how much we should invest in each component to get the most energy savings. For this report the HVAC engineers did use a basic computer model called "Equest". A more complex program, provided by the DOE, will ultimately be used to take all major factors into consideration. See [www.doe2.com/energy](http://www.doe2.com/energy) for a free program download.

Our HVAC engineers have shown that there is substantial energy savings using the Ground Source Water Heat Pump. Initial equipment installation would be \$ 1,300,000 as compared to a typical Roof Top Unit HVAC system for this building costing \$ 500,000. Over a period of one (1) year there would be an operational savings of \$ 18,000 by using the Heat Pump System.

Rising Sun, our daylighting/ lighting engineers, believe that more efficient 'linear pendant' lighting can be installed for approximately the same price as the 'troffer-type' typical office fluorescent. Each 'linear pendant' fixture costs about twice as much as a troffer, however, they are spaced more widely and wired at fewer locations. The savings over one (1) year, as indicated by Rising Sun, would be \$ 11,000 if we install their design. Though Rising Sun indicates that the product and installation costs of a progressive 'Daylighting' system will be the same as for ordinary 'troffer' lighting we believe that labor costs in the Northeast will incur an incremental fee.

As shown by their diagrams fixed reticulated metal panels are recommended by Rising Sun to shield summer sun on the outside of the building as well as to reflect sun off the ceiling at the inside of the building. Their value is really integrated with the progressive switching concepts outlined in their report. In simple terms, the lights can be used less if the sunlight can be directed by reflection deeper into the building by interior fixed panels. Exterior fixed panels will reduce glare and heat gain. Actual monetary energy payback savings cannot be determined at this time, however, future computer modeling could demonstrate a decrease AC use by calculating lowered direct sun exposure at windows.

We propose a Wind Power Generator for this site as a demonstration project to raise public attention about the possibility of generating electricity by non-fossil means. Looking at the Solartech report we see that we will be paying twice as much for the electricity produced over a 30 year machine life span.

Solartech introduced us to Dr. Richard Komp, a solar cell expert, who has developed a multi-function solar panel. The panels have electrical output as well as heat output from circulating liquid. We would like to help develop this technology by installing enough of these solar panels such that the domestic hot water of the building will be heated by these units. A combination of these panels as well as regular electricity-only panels would produce electricity and we would feed the electrical grid along with the Wind Power Generator output.

Our 'Green Roof' will cover 8,000 sq. ft. of roof area. It is indicated by RoofScapes Inc., (the subcontractors who install 'Roofmeadow', our chosen system) that we can achieve R-6 insulation with a 3 inch thick installation. The initial installation will cost \$ 160,000 (\$20/sq. ft.) Anticipated savings due to this added insulation will be valuable to calculate in a more complex computer energy model. As an added feature the 'Green Roof' will reduce by 11% the amount of rain water that will travel to the detention tank below the building and subsequently to the surrounding wetlands.

## 2. Architectural Design

The underlying purpose of our building design is three fold. Firstly, the design faces windows toward the East and West to receive the lower angled and less intense rays of the sun at the beginning and end of the day. Secondly, the massing of the building terraces on the West elevation create balconies where people can enjoy outdoor views of the Blynman canal. Greenroof low covering plants and wood decks are planned for those balcony surfaces as well. The third salient feature of the design is that the terraced building is dug into a hillside.

The Schematic intent of the building as described can be summarized as follows:

1. To take advantage of light angles which penetrate deep into the building.
2. To avoid sun direct penetration into windows at the early afternoon when the sun is strongest.
3. To create a people friendly environment that allows occupants to enjoy the beautiful local water views. The balconies themselves will have a natural and inviting feel with wood and plants.
4. To partially embed the building into the hillside to allow us to feel that it is integrated into the landscape and not dominating it. The exterior finish colors will match indigenous colors of the site and will help integrate the building into the landscape.

The exterior wall will be a minimum R-21 (5 ½") *'Icynene'* insulated wall panel with the roof being insulated with an R-30 *'Polyisocyanurate'*. Areas bearing a 'Green Roof' will meet R-36 during dry periods. We find that the sprayed *'Icynene'* foam bonds tightly with the inside of exterior panel surfaces and seals seams tightly to reduce air infiltration. The insulated glass (as recommended by our Daylighting/Lighting consultant) will ride the line between warding off excess Summer heat and glare while retaining warmth in the Winter. The target U-Value of the glazing will be U-.33.

Our intent has been to design a building that will have a long life span. 33 Emerson will be a Commercial Building that is designed to be transformable to a Residential use if that becomes more economically viable. As the building can serve dual purposes the resources consumed in construction will continue in use for many years.

### **3. WIND & SOLAR POWER ANALYSIS**

1. SUMMARY
2. DESCRIPTION OF STUDY
3. ANALYSIS
  - A. Wind Study
  - B. Solar Photovoltaic
  - C. Options
  - D. Photovoltaic Hybrid (to be added)
4. SYSTEM RECOMMENDATIONS

#### **1. SUMMARY**

The study performed by SolarTech Inc. gathered site-specific wind and solar information for 33 Emerson Avenue in Gloucester Massachusetts in order to assess the viability of utilizing solar and/or wind power for electrical energy production. On-site instrumentation such as a weather station (with an anemometer), solar panel and a programmable logic controller (Modicon PLC) collected data and logged the weather conditions. At Emerson Avenue the data was compared to the National Weather Service (NWS) data at the Boston airport (Logan International Airport) to determine their correlation so that the NWS data for 2002 could be used for this feasibility study.

At Emerson Avenue the daily average wind speeds were 90% of the wind speeds recorded by the National Weather Service at the Boston Airport location. The data was an excellent match and is used for evaluation. By modeling the National Weather Service wind data for the year 2002, a 50 Kw wind turbine could have produced 45,740 Kwhrs/yr at an installed cost of \$186,114. Over a 30 year period 1,372,140 Kwh could be produced for a calculated per Kw cost of \$0.13.

Solar photovoltaic power relies on exposure to the sun. For the year 2002 the percent clear skies at the Boston Airport was 46%. According to historical National Weather Service the Northeast data indicates a percent clear skies average of around 50%. Although seasonally there are 9 to 15 hours (NWS data) of available sunlight you can only count on 4 ½ to 7 ½ hours on average per day for solar collection. Results from the study show 117,379 Kwhrs/year could be collected from 357 photovoltaic panels at an installed cost of \$445,777. Over a 30 year period 3,521,359 Kwh could be produced for a calculated per Kw cost of \$0.13/ Kwh.

From analyzing the data, three viable options are recommended based on a capital constraint \$500,000.

#### **Option 1**

With a 50 Kw wind turbine the 2002 production could have been 45,740 Kwhrs. The average cost per Kwh would have been \$0.13.

#### **Option 2**

With a 50 Kw wind turbine, 249 photovoltaic 170-watt panels and 18 photovoltaic Hybrid Panels the 2002 production could have been 138,393 Kwhrs. The average cost per Kwh would have been \$0.16.

### Option 3

With 357 photovoltaic 170-watt panels and 18 photovoltaic Hybrid Panels the 2002 production would have been 128,164 Kwhrs. The average cost per Kwh would have been \$0.15.

Because of the lower maintenance cost and the higher Kwh production, lower cost per Kwh and hot water can be produced option Three is recommended. Photovoltaic panels are warranted for power output for 25 years and it is not uncommon for them to produce in excess of 30 years.

## 2. DESCRIPTION OF STUDY

This study reviewed both the wind and solar power potential of the 33 Emerson Avenue site. The intent was to provide site-specific data versus generalized tables and maps portraying weather data by the National Renewable Energy Laboratory (NREL). The neighboring business/facility, Gloucester Transit Mix, was instrumental to the study by supplying power, a telephone service node and a structure to mount the anemometer and solar panel instruments.

The wind study utilized a Davis Instruments Weather Wizard III Data Logger. The weather station was setup at the Gloucester Transit Mix facility, which is adjacent to the Emerson Avenue project location, on February of 2003 (**see picture below**). For a 3-month period, over 3600 wind speed and prevailing wind direction data points were collected.



For the solar photovoltaic aspect of the study, the primary focus was correlating the National Weather Service (NWS) percent available sun or percent clear skies to a typical photovoltaic panel's power production. A British Petroleum (BP) 170-Watt High-Efficiency Monocrystalline Photovoltaic Module measuring 31 inches wide by 62 inches long was installed with a resistance load that was designed to equate the amperage output to the measured voltage. The accumulated watts per day were recorded with a Modicon programmable logic controller and an analog voltage input module. The data was collected during the months of May, June and July, 2003.

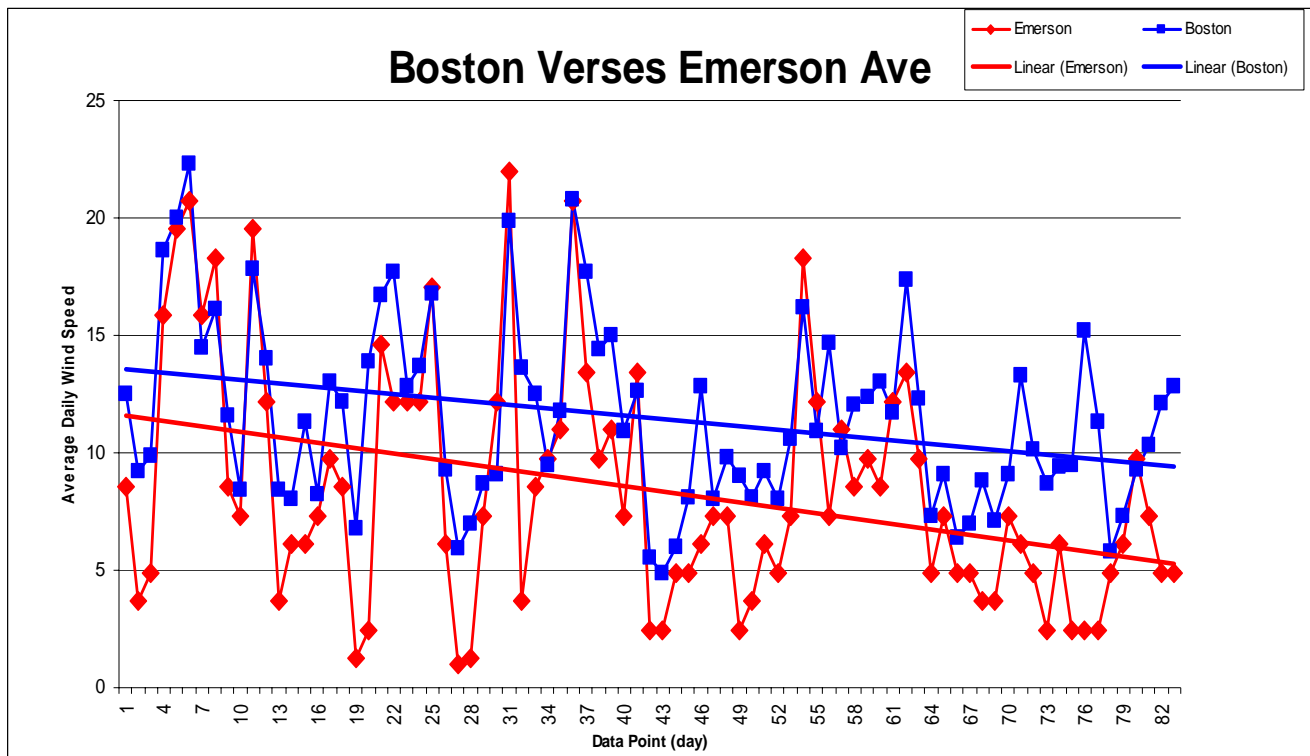
### 3. ANALYSIS OF WIND, SOLAR PHOTOVOLTAIC and HYBRID PV PANEL

#### A. Wind Study

The purpose of this portion of the study is to understand the relationship between the winds experienced at the Boston airport relative to Emerson Avenue so that historical data for Boston can be more accurately modeled to the site location.

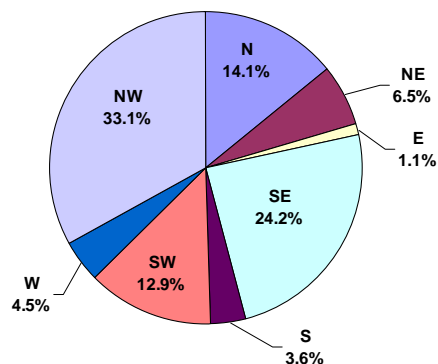
**GRAPH 1**

Comparing daily averages with the Boston airport data the speed curves are as shown in **Graph 1** below.

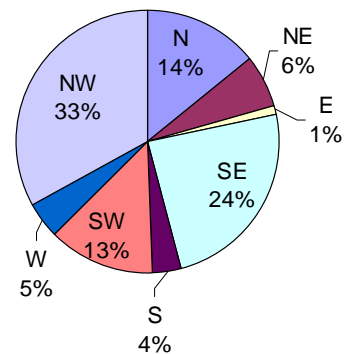


The trend lines begin to drift apart towards the latter part of the spring season. The prevailing winds, **pie charts** below for 2003, shifted from the winter pattern of Northwest winds to the spring pattern of Southeast for Boston and Emerson Avenue. The pie charts demonstrate how closely correlated the wind pattern at Boston is to what was recorded at Emerson Avenue.

**Prevailing Winds Jan to May 2003 Boston**



**Prevailing Winds Jan to May 2003 Emerson**



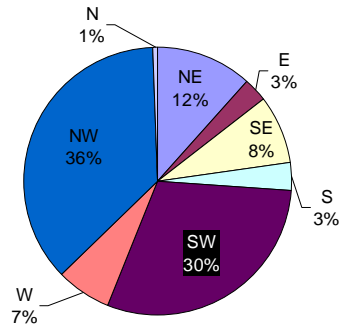
The Data for 2003 spring prevailing wind shift into the Southeast direction was unusual. Typically the prevailing winds shift from Northwest to Southwest as the data extracted from the National Weather Service data from 1930 to 1996 shows below.

**Boston**

<b>JAN</b>	<b>FEB</b>	<b>MAR</b>	<b>APR</b>	<b>MAY</b>	<b>JUN</b>	<b>JUL</b>	<b>AUG</b>	<b>SEP</b>	<b>OCT</b>	<b>NOV</b>	<b>DEC</b>
WNW	WNW	WNW	WNW	SSW	WSW	WSW	WSW	WSW	WNW	WNW	WNW

For January to February 2002 the pie chart to the right shows the typical seasonal pattern.

**Prevailing Winds Jan to May 2002 boston**



The abnormal wind direction shift and the difference in the topography in Boston and Emerson Avenue explain the 2003 decline in wind speeds at Emerson Avenue (see **illustrations 2 to 4 below**). At the Boston location, **Illustration 4**, the airport winds are relatively unobstructed from the Northwest to the Southeast. At Emerson Avenue the Northwest is relatively unobstructed but the town of Gloucester hills and buildings hinder the flow of the wind in the Southeast direction, see **illustration 2 and 3**. The Southwest direction at Emerson Avenue, on the other hand, is relatively unobstructed. From this it can be rationalized that if the winds had followed the historical Northwest to Southwest patterns the speed curves would have maintained a parallel relationship. The calculated offset with the winds from the Northwest for Emerson Avenue was 90% of Boston airport.

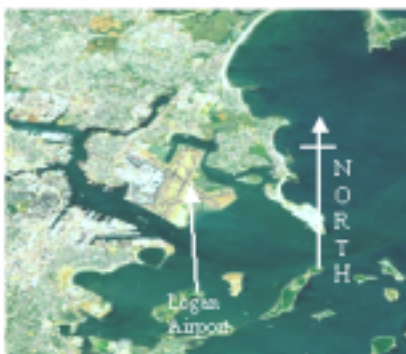
**Illustration 2**



**Illustration 3**



**Illustration 4**



## Wind Power Production

Using the BWC XL Wind Power model for an 50 kW wind turbine, based on US Wind Atlas and wind speed probability calculated as a Weibull curve (per standard factors), **Table 1** below shows the 2002 monthly output and the total annual output for a 50 Kw wind turbine at 120 feet.

**Table 1**

2002 Month	Average Wind Speed		Kwh
	Boston Airport	Emerson Avenue	
Jan	11.8	10.6	3,873
Feb	12.2	11.0	4,371
Mar	11.1	10.0	3,223
Apr	11.8	10.6	3,889
May	12.0	10.8	4,159
Jun	10.9	9.8	3,035
Jul	10.6	9.6	2,760
Aug	10.1	9.1	2,320
Sep	10.4	9.4	2,566
Oct	13.6	12.3	6,070
Nov	12.5	11.3	4,746
Dec	12.5	11.3	4,726
<b>Annual Total</b>			<b>45,738</b>

**Table 2**

<b>Installed Cost Estimate for Windmill Installation (+/- 20%)</b>	
Excell Wind Turbine with GridTek Grid Tie Inverter	\$110,000
Tower Wiring Kit	\$1,500
Enhanced Corrosion Resistance	\$300
120 foot Rohn SSV galvanized 6m (20 ft) lattice type tower	\$16,000
Taxes	\$7,668
Tower Base	\$ 7,000
Crane	\$ 1,500
Labor Assembly, Commissioning, Wiring, Etc	\$ 5,000
Bergey On-Site support	\$ 4,000
Shipping	\$ 2,200
<b>Total</b>	<b>\$155,168</b>

As shown in **Table 1** the annual power production for 2002, for one BWC XL 50 wind turbine, could have been 45,738 Kwh. Properly maintained, the Bergey unit has a 30-year life expectancy. Over 30 years 1,372,140 Kwh could be produced. **Table 2** shows an estimated installed cost of \$155,000. This equates to a \$/Kwh rate of \$0.11/Kwh. **Table 3** shows the projected Kwh electrical cost, over 30 years, assuming an average rate increase of 3% a year. In 30 years the cost could be \$0.22/kwh.

**Table 3**

**Yearly electric cost assuming 3% increase per year.**

Year	\$/Kwh	Year	\$/Kwh
1	\$ 0.09	16	\$ 0.14
2	\$ 0.10	17	\$ 0.15
3	\$ 0.10	18	\$ 0.15
4	\$ 0.10	19	\$ 0.16
5	\$ 0.10	20	\$ 0.16
6	\$ 0.11	21	\$ 0.17
7	\$ 0.11	22	\$ 0.17
8	\$ 0.11	23	\$ 0.18
9	\$ 0.12	24	\$ 0.18
10	\$ 0.12	25	\$ 0.19
11	\$ 0.12	26	\$ 0.19
12	\$ 0.13	27	\$ 0.20
13	\$ 0.13	28	\$ 0.21
14	\$ 0.14	29	\$ 0.21
15	\$ 0.14	30	\$ 0.22
Average/year		\$	0.15

## Carbon Dioxide Mitigation

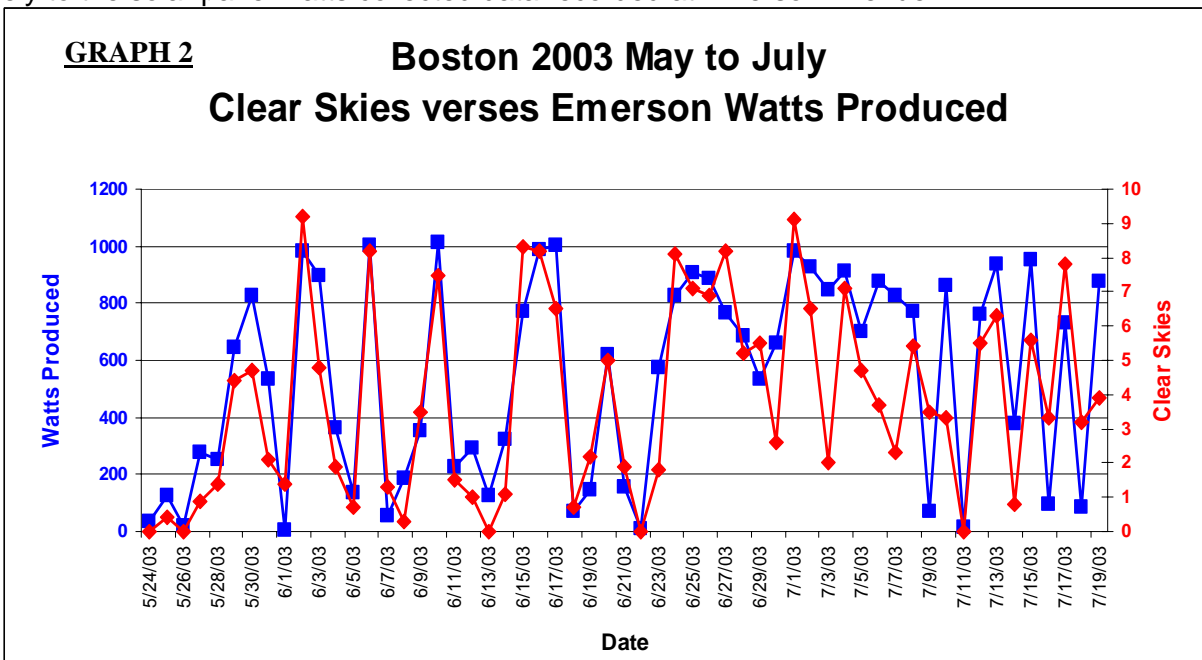
Electricity from coal or oil fired power plants releases tons of CO<sub>2</sub> into the atmosphere.

Approximately 1000 Kw of wind turbine power will eliminate approximately one metric ton of CO<sub>2</sub> that would have been produced from a traditional power plant to provide similar power for the facility.

With 1,372,140 Kwh produced, over a 30-year period by the wind turbine, 1,372 tons of CO<sub>2</sub> will be saved from entering the atmosphere.

### B. Solar Photovoltaic Study

The purpose of this portion of the study is to understand the relationship between the percent cloud cover, which the National Weather Service publishes for the Boston airport, relative to Emerson Avenues potential power production. **Graph 2** shows that cloud cover reported in Boston correlates closely to the solar panel watts collected data recorded at Emerson Avenue.



This means the Boston historical data can be used to predict potential KW production at Emerson Avenue. For this study, calculating output based on hours of sunlight the percent clear skies will be factored in. In addition, evaluating the benefits of tracking the sun versus securing the panels at one angle can be quantified.

**Table 4**, below, illustrates the effect of panel angle relative to the seasonal angle of the sun. Based on 2002 NWS Boston data the calculated watts produced, per square foot of panel area of a current technology solar panel, angling the panels to the sun provides a 25% improvement in power production. This mounting system is more expensive but could be considered in the final phase of this project.

**Table 4**

2002				
Month	Average Daily Dawn to Dusk Hours of Sunlight	NWS % SkyClear	With Angle Adjustment KWhr/sqft per Month	No Angle Adjusment KWhr/sqft per Month
Jan	9.31	40%	0.8	0.6
Feb	10.70	55%	1.1	0.9
Mar	11.91	38%	1.0	0.9
Apr	13.42	44%	1.2	0.9
May	14.57	45%	1.4	1.0
Jun	15.15	43%	1.4	1.0
Jul	14.97	52%	1.7	1.2
Aug	13.87	57%	1.7	1.2
Sep	12.43	50%	1.3	0.9
Oct	11.05	47%	1.1	0.9
Nov	9.86	36%	0.7	0.7
Dec	9.16	52%	1.0	0.7
		<b>Total</b>	<b>14.5</b>	<b>10.8</b>

The 2002 power production with 357 photovoltaics and:

- the panels at a fixed angle of 40 degrees;
- the daily dawn to dusk hours considered for each day;
- and the percent clear sky

taken into account, would be 117,379 Kwh per year. Over a 30-year period 3,521,359 Kwh would be produced for an installed cost of \$445,777. This equates to \$0.13/ Kwh.

**Carbon Dioxide Mitigation**

Approximately 1000 Kw of solar panel power will eliminate approximately one metric ton of CO2 that would have been produced from a coal or an oil-fired power plant providing similar power. With 3,521,359 Kwh produced from solar power over a 30-year period, 3,521 tons of CO2 will be prevented from entering the atmosphere.

**C. Options**

With the knowledge gained from the study, performance modeling and a \$500,000 budget constraint, three options are provided. Solar panel mounts are not included in the pricing and are considered part of the building structure. Both estimates are a class 20 estimate (accurate to within +/- 20 %).

**1. Wind Turbine Only**

		Calculated 2002	30 years	
	Installed cost	kwh Produced	Kwh	\$/Kwh
Wind	\$186,114	45,738	1,372,140	\$0.13

**1. Combination of Wind Turbine, Traditional and Hybrid Photovoltaic**

		Calculated 2002	30 years	
	Installed cost	kwh Produced	Kwh	\$/Kwh
Wind	\$186,114	45,738	1,372,140	\$0.13
Solar (249 panels)	\$259,663	81,869	1,347,054	\$0.19
Hybrid PV	\$54,223	5,730	323,570	\$0.17
Hybrid Hot Water Equivalent Kwhr		5,056		
<b>Total</b>	<b>\$500,000</b>	<b>138,393</b>	<b>3,042,764</b>	<b>\$0.16</b>

## 2. Traditional and Hybrid Photovoltaic Only

			Calculated 2002	30 years	
		Installed cost	kwh Produced	Kwh	\$/Kwh
	Solar (357panels)	\$445,777	117,379	3,521,359	\$0.13
	Hybrid PV	\$54,223	5,730	323,570	\$0.17
	Hybrid Hot Water Equivalent Kwhr		5,056		
	<b>Total</b>	\$500,000	128,164	3,844,929	\$0.15

The major components used for this estimate are:

### Wind

- Bergey Excel Wind Turbine 50 KW with Bergey Grid Tie Inverter
- 120 foot Rohn SSV galvanized 6m (20 ft) lattice type tower

### Solar

- BP 5170 Monocrystalline Photovoltaic Modules 170 Watts
- Xantrex PV45208 Grid Tie 45 Kw inverters
- Dr. Komp Hybrid Panels 110 Watt

## **4. Daylighting & Electrical Lighting Design**

### **Introduction**

The existing design of the building at 33 Emerson, in Gloucester, Massachusetts, has many opportunities for daylighting, lighting connected load reduction, and excellent views. These factors can all lead to a highly effective commercial environment, with increases in worker productivity. By increasing occupant awareness of the proposed daylighting and associated reduction in energy usage, employees in the building will have a sense of contribution to sustainability and conservation of natural resources.

In addition, the building's orientation and basic design allow for many commercial or residential build-out opportunities. Careful attention to daylight control, electric lighting circuiting and control, interior finishes, and traffic patterns, can enhance the building's ability to reduce electricity use and its impact on natural resources. As an added bonus, the stepped terraces on the building provide opportunities for passive and dynamic displays of light and shadow, allowing the occupants to see the constant change in light as the year passes.

### **The Economics of Daylighting**

Employee cost is the largest portion of a building's operating budget. As such, employee productivity, reduction of sick or injured time, reduced turnover, and similar factors affect a business' bottom line more than any energy cost-saving measure could produce.

For example, consider the typical employee at a \$50,000 salary. Conservatively, the cost to employ this person in insurance, office equipment, etc, adds 40% on to the salary, or in this case, \$22,800.00, plus salary. Average overall space per person is about 200 square feet, so the employee cost per square foot may be calculated as:

$$(\$25/\text{hour} * 2080 \text{ hours} * 1.4)/200, \text{ or, } \$364 \text{ per square foot.}$$

A 5% productivity increase by the employee is worth \$18.20 per square foot annually. By comparison, a projected savings of 0.3W/sqft with good lighting design will save:

$$((0.3W * 3744 \text{ hours})/1000) * \$0.10/\text{kWh}, \text{ or } \$0.11 \text{ per square foot.}$$

If this is the case, how do we increase employee productivity?

Daylighting offers many ways to increase employee productivity, as noted in several recent studies. With direct effects on health, morale, circadian rhythms, and indirect effects on sick time, employee turnover, and learning ability, access to daylight is clearly important to an employee's health, well being, and productivity.

## Physiological effects

- The human visual system evolved to scan the horizon and detect motion in the periphery, for both hunting and safety from predators. When eyes are relaxed, they shift to far-field vision. Near-field tasks such as computer work, reading, and manufacturing of small components, require the eye to change shape by flexing muscles. Over time, this flexing can lead to fatigue and eyestrain. Daylighting, by providing windows and views, allows occupants to relax their eyes to far-field conditions periodically. Modern society has the highest incidence of nearsightedness in history, and recently, a higher incidence of presbyopia (needing bifocals) has been noted in younger people. Researchers believe this is related to near-field office tasks.
- UV light, although damaging in high doses, triggers the body to dilate blood vessels, lowering blood pressure.
- Metabolism of Vitamin D, which helps strengthen bones, is triggered by daylight.
- The body clock (as well as most of nature) is directly affected by time and exposure to high light levels. In plants, the exposure to the light and the duration signals the change of seasons. In modern humans, it is most noticeable as Seasonal Affective Disorder (SAD). Some estimates show that as much as 40% of the northern population may be affected by sub-clinical SAD.
- Studies show that memory is directly affected by exposure to daylight.

## Psychological Reasons

- Studies show that office employees like views, for clues about the time-of-day, weather, and general interest. People tend to like dynamic views rather than stable ones. One study showed that people with access to windows had less clutter and decoration at their desks.
- Daylighting helps model forms and objects in space very well. There is less chance of disorientation due to softly modeled shapes (the 'cloudy day' effect).
- In addition to reducing blood pressure, daylighting and views allow employees visual access to the outside. This can significantly reduce stress, which leads to fewer sick days and less employee turnover.

## Anecdotal evidence of increased productivity

- Lockheed increased daylighting in one building, **reported saving \$500,000 in energy costs**, with a corresponding 15% increase in worker productivity, and a 15% decrease in absenteeism.

- West Bend Mutual Insurance increased daylighting, cut energy costs by 40%; claim processing productivity increased 16%.
- Electric Power Research Institute (EPRI) shows that errors in computer data entry due to poor lighting cost \$5-10 per square foot.
- Remo Drums reduced employee turnover in a new daylit building: 100% of original employees were still there after 2 years.
- Grade School students in San Juan Capistrano, California, Seattle, Washington, and Fort Collins, Colorado, showed grade-level increases of as much as 2 grades per year when compared to students in non-daylit rooms.
- Costco has used skylights on their stores since the late 1980's. They estimate an average annual per store energy savings of 1.5kWh/sf/year or \$23,000.
- Wal-Mart, as reported in the Wall Street Journal in 1995, noted "significantly higher" sales in a daylit area of a new store in Lawrence, KS. Since then, all Wal-Marts are daylit.
- California State Automobile Association Headquarters saves 32% of electric lighting energy through daylighting. Employees turn down transfers out of the building, even when offered raises.
- Sacramento California Municipal Utility District Customer Service Center saves \$56,000 per year in electricity due to aggressive daylighting.
- The Heshong Mahone Group, in a major study of daylighting in retail, shows an increase in sales of up to \$2.98 per square foot in daylit stores when compared to non-daylit stores.

In addition to increased employee productivity, considerable savings may be gained from daylighting in the form of reduced energy consumption. Although Massachusetts has a fairly aggressive energy code (780 CMR 13) which sets limits on Unit Power Density (UPD) for non-residential spaces, aggressive design can out-perform the code requirements and provide energy and monetary savings.

All commercial lighting has to start with electric light sources. Regardless of available daylighting opportunities, buildings are used after dark, so the base design must provide adequate lighting without consideration given to daylight. Office spaces are typically lit to between 30 and 50FC at the work plane (2.5 feet above the floor), with local task lighting boosting light at the desk. 78 CMR 13 restricts office lighting to a UPD of 1.3 W/sqft, for both task and ambient lighting combined. While this UPD is easily met with recessed fluorescent troffers, such as the typical 2x4 louvered fixture seen in most commercial spaces, this fixture is not the best-performing option.

Recessed troffers use 32 Watt lamps and electronic ballasts. Their efficiency (the amount of light which actually gets out of the fixture) ranges from the low 60% range to the mid

70% range. Although the fixture price-per-unit is quite low, the light trapped inside and the performance of the fixture leave a lot to be desired. New linear direct-indirect pendant systems using 54Watt high-output lamps are a better solution, for many reasons:

- Luminaire efficiency as high as 99.2%
- One 54 Watt lamp provides about as much light as two 32 Watt lamps
- Overall per-unit installation takes less time than troffer systems
- Superior optics reduce glare in computer monitors
- Fixtures have a higher spacing criteria than troffers, reducing total number of units

Linear direct-indirect pendants, by virtue of their improved optics, can provide the 30-50FC of ambient light with better uniformity, at a considerably lower UPD, approximately 0.8 to 1.0 W/sqft., or up to 38% savings annually compared to the maximum allowed UPD.

### Assumptions of energy savings at 33 Emerson

Estimated Operating hours per year: 6AM – 6PM, 6 days per week = 3,744 hours

Allowed Office Space Unit Power Density (UPD) per Massachusetts 780 CMR 13:  
1.3W/sqft

Assuming a total of 49,540 square feet of open office space, if the lighting was designed to the maximum UPD, the annual lighting energy would cost:

$$(49,540\text{sqft} * 1.3\text{W/sqft} * 3744 \text{ hours}/1000) = 241,121 \text{ kWh}$$

$$241,121 \text{ kWh} * \$0.10 = \$24,121.00 \text{ annually}$$

Target UPD for Office Space: 0.8W/sqft

$$(49,540 \text{ sqft} * 0.8\text{W/sqft} * 3744\text{hours} /1000) = 148,382 \text{ kWh}$$

$$148,382\text{kWh} * \$0.10 = \$14,838.00 \text{ annually, or } \$ 9,274.00 \text{ (37\%)} \text{ savings.}$$

The above calculation does not take into account reduced wattage due to dimmed lights in daylight areas. A conservative assumption is a further wattage reduction of 25% annually (more in summer, less in winter), making the total saving projection closer to:

$$(49,540 \text{ sqft} * 0.6\text{W/sqft} * 3744\text{hours} /1000) = 111,287 \text{ kWh}$$

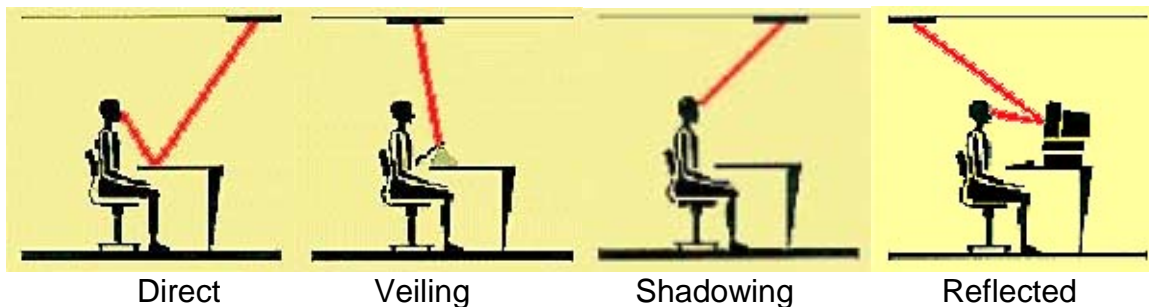
$$111,287 \text{ kWh} * \$0.10 = \$11,128.00 \text{ annually, or } \$12,983.00 \text{ (50\%)} \text{ savings over the base case.}$$

In the best-case scenario, 129,834 kWh are saved, eliminating 360,729 pounds of CO2 annually.

## Daylighting Design Considerations

The major benefit of daylighting is that daylight is free. All that has to happen is that a building is designed to collect the free light and distribute it properly. Daylighting design, however, is not simply putting large windows into the walls; the free light must be controlled or it will cause major glare and heat gain problems. Adequate shielding, sunshades both inside and outside, proper glazing selection, as well as interior finishes can significantly affect the performance and success of a daylit building.

Glare is the biggest potential problem in daylit buildings. Summertime sunlight can be in excess of 10,000fc in the middle of the day, while winter can exceed 4,000fc. Typical offices are lit to 30-50fc, with task lighting boosting desktop levels to 50-60fc. If the glazing and sunshading are not designed properly, extremely bright sunbeams can enter at the window wall, with light levels in the 2,500fc range. The contrast between the sunbeam and the surrounding ambient light can be 70:1 or higher. Offices are designed to 8:1 or lower, so obviously the high amount of light in a sunbeam can become a serious problem. However, there are several solutions that can avoid this issue: proper selection of glazing, sunshading systems, and space planning.



Glare is defined as excessive contrast. The human eye has a sensitivity range of over 1,000,000:1, but is very sensitive to contrasts as low as 4:1. The differences between very bright and very dim areas, especially when the bright and dim are adjacent, can cause eyestrain as the eyes try to adjust to the light levels.

In order to reduce glare in office environments, the lighting must be designed to keep contrasts as low as possible. Indirect lighting, full-shielded light sources, and choice of interior finishes can reduce glare. In addition, as computer usage shifts from black-screen (AutoCAD, VAX, etc.) to white-screen (MS Word™, Excel™, etc.) and monitors begin to change from CRT to LCD, glare conditions on the screen change.

Glare causes eyestrain, particularly in computer monitors. If an image of a light source is present in a monitor, the focal distance from the eye to the glare is the distance from the eye to the monitor *plus* the distance from the monitor to the light source. As the eye tries to focus between the monitor and the reflected glare image, it is shifting between near-field and far-field focusing, which requires the muscles around the eye to flex repeatedly, literally changing the shape of the eye and iris to accommodate. This repeated flexing leads to fatigued muscles and eyestrain.

In addition to eyestrain, computer users often have neck or back strain as they consciously or unconsciously shift their position to avoid glare. This can lead to employee sick time, disability, and certainly a lack of productivity.

Linear direct-indirect pendant lighting systems reduce glare using well-designed optical trains; in a similar manner, the windowing system must be designed to reduce glare and direct sunbeam penetration into the office spaces.

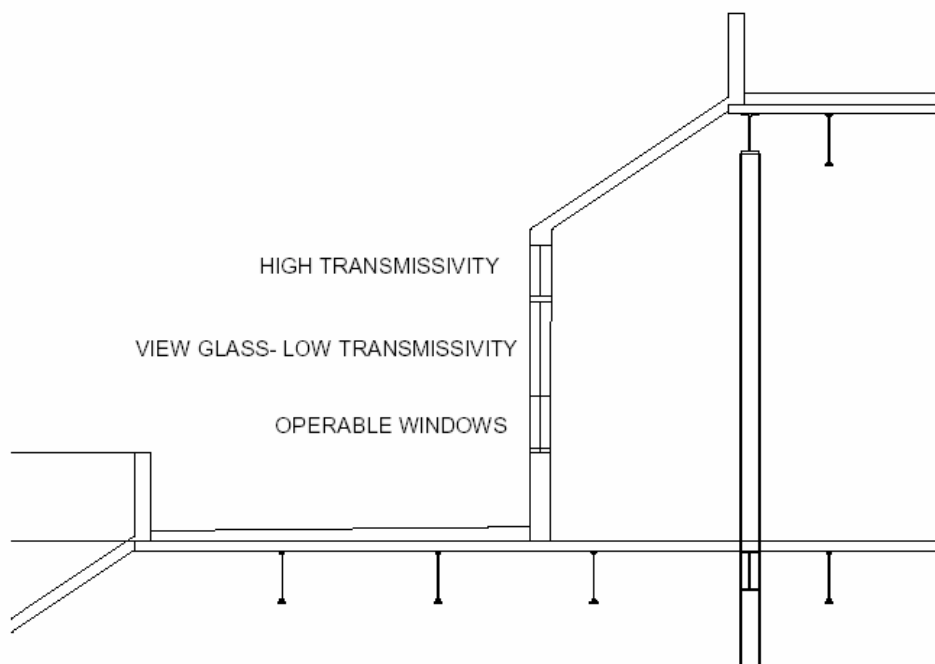
### Window Configuration

It is assumed that all glazing will be at least double, with a low-e coating to reduce infrared radiation into the building through the glass.

In general, the windows should be divided into thirds, with the lower section being operable, the middle section being a low-transmissivity clear glass, and the upper being a high transmissivity clear glass.

Visible transmittance (VT) on lower (operable) and middle (view) windows should be .50-.70, preferably without tint. VT on upper windows should be .70-.80 to allow more usable light inside. The clear glass does not impede views, but since the middle section may be quite large, transmissivity must be restricted to reduce glare.

Solar Heat Gain Coefficient (SHGC) for all vertical glazing should be low, .20-.50, with lower numbers being preferred. Coupled with a low-e coating, this will reduce the amount of direct heat into the glazing. Glazing selection and actual values will depend upon manufacturer specifications, but the overall perception of the glass to occupants should be that there is no difference between glazing sections.



## Sunshading

By using exterior and interior sunshading systems, the direct penetration of the sunlight can be reduced, and the indirect light can be utilized. Shading systems can be placed at the top of a window, at the upper third of the window, and both on the inside and outside.

Exterior sunshades, such as trellises, louvers, awnings, or solid overhangs, are the most effective at reducing direct daylight penetration. However, if they are too large or placed incorrectly, they can block too much sunlight. The exterior shading system should be designed to keep the most direct summer sunlight out of the window while allowing low angle winter sun to enter. This helps control the amount of heat as well as light, blocking the hot summer sun while gathering the energy in winter.

If the exterior shade is placed at the mullion between the middle and upper third of the windows, an interior shade can serve to further shield the floor and workstations, while bouncing light back towards the ceiling.

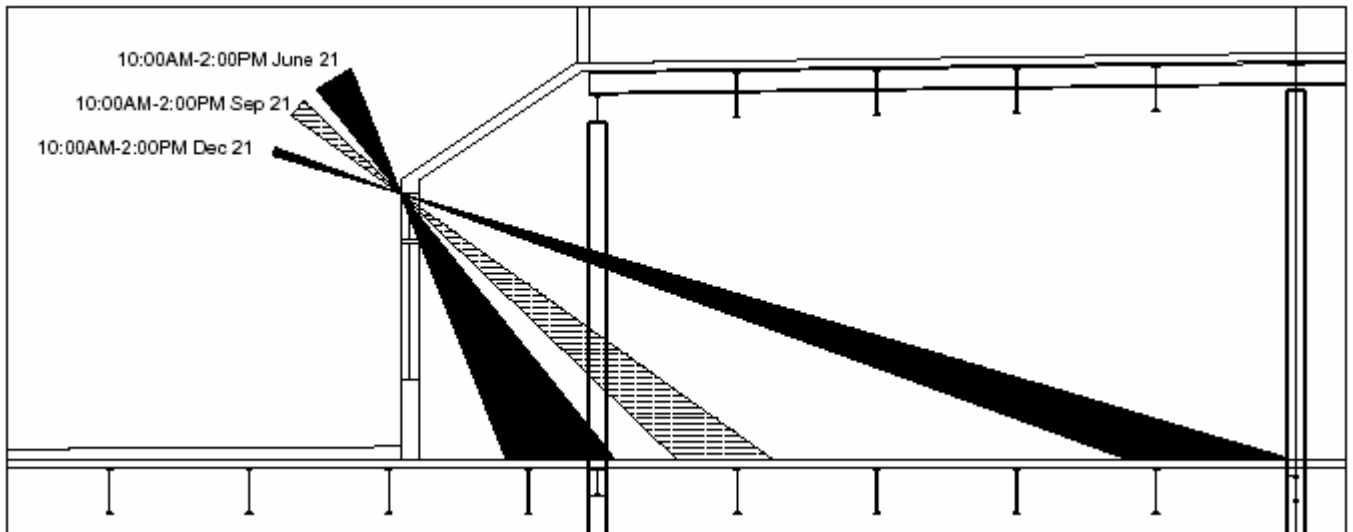
Great consideration must be given to the materials of both the interior and exterior shading devices. The exterior shades must block direct sunlight without catching water, snow, wind, and leaves. A trellis is ideal for this, and the blades of the trellis can be designed to the appropriate size based upon the orientation of the window and its height. There are many materials that can be used. We have had success using a lightweight resin-based catwalk grating. It is inert, will not suffer UV-degradation, is considerably less expensive than custom solutions, and can be ordered in different widths and lengths.

Interior shades must be lightweight, visually appealing, and must allow access to the windows for cleaning. In large spaces, such as gyms, these may be designed with a gap for window access. For offices, the shades will typically be narrower and mounted directly to the window. Lightweight materials such as G.E. Thermoclear Lexan panels can be lifted easily for cleaning.



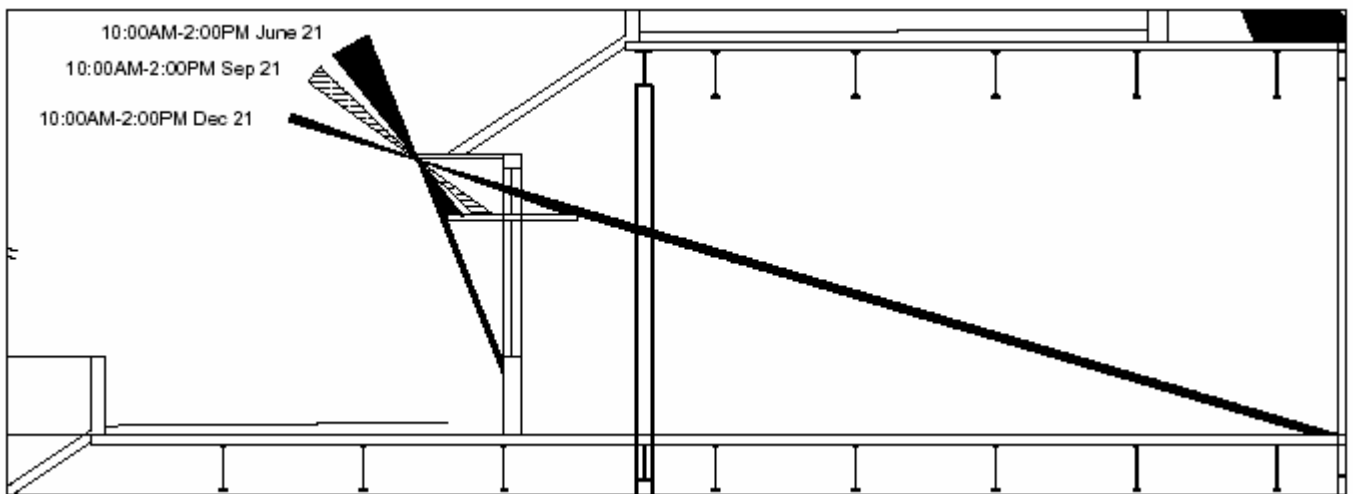
Interior sunshade at Washington State University Student Recreation Center, Double IIDA Award Winner, 2001. Note space at back of shades for window access.

Due to the different solar aspects of the building, two approaches to the sunshading need to be used. On the southern side of the building, horizontal exterior and interior shades will block sun from mid-morning to mid-afternoon. Pulling the windows back under the edge of the building will also help with shading.



Section through southern exterior wall

By setting back the windows along the southern walls, the direct sunbeams can be reduced. However, setback alone will not completely reduce solar penetration, By adding horizontal shading at the building edge and at the mullion, almost all direct sunbeam penetration can be eliminated, while allowing diffuse light to enter the building.



Section through southern exterior wall

In this manner, the sunbeams along the southern side of the building can be reduced significantly, and the hottest and brightest sunbeams (June) will only fall along the window wall itself.

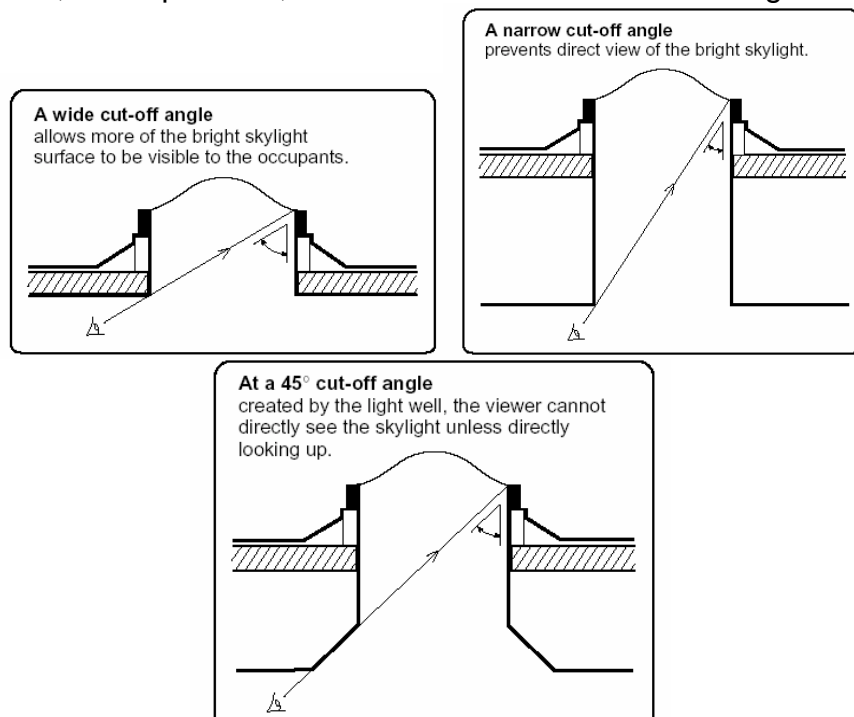
However, the eastern and western sides of the building will require extremely long horizontal shading, so a vertical approach is preferred. The solar angle is quite low and is coming in at an oblique angle to the windows. The sunbeams will tend to run along the walls rather than deep into the building, but the lower angles can create disability glare for occupants. Vertical louvers will solve this problem, but they will also block views, so careful consideration has to be given to their design. It may be possible to set the windows back and align vertical slats at major window divisions, with the spacing set so that view restriction is minimized. As the sections are developed, the vertical slats can be finalized.

### Top lighting

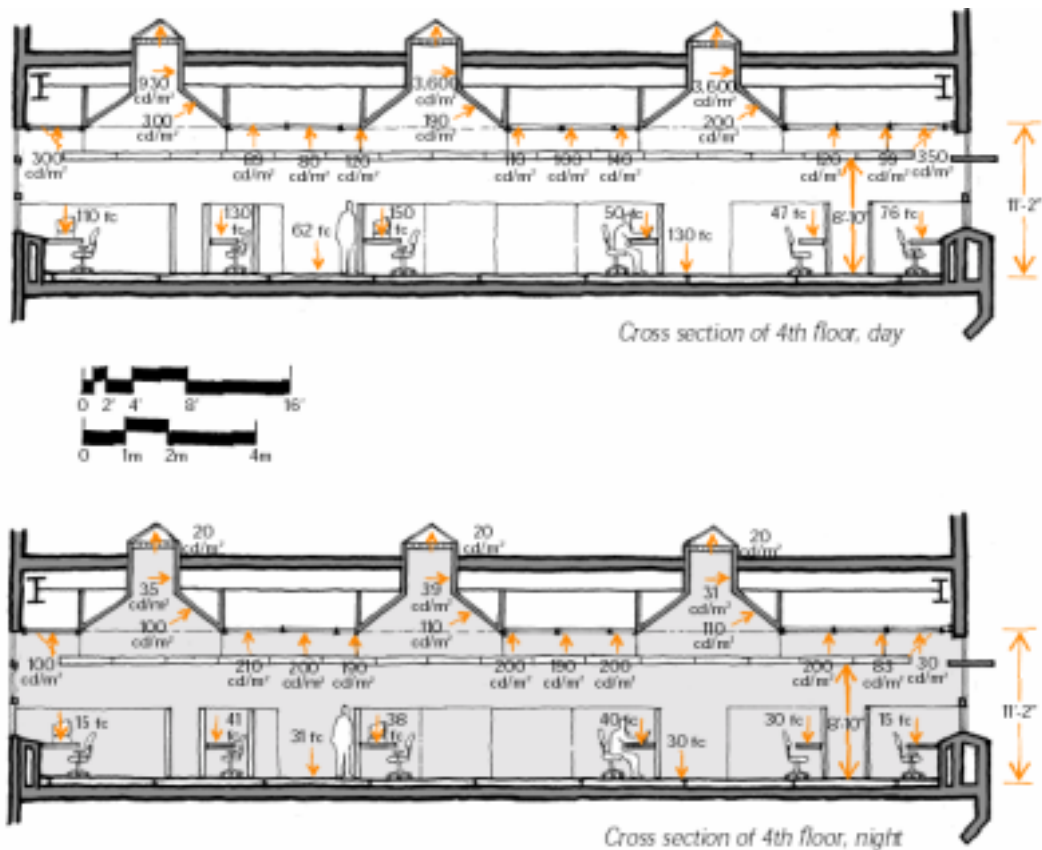
Many opportunities for top lighting are present in the building at 33 Emerson. The stepped-back section allows some top lighting on the lower floors, and the third floor allows almost complete coverage.

Skylights suffer from the same glare issues as windows, but in many ways, these are easier to fix. First, a deep well below the skylight will help capture and control the direct sunbeam. Second, a milk-white or similarly diffuse skylight material will also help avoid sunbeam penetration. At one building in Portland, Oregon, I measured 9,300fc on a conference table located directly under a clear skylight. Obviously, this was more light than they needed and made watching slides somewhat difficult.

Skylights should be spaced roughly 1 to 1.5x ceiling height for ideal coverage. The depth of the well will be based upon the structure and plenum depth. Skylight wells should be painted flat white, and if possible, flared outwards to act as a floodlight.



Examples of skylight wells (image courtesy of Lighting Research Center)



Skylight Wells at Sacramento Municipal Utility District Building. The well design blocks glare from the skylights to the occupants below.

(image courtesy of Lighting Research Center)

Skylight glazing should be diffuse to reduce direct sunbeams and glare. Visible transmittance will vary by manufacturer and material, and will typically be .40 to .70, but final specification will depend upon material preferred. SHGC in any case should be .25-.35 to reduce heat gain. Careful consideration must also be given to snow load, safety of maintenance personnel on the roof, and if the skylight is to be equipped with a fusible link in order to open automatically in the event of a fire for venting of smoke and gasses.

Other Opportunities

Stairwells, restrooms, and similar core-and-shell necessities offer opportunities to create lightwells, shafts, and similar passages for light transmission. Glass-walled stairwells can allow toplight to carry through sections of the building where sidelighting does not provide access. Restrooms can be located so that they are top-lit, eliminating the need for electric lighting during the day. Traffic flow through the building can also be routed from light pool to light pool, follow window walls, and generally be planned in such a manner as to reduce the chance a workstation could end up in a direct southern sunbeam.

## **Electric Lighting Recommendations**

The electric lighting in the building should be high-efficacy light sources, such as linear fluorescent, compact fluorescent, and ceramic metal halide. Where appropriate, sources such as halogen, and induction may be used.

The T-5 lamp, either normal-output or high-output, provides up to 96 lumens/Watt, and when utilized inside a highly efficient luminaire, can provide 30 FC average illuminance in open-plan office spaces. If coupled with highly efficient task lights in the cubicles, connected load in office spaces can be as low as 0.8W/sqft. Massachusetts allows 1.3W/sqft in such spaces, so the energy savings can be significant (up to 40%) over T-8 lamped systems.

The primary luminaire should be a linear indirect-direct, in nominal 4' modules, with a distribution of approximately 75% up and 25% down, with an efficiency of 92% or higher. Careful study of labor costs and product costs as compared to recessed 2X4 troffers should show that the linear system installs with less labor and operates at higher efficiency, reducing the installation and operation cost per square foot. The electrical contractor should be involved early in the product specification process to select the linear system he thinks will be easiest (and thus least expensive) to install.

Secondary luminaires, such as corridor downlights, should be a vertical-lamp, clear-finished reflector, with universal 120-277V ballast, capable of lighting 26W, 32W, or 42W triple-tube amalgam lamps. By using universal ballasts, installation and circuiting conflicts can be avoided, as well as different lamps may be selected to optimize performance.

Spaces such as restrooms, corridors, mechanical rooms, and similar spaces can use a combination of compact and linear fluorescent. Spaces such as garages, hard-to-access luminaires, and always-on systems can use induction for maximum life span, with each lamp lasting up to 100,000 hours. In the case of conference rooms, a combination of fluorescent and dimmable halogen will provide light for meetings and slide or A/V presentations.

### **Schematic Luminaire Schedule**

F1: Linear Indirect-direct pendant, 1-lamp cross section, steel housing, louvered downlight component, tandem-wired for 8' section. High-efficiency reflector, painted housing, color to be determined. Alera CV-1T5HO-LV-24-\*\*-\*\*-\*\*-HRF or as approved. See plans for dimming and emergency-specific fixtures.

F2: Vertical lamp downlight, clear Alzak reflector, universal electronic ballast. Prescolite CFT-6EB-\*\*-STF602 or as approved. See plans for emergency-specific fixtures.

## **Lighting Control**

Lighting control in open-plan and circulation spaces will be a combination of dimmable and non-dimmable ballasts, which will be switched by photocells, low voltage relays,

timeclocks, and occupancy sensors. Private offices, restrooms, break rooms, and conference rooms will rely on occupancy sensors and low-voltage relays for controls. Garages and outdoor lighting will be switched by timeclock and photocell. Only mechanical rooms will be switched manually for safety during maintenance work.

### **Photocell control**

Low-voltage photocells will directly control fluorescent ballasts in daylit areas. Up to 100 ballasts can typically be controlled by a photocell, allowing for variable size areas to be controlled by single photocells. The daylit spaces will be divided into control zones, with the dimmable fixtures close to windows and non-dimmable fixtures closer to the building core. By controlling the ballasts via a low-voltage system rather than line-voltage, tenant modifications can be made without requiring re-wiring of the branch lighting circuits. Instead, if walls are added or removed, the low voltage control is re-routed easily.

**NOTE: FINE-TUNING OF THE PHOTOCCELL CONTROL SYSTEM WILL TAKE AT LEAST ONE YEAR. THE SYSTEM WILL HAVE TO BE ADJUSTED BY MAINTENANCE STAFF DURING THE FIRST YEAR OF OPERATION TO DETERMINE PROPER ON AND OFF TIMES AS WELL AS DIMMED LEVELS. IT IS CRITICAL THAT THE TENANT BE MADE AWARE THAT DAYLIGHTING COMPENSATION TAKES TIME TO SET UP AND USE PROPERLY.**

### **Low voltage relays**

A building-wide switching system, with integral astronomical timeclock and local override switches, will control overall lighting operation. The timeclock can switch on the building at a specified time (e.g. 6:00AM) and switch off the building after cleaning (11:00PM). Occupants can easily override the lights-off mode for their area in the event they are working late. The lighting control system can be set to keep the lights off at certain holidays when the building will be closed, and can also control parking and site loads, with both dusk-on and photocell-on inputs. A hard time-of-day can be set for parking and site to be off. The timeclock will automatically adjust for Daylight Savings and daily sunrise-sunset times. Holidays will need to be re-programmed annually.

### **Local Occupancy Sensors**

A variety of occupancy sensors will be used in open-plan and closed spaces. Open plan areas will be controlled in areas of up to 1,000 sqft, switching the lighting off when unoccupied. As soon as someone enters the space, the lighting in that area will switch on, and the local photocell will dim the lighting to the appropriate level. In small rooms such as private offices and conference rooms, wall-switch style sensors will provide control. In restrooms and spaces with high partitions, ultrasonic occupancy sensors will be used to detect people behind the partitions. In most cases, on-time will be set to 2 to 3 hours in order to reduce switching of fluorescent lamps, which will shorten lamp life. These spaces will be swept off at night at a pre-determined time. In the morning, power to the circuits will be turned on, but the lights will not come on until someone trips the occupancy sensor.

## Manually controlled spaces

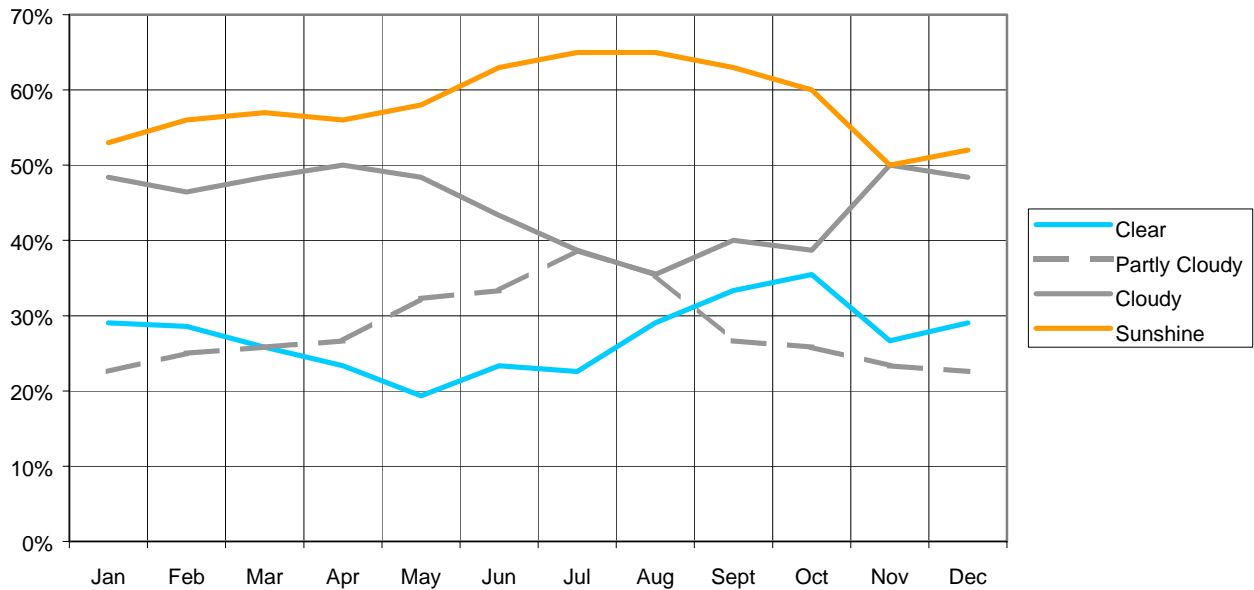
Mechanical, electrical, elevator, and similar equipment service spaces will be switched manually for operator safety. These spaces will normally be off and do not contribute significantly to the connected load of the building.

## Emergency and Egress Lighting

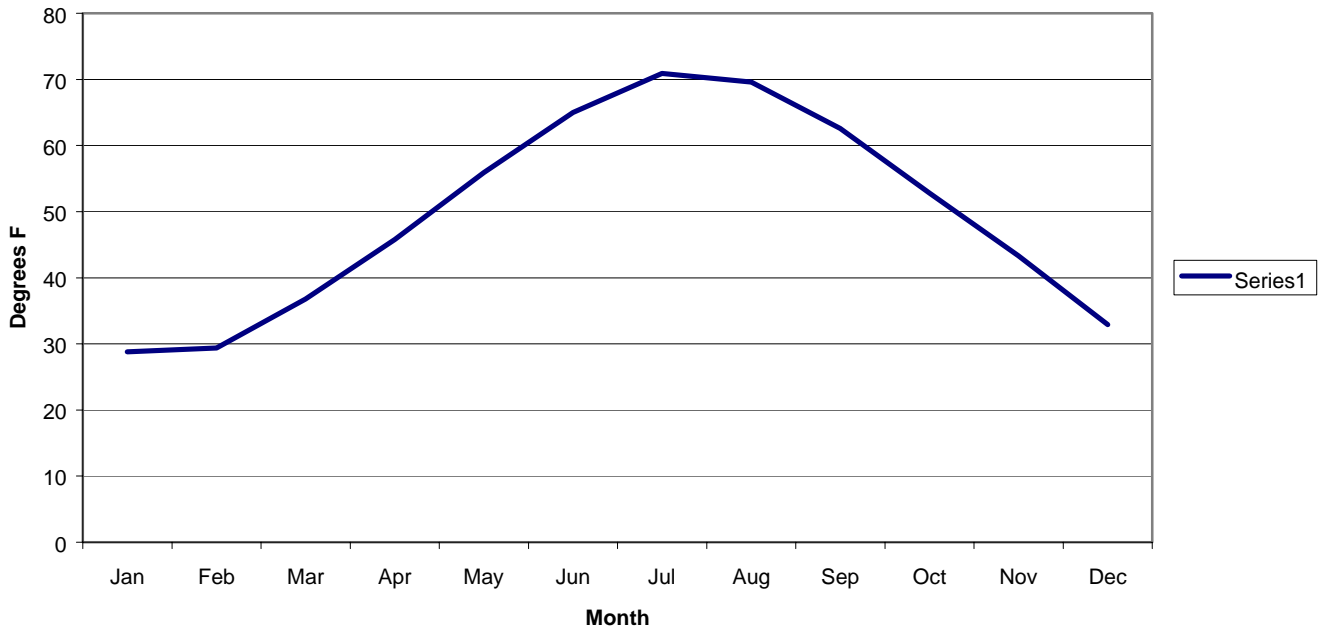
Certain circuits to the building will be fed by an auxiliary power supply, as required by UBC and NFPA. These circuits will be run through the lighting control panel on normally closed relays. In the event of loss-of-power, the luminaires on these circuits will be energized through the emergency-transfer relay, located 'upstream' of the lighting control panel. These circuits will be unswitched by photocells or occupancy sensors, and will generally be along corridors and circulation areas.

## Climate Data

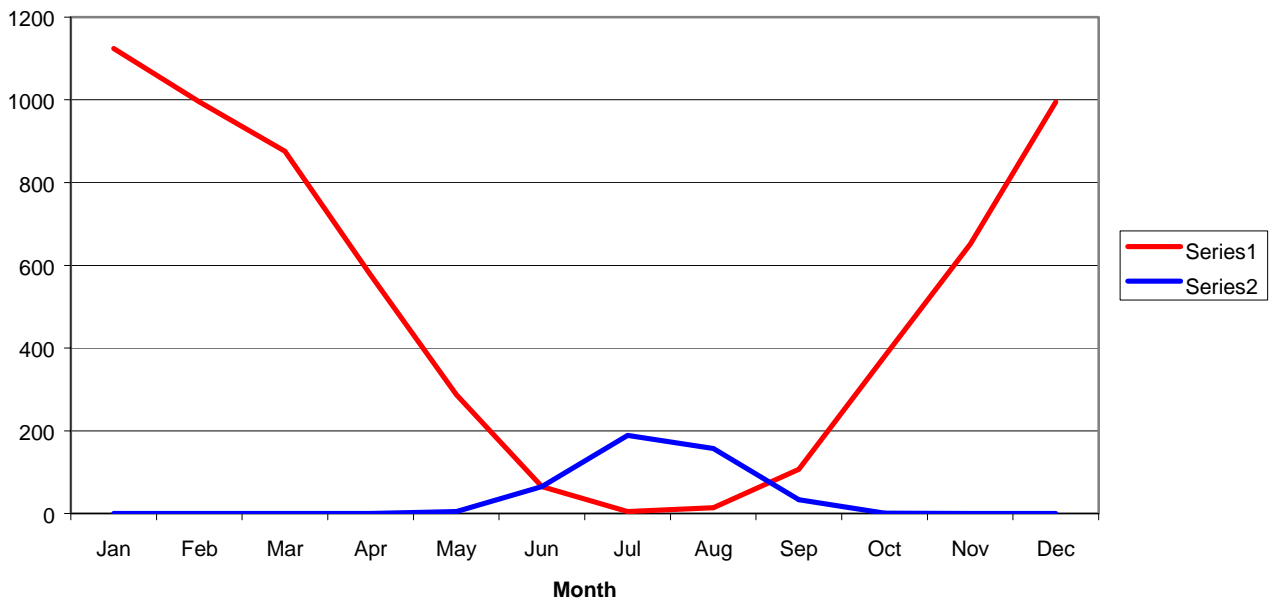
Cloudiness, Eastern Massachusetts  
Averages, 1931-2000



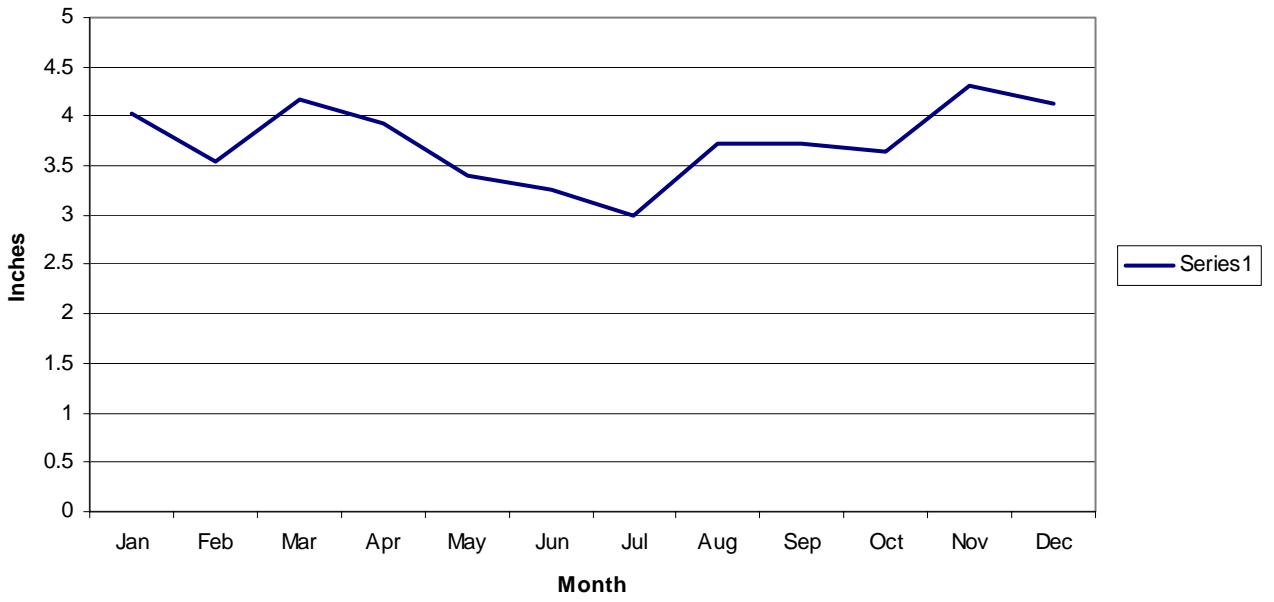
Mean Temperature, Eastern Massachusetts  
Averages, 1931-2000



Heating & Cooling Degree Days,  
Eastern Massachusetts Averages, 1931-2000



Precipitation, Eastern Massachusetts  
Averages, 1931-2000



**SunPosition - Latitude is 42.61 degrees north. Output angle units are degrees**

date	time	altitude	azimuth	date	time	altitude	azimuth	date	time	altitude	azimuth
6/21	00:00	-23.97	180.00	9/21	00:00	-45.94	180.00	12/21	00:00	-70.82	180.00
6/21	01:00	-22.53	165.10	9/21	01:00	-43.93	158.94	12/21	01:00	-67.14	142.31
6/21	02:00	-18.40	151.08	9/21	02:00	-38.35	140.40	12/21	02:00	-58.65	118.13
6/21	03:00	-12.03	138.44	9/21	03:00	-30.25	125.08	12/21	03:00	-48.31	102.73
6/21	04:00	-3.93	127.20	9/21	04:00	-20.58	112.36	12/21	04:00	-37.36	91.29
6/21	05:00	5.42	117.09	9/21	05:00	-10.04	101.29	12/21	05:00	-26.36	81.54
6/21	06:00	15.61	107.69	9/21	06:00	0.91	90.99	12/21	06:00	-15.62	72.31
6/21	07:00	26.36	98.46	9/21	07:00	11.90	80.70	12/21	07:00	-5.42	62.90
6/21	08:00	37.36	88.70	9/21	08:00	22.55	69.63	12/21	08:00	3.92	52.79
6/21	09:00	48.30	77.27	9/21	09:00	32.39	56.84	12/21	09:00	12.02	41.55
6/21	10:00	58.65	61.87	9/21	10:00	40.72	41.27	12/21	10:00	18.39	28.91
6/21	11:00	67.14	37.69	9/21	11:00	46.53	22.09	12/21	11:00	22.52	14.90
6/21	12:00	70.82	0.00	9/21	12:00	48.64	0.00	12/21	12:00	23.96	0.00
6/21	13:00	67.14	-37.69	9/21	13:00	46.50	-22.08	12/21	13:00	22.52	-14.90
6/21	14:00	58.65	-61.87	9/21	14:00	40.66	-41.22	12/21	14:00	18.39	-28.91
6/21	15:00	48.31	-77.27	9/21	15:00	32.31	-56.77	12/21	15:00	12.02	-41.55
6/21	16:00	37.36	-88.71	9/21	16:00	22.45	-69.53	12/21	16:00	3.92	-52.79
6/21	17:00	26.36	-98.47	9/21	17:00	11.79	-80.58	12/21	17:00	-5.42	-62.90
6/21	18:00	15.62	-107.69	9/21	18:00	0.78	-90.85	12/21	18:00	-15.62	-72.30
6/21	19:00	5.42	-117.10	9/21	19:00	-10.20	-101.12	12/21	19:00	-26.36	-81.53
6/21	20:00	-3.92	-127.21	9/21	20:00	-20.77	-112.17	12/21	20:00	-37.37	-91.29
6/21	21:00	-12.02	-138.45	9/21	21:00	-30.48	-124.88	12/21	21:00	-48.31	-102.72
6/21	22:00	-18.39	-151.09	9/21	22:00	-38.64	-140.21	12/21	22:00	-58.66	-118.12
6/21	23:00	-22.52	-165.10	9/21	23:00	-44.27	-158.81	12/21	23:00	-67.15	-142.30

## 5. Mechanical Engineering System Recommendation (HVAC)

We have performed an investigation as to which heating, ventilating and air conditioning (HVAC) system is best suited for this 60,000 square foot commercial office building. We understand that this building will incorporate many energy efficient elements throughout including electrical lighting, building envelope, and HVAC.

We recommend that the owner incorporate a geothermal water source heat pump system into 33 Emerson Ave. This system uses the ground as a source of energy. The ground temperature is constant between 48F and 52F both in Summer and Winter. We had considered alternative systems such as a 'variable air volume' system, a 'standard water source heat pump' system that utilize cooling towers and auxiliary heating boilers as well as a 'standard rooftop unit' system. We believe, however, that the geothermal heat pump makes the most sense as we are able to save fossil fuel by using a natural source of energy; the earth.

In the geothermal water source system the heat pump draws or rejects heat from the fluid that circulates through pipes in the earth below the building. The controls of the system make sure the building temperature requirements are met. During times when the building is unoccupied the controls set temperature to a 'night set-back mode' in order to minimize operating costs. In the winter, the refrigerant swaps cold air for warm and the fan supply's warm air through ductwork to the various portions of the building. In the summer, the building air heats up the refrigerant in an air exchanger. The refrigerant circulates down to the earth where it is cooled and sent back to the building.

There are four (4) major components of this system: in-ground heat exchanger pipes, the heat pump, an indoor heat exchanger, and computerized controls. The compressor inside the heat pump increases pressure and temperature of the refrigerant. This process allows the heat energy developed to be transferred to the building.

This system requires several wells (holes) be dug. Each hole should be approximately 6 inch diameter and be 100 feet deep. This is where the in-ground heat exchanger is located.

A conventional heat pump system dissipates heat to the atmosphere through a closed circuit cooling tower. A geothermal heat pump discharges its heat to the ground. The discharge supply air temperature can go as low as 45F. A conventional heat pump requires auxiliary heat such as gas fired boilers to maintain minimum water loop temperatures. Auxiliary heat is not required when using a geothermal heat pump system. Instead of pumping water, as you do, in a conventional heat pump system, the geothermal system pumps refrigerant. This results in lower motor horsepower ratings and reduces operating costs.

In referencing efficiencies, the seer of standard water to air heat pump is 9.2 and the seer of a geothermal heat pump is 17.0. This relates to a substantially reduced operating cost.

With a heat pump system, there will not be long term shutdowns as there is diversity and flexibility in the system. Usually spare parts or complete units of different sizes will be

available in case of emergencies. If a single heat pump becomes disabled, only that zone is affected, not the entire building. Heat pumps do require periodic servicing such as changing filters, checking belts and oiling moving parts. There is plenty of tenant flexibility. If a tenant relocates, the respective heat pump can be relocated on the loop. The loop must be sized for this flexibility.

*Supply air is distributed through a ducted system to each space through supply diffusers, returned through return registers. The return air is mixed with outside air. The outside air should be preheated before it reaches the heat pump. The standard conventional way is to provide a gas-fired (one hundred percent fresh air heating only) unit to supply air through a ducted system to the return ducts on each heat pump. This will provide enough ventilation air to meet building code requirements. An alternate and more cost effective approach would be to utilize energy recovery ventilators. In the summer, the cooler indoor air pre-cools the incoming fresh air and in the winter, the warmer indoor air preheats the incoming fresh air. The energy recovery ventilator has two fans which control the amount of air through each side of the ventilator, fresh air and exhaust air. The energy recovery ventilator has a wheel inside the unit which separates the two air systems. The wheel transfers both sensible and latent heat. This is a good way to control humidity in the building. The amount of exhaust air exiting the building must be close to the amount of fresh air being introduced to have a balanced ventilator. The building should have some positive intake pressure to prevent or eliminate infiltration. Infiltration is air that leaks into the building through doors and windows.*

The outside air requirement can be reduced by installing carbon monoxide (CO) sensors. The higher the concentration level, the more outside air required. When fewer people are in the building, the CO level is reduced and less outside air is required. This translates to a lesser operating cost.

In conclusion we finally compared a conventional water source heat pump system to a gas-fired rooftop system. Referring to the graphs which follow, the heat pump system will cost \$143,177.00 a year for gas and electricity where the rooftop unit system will cost \$161,366.00 a year for gas and electricity. The difference is \$18,189.00 annual saving. The parameters used for the comparison of the two systems is as follows; ventilation was base on default values of our energy cost evaluation modeling program with ventilation rates modified to meet the most recent code compliance. We based building operating costs on a 190 ton system. The sizing was preformed using Carrier E20-II Hourly Analysis Program. This included a people load of 100 square feet per person and 20 cfm per person for ventilation. Lighting was taken at 1 watt per square foot and a 600 btu per hour auxiliary equipment load for each computer system. We estimated that seventy five percent of total people will be with a computer.

The electrical consumption for space cooling for the year projects to 198,600 kwh for a rooftop system whereas for a heat pump system, the electric consumption is 60,400 kwh. The heating gas consumption for a rooftop system is 1,057,000,000 btu whereas for a heat pump system, the gas consumption is 471,150,000 btu. In addition, there is a 39,200 kwh electric consumption to be considered since the compressors operate in the heating mode for the heat pump system.

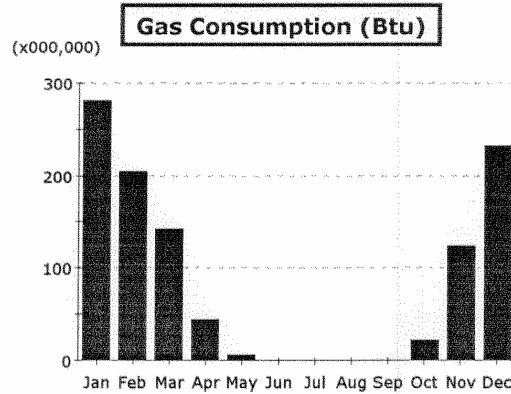
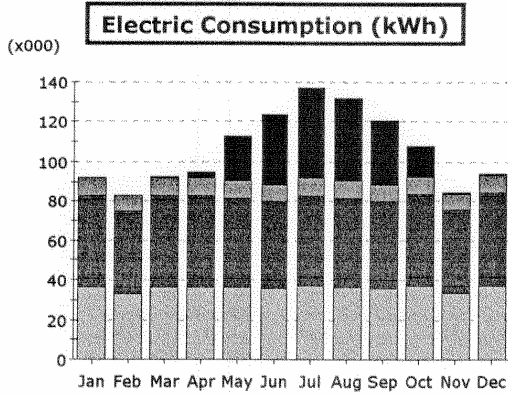
Due to the limitations of our software, we compared a standard water source heat pump system to a conventional gas-fired rooftop system. The sizing of both cooling tower

and gas-fired boiler for a conventional heat pump system has the capability of heating and rejecting the total building heating and cooling requirements. This procedure yields a much higher energy usage, therefore increasing operational costs.

As stated initially at the beginning of this report, we are recommending a geothermal water source heat pump system in lieu of the conventional type. By doing this, the cooling tower and boiler could possibly be eliminated since the ground temperature is constant all year round. We suggest, as a backup mode to install a boiler and cooling tower. However this equipment does not have to be of full system capacity.

In addition to the geothermal heat pump, we advise installing an energy recovery wheel. The process will decrease the ventilation heating and cooling requirement, thereby, reducing the overall building tonnage. This will result in lower operating costs.

The following three (3) chart pages compare the energy consumption of a Heat Pump System verses a typical Roof Top Boiler Unit HVAC System.



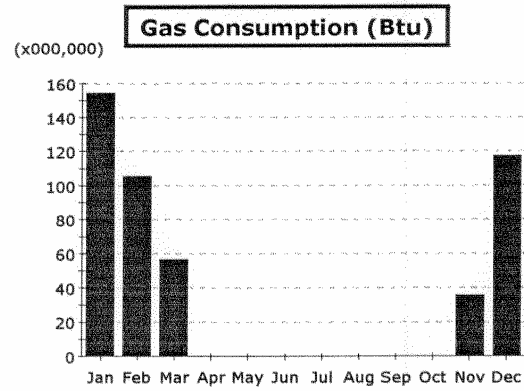
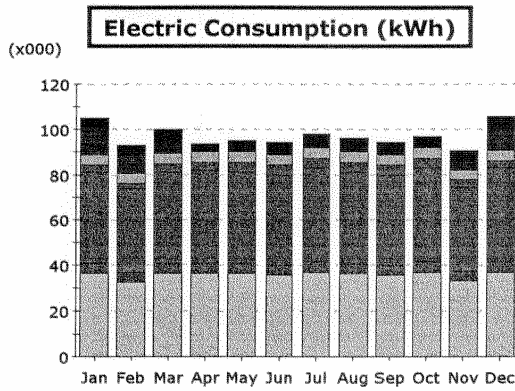
- Area Lighting
- Misc. Equipment
- Pumps & Aux.
- Water Heating
- Space Heat
- Task Lighting
- Exterior Usage
- Ventilation Fans
- Ht Pump Supp.
- Refrigeratic

**Electric Consumption (kWh x000)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	1.2	3.0	22.4	35.5	45.2	41.7	32.8	15.5	0.6	0.7	198.6
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	8.8	8.0	8.8	8.7	8.8	8.6	8.9	8.8	8.6	8.9	8.3	8.9	104.0
Pumps & Aux.	1.6	1.5	1.6	1.2	0.2	-	-	-	0.0	0.4	1.3	1.5	9.5
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	40.6	36.7	40.6	40.8	40.6	39.9	41.5	40.6	39.9	41.5	37.2	41.5	481.3
Task Lights	4.4	4.0	4.4	4.4	4.4	4.3	4.5	4.4	4.3	4.5	4.0	4.5	52.2
Area Lights	36.3	32.8	36.3	36.5	36.3	35.6	37.1	36.3	35.6	37.1	33.2	37.1	430.4
<b>Total</b>	<b>91.7</b>	<b>83.0</b>	<b>92.9</b>	<b>94.5</b>	<b>112.8</b>	<b>123.9</b>	<b>137.2</b>	<b>131.9</b>	<b>121.3</b>	<b>108.0</b>	<b>84.7</b>	<b>94.2</b>	<b>1,276.0</b>

**Gas Consumption (Btu x000,000)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	282.0	204.2	142.0	43.0	6.0	0.3	-	-	0.2	22.1	123.6	233.6	1,057.0
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total</b>	<b>282.0</b>	<b>204.2</b>	<b>142.0</b>	<b>43.0</b>	<b>6.0</b>	<b>0.3</b>	<b>-</b>	<b>-</b>	<b>0.2</b>	<b>22.1</b>	<b>123.6</b>	<b>233.6</b>	<b>1,057.0</b>



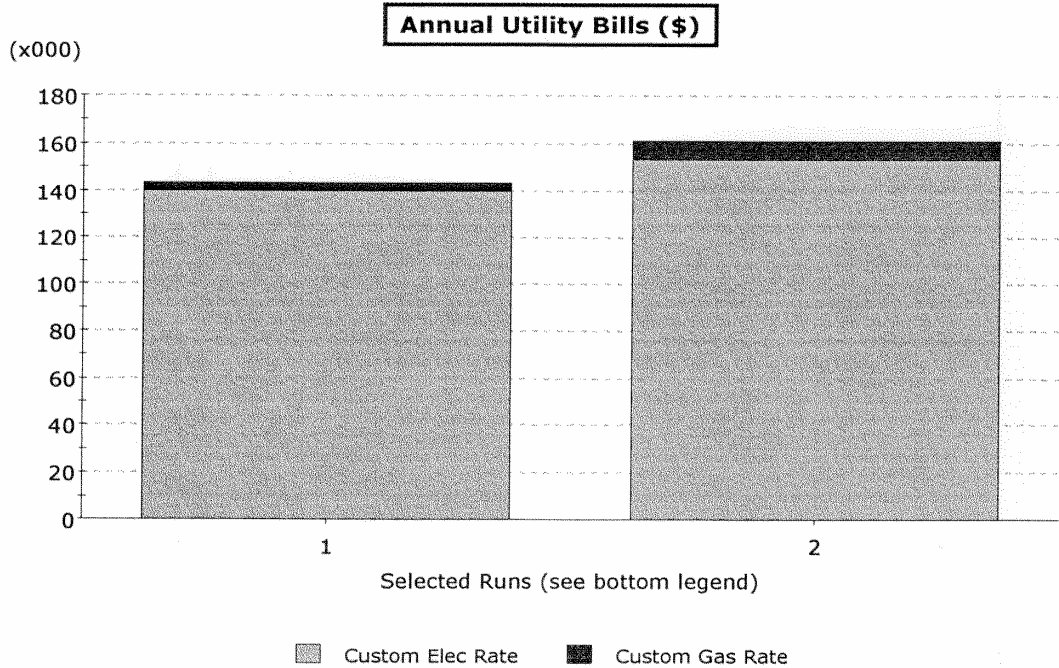
- Area Lighting
- Task Lighting
- Exterior Usage
- Misc. Equipment
- Pumps & Aux.
- Ventilation Fans
- Water Heating
- Ht Pump Supp.
- Space Heat Refrigeratic

**Electric Consumption (kWh x000)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.7	4.7	5.3	2.9	5.0	5.7	6.1	6.0	5.8	4.4	4.6	5.3	60.4
Heat Reject.	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	11.7	8.2	5.2	0.5	0.0	-	-	-	-	0.2	4.0	9.2	39.2
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	4.4	4.0	4.4	4.4	4.4	4.3	4.5	4.4	4.3	4.5	4.2	4.5	52.5
Pumps & Aux.	3.0	2.9	3.5	4.3	4.4	4.3	4.4	4.4	4.3	4.4	3.4	3.2	46.4
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	40.6	36.7	40.6	40.8	40.6	39.9	41.5	40.6	39.9	41.5	37.2	41.5	481.3
Task Lights	4.4	4.0	4.4	4.4	4.4	4.3	4.5	4.4	4.3	4.5	4.0	4.5	52.2
Area Lights	36.3	32.8	36.3	36.5	36.3	35.6	37.1	36.3	35.6	37.1	33.2	37.1	430.4
<b>Total</b>	<b>105.1</b>	<b>93.3</b>	<b>99.8</b>	<b>93.8</b>	<b>95.2</b>	<b>94.2</b>	<b>98.1</b>	<b>96.2</b>	<b>94.2</b>	<b>96.6</b>	<b>90.6</b>	<b>105.3</b>	<b>1,162.5</b>

**Gas Consumption (Btu x000,000)**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	154.14	106.19	56.80	-	-	-	-	-	-	-	36.16	117.86	471.15
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
<b>Total</b>	<b>154.14</b>	<b>106.19</b>	<b>56.80</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>36.16</b>	<b>117.86</b>	<b>471.15</b>



1. 33 Emerson Ave HeatPump - Baseline Design (10/31/03 @ 12:19) (annual bill: \$ 143,177)
2. 33 Emerson Ave RTUs - Baseline Design (10/31/03 @ 12:32) (annual bill: \$ 161,366)

## **6. Green Roof Study**

The phrase “Green Roof” means that the roof of a building is covered with large amounts of plantings intended to save energy and control rainwater run-off. Energy is saved when the green plantings and dryer soil act as insulation preventing the loss of heat during the Winter and preventing heat gain during the Summer. As wind does not directly blow over the roof surface the roof planting materials can help retain the temperature defined by the HVAC system inside. A side benefit is that underlying roof surfaces are, said, by promoters, to last longer as ultra-violet rays will not decay the surface. The root systems, soil, and different types of plastic mats also retain rainwater and allow it to be absorbed by the plants, evaporate, or slowly drain from the roof. Our building is surrounded by sensitive wetlands, therefore, the slow dispersal of rainwater from a large roof is requisite.

The temperature controlling features of a ‘Green Roof’ is complex in that they vary with the amount of moisture retained by the system at any given time. Charlie Miller, P.E. of “Roofscapes, Inc.”, promotes a service of building envelope analysis “that can integrate the effects of insulation, shading, and thermal mass”.

As noted above, ‘Green Roof’ serves in much the same way as “Sod Roofs” have for centuries. The ‘Green Roof’, however, uses lighter materials. Though some systems can be ordered in combination with the building roof itself, “Green Roof” systems available on the market all use some combination of the following:

1. Plant Cover
2. Light Media Planting Soil composed primarily of Vermiculite or a similar product.
3. Tight fiber mats to retain soil, keeping it from being washed or blown away.
4. Water retention layer that would be a plastic mat or pocketed tray.
5. A Barrier Mat to prevent damage to the roof by growing root systems & garden tools.

‘Green Roof’ vocabulary describes low ground cover of 2 ¾” -4” as ‘Extensive’ planting and larger individual trees and shrubs as ‘Intensive’ planting. Though we intend to install some decorative trees & bushes in planters our main interest is to cover vast areas of the roof with ‘Extensive’ planting. Emory Knoll Farms of Street, Maryland is a provider of plant material to ‘Green Roof’ installation companies. Emory describes the advantages of the ‘Extensive’ ‘Green Roof’ in their web site [www.greenroofplants.com](http://www.greenroofplants.com).

- A. Rapid growth and spreading.
- B. High Drought Tolerance.
- C. Fibrous roots as opposed to tap roots to protect roofing membranes.
- D. Low maintenance – trimming, weeding, & feeding.

With 2 ¾” of soil depth we would be able to plant Sedum and other ground cover. With 3” of soil Sedum and leafy perennials can be planted. If we invest in 4” of soil, Herbs, wild flowers and grasses can be planted. Prior to installation we will be advised by plant experts Ed Snodgrass at ‘Emory Knoll Farms’ as well as local landscaper David Carvill of ‘Plants and Pleasantrees’. We had considered planting indigenous beach grass, however, there were several reasons for abandoning this idea. Ed Snodgrass told us that the plant requires much more attention than low-lying ‘succulants’. Over time dead grass builds into a ‘bio-mass’ and may present a suspected hazard to the Fire Department and insurance company. There would also be extra cost incurred by the required depth of 8-12” soil for beach grass and the possible additional building structure required to hold up the added weight of this soil.

In some small areas we will create ‘Intensive’ plantings with deeper soils. These will be limited to individual planters. If we use Perennials, grass lawns, and shrubs we will install 6-8” of soil. For Perennials, large shrubs and small trees we would be installing at least 10” of soil. The above soil

depth figures are recommended by “American Hydrotech, Inc.” and are generally agreed upon standards in the field of ‘Green Roof’ planting’.

Below we describe the ‘Green Roof’ systems that are available in the Northeast of the United States.

#### A. “ROOFSCAPES” ‘Roofmeadow’ SYSTEM

“Roofmeadow” is a European system that is installed on existing roof surfaces. The local installer prefers to install over a ‘Sarnofil’ roof as that membrane company will warrantee their roof with the “Roofscapes” garden installed. The product consists of ‘moisture management/protection fabric’ laid on the roof membrane. On top of this fabric is lain an open weave vinyl ‘shovel protection mesh’. A pebble layer of expanded shale is spread on top of the ‘protection mesh’. ‘Separation fabric’ is lain over the shale. The proprietary ‘growing media’; composed of **shale, vermiculite & 10% organic earth**; is shoveled on top of the ‘separation fabric’. Jute fabric is lain on top of the ‘growing media’ to keep soil in place while plants develop roots. “Roofscapes” does not provide roofing material, only the ‘green roof’ garden material & labor.

1. Weight 8 lb/sf dry, 13lb/sf wet (weights include mesh, fabrics, & soils)(roof surface)
2. Negatives relative to our project : “Carlisle” EPDM-type & “Barrett” bituminous roofs will not warranty roof at this time, but, negotiations are under way between the system manufacturer and various roofing companies. (The installer warrantees the roof against leaking at an additional charge.) Another issue that concerned us was that the local installer/franchisee has only installed one major roof garden.
3. Positives: Seems to be a simple, straight-forward system. ‘Sarnafil’ will directly warrantee use. System claims to have 30 year development in Europe. As an option the installer provides an electronic roof leak detection report for .50 cents / sf for the existing roof prior to installation of the ‘Green Roof’.
4. Cost – Approximately \$15-20/s.f. including fabrics, 2” soil, and ‘extensive’ growth succulent plants.
5. Manufacturer - “Optigrun” (German company)
6. Distributer - “Roofscapes, Inc.”, Philadelphia, PA (215)247-8784 - Charles Miller, P.E.
7. Local Licensed Installer - J. Michael Leshner, Pres. -- J. Michael Landscaping, Marshfield, MA (781) 837-6700

#### B. “WESTON SOLUTIONS” ‘Greengrid’ SYSTEM

“GreenGrid” is a modular system based on 2’x4’ plastic containers. A waffle-type relief pattern is in the floor of these 2’x4’ plastic tray “modules” to trap some water. Some water is trapped to slow rain run-off and retained to feed the plants. A ‘root barrier/drainage fabric’ is lain in the bottom of the trays. A proprietary growing media of “**compost, sand, & waste bark**”. “Weston Solutions” can also provide roofing installation, underlayment, or waterproofing membrane, upon request.

1. Weight-Appr.18 lb/sf dry –34 lb/sf wet (incl. trays, fabrics, &soils)(4” Planting Media)  
Appr. 25 lb/sf dry- 50 lb/sf wet (incl. trays, fabrics, & soils)(8”Planting Media)
2. Positives - “Module” is made of recycled HDPE. “Modules” can be filled and pre-grown in a hot house prior to transport to the site. “Modules” can be removed in various areas to search for future roof leaks without disturbing the whole garden. Cost seems cheaper than the others.
3. Negatives - Need to see how this actually looks installed. We are somewhat concerned that the surface may look like a series of squares, especially in the early stages of growth. Pictures of developed roofs show a planting surface that appears continuous.
4. Cost - \$9-12 /sf installed for “Extensive” module system.
5. Manufacurer – “Weston Solutions”, Glastonberry, (860)368-3200 Andy Harris
6. Local Licensed Installer - Todd Walles (860)368-3211

### C. "HYDROTECH" 'Roof Garden' System

"Hydrotech" 'Roof Garden' system was developed by a roofing company as an extension to their existing basic roof product line. "Hydrotech" involves putting a bituminous sheet w/ gravel "root barrier" laid atop the rigid insulation. A "retention mat/ protection layer" is placed atop the "root barrier". Installed next is an egg carton-type "Florodrain" plastic planting field that is filled with shale drainage media and topped with a "filter sheet" to hold "planting soil" above the plastic. The plastic "Florodrain" holds rain water in lower cup depressions and drains out water when the level reaches half the height of the plastic. Some water retained to avoid massive rain run-off and for long-term plant feeding.

Roof system can include high grade bituminous layered roof with rigid insulation laid on top of the membrane.

1. Weight - Roof Membrane (1.5 lb/sf) + 3" rigid insulation (.6 lb/sf) = 2.1 lb/sf
2. Weight - (30 lb/sf) wet = 32.4 lb/sf  
root barrier (1.2 lb/sf) + Floromat (1.2 lb/sf) + 4" soil
3. Negatives for our project - Installing Insulation on top of cap sheet seems messy as roof leak repairs will require removal of insulation as well as roof garden. The product is heavier than the others. Roof garden or recycled rubber pavers act as ballast that would otherwise be required.
4. Positives for our project - Total system, including bituminous membrane, has a long-term leak warranty.
5. Total Cost \$ 15 - \$ 22 /sq. ft. Approx. Component Costs: (\$ 9 /s.f. for roof membrane & insulation) (\$ 8/s.f. for green roof plastic field & fabrics) (\$ 4 /sf plants)
6. Manufacturer: "Hydrotech" 'Garden Roof', (804) 378-6125 Matt Carr, Rep.
7. Local Boston Licensed Installer - Mike Maloney, (508)269-6333 cell, (508)238-0377 office

### D. SUMMARY

After careful consideration the building owner is intending to install the "Roodscape" 'Roofmeadow' System. There are several reasons for this choice as outlined below:

1. The "Sarnafil" roof material manufacturer has been a successful product used by the Architect and Owner. The "Sarnafil" company will accept and warrantee their roof system with the 'Roofmeadow' System installed.
2. The product seems to install and to be less weight than the other systems.
3. Ed Snodgrass of "Emery Knoll Farms" has expressed the idea that the 'Roofmeadow' System allows the roots of the plants to be near the water where other systems might retain excess water in plastic pockets below the roots. [www.greenroofplants.com](http://www.greenroofplants.com) is an informative & in-depth greenroof website that has many links to greenroof construction companies.
4. See the Water Run-Off Section of this report to read about the effect of the Green Roof on rainwater control.

## **7. Wetland Water Run-Off Control**

Conforming to the “Mass. Wetlands Protection Act” Gateway Consultants has filed Stormwater Management information with the State. A 35,524 sq. ft. ‘impervious area’ (which is the total area of the roof) has a pre-development discharge volume of 2,960 cubic feet. This was based on a 1” rainfall. This discharge does not take into account any “Green Roof” advantage. It is also noted that as part of the Conservation Commission’s “Order of Conditions” that no impervious paving will be added to the site for parking. This will enable site rainwater to leech directly into the soil.

The following is derived from a Nov. 18, 2002 ‘Technical Memorandum’ by Charlie Miller, P.E. of ‘Roofscapes, inc.’:

“Initial abstraction is an engineering term that describes the quantity of rainfall that must occur before appreciable runoff will commence. An approximate rule-of-thumb for a wide range of Green Roofs is that the initial abstraction will equal about 1/3 of the maximum water capacity, MWC, of the growing medium. The MWC is a benchmark number that is measured in a specific test used in Europe. For example, a Green Roof with an MWC of 2.5 inches will not generate significant runoff until at least 0.5 inches of rainfall has occurred.

Vegetated roof covers are very effective in reducing total runoff volume. A predictor of the percent reduction in total annual runoff volume is:

$$\begin{aligned} \% \text{ Reduction} &= 100 \times 0.45 \times \text{MWC (to } 1/3 \text{ power)} \\ \text{MWC for Roofscape/JML Media} &= .30 \times \text{Depth in Inches} \end{aligned}$$

A typical Green Roof with about 3 inches of growing media can be designed to reduce annual runoff by more than 50%. ...this information is based on experience in temperate climates with a rainfall pattern similar to the American Northeast”.

Though we are providing a rip rap lined Stormwater Treatment Basin with Erosion Control Barriers and a Stormwater Treatment Basin with 2 foot Sump Pump, we will be reducing the runoff in a 1” rainfall by 334 cubic feet of water. The extra expense of the Green Roof, while serving other environmental purposes, will also reduce runoff to surrounding Wetlands by 11%.

## 8. “Leeds” Points

We will be using and registering under the LEEDS Rating System to make clear our identification as a ‘Green Building’. The list of LEEDS Point categories below shows what we hope to achieve. With these 26 Points we will attain the “LEEDS” “**Certified**” designation.

### SUSTAINABLE SITES

- R EROSION & SEDIMENTATION CONTROL
- 1 STORMWATER MANAGEMENT, (RATE OR QUANTITY)
- 1 LANDSCAPE & EXTERIOR DESIGN TO REDUCE HEAT ISLANDS. (NON-ROOF)
- 1 LANDSCAPE & EXTERIOR DESIGN TO REDUCE HEAT ISLANDS, (ROOF)

### WATER EFFICIENCY

- 1 WATER EFFICIENT LANDSCAPING (REDUCE BY 50%)

### ENERGY & ATMOSPHERE

- R FUNDAMENTAL BUILDING SYSTEMS COMMISSIONING
- R MINIMUM ENERGY PERFORMANCE
- R CFC REDUCTION IN HVAC&R EQUIPMENT
- 2 OPTIMIZE ENERGY PERFORMANCE, (20% NEW)
- 1 RENEWABLE ENERGY 5%
- 1 MEASUREMENT & VERIFICATION

### MATERIALS & RESOURCES

- R STORAGE & COLLECTION OF RECYCLABLES
- 1 CONSTRUCTION WASTE MANAGEMENT, (DIVERT 50%)
- 1 RESOURCE REUSE 5%
- 1 RECYCLED CONTENT 25%
- 1 LOCAL/REGIONAL MATERIALS (20% MANUFACTURED LOCALLY)
- 1 CERTIFIED WOOD

### INDOOR ENVIRONMENTAL QUALITY

- R MINIMUM IAQ PERFORMANCE
- R ENVIRONMENTAL TOBACCO SMOKE (ETS) CONTROL
- 1 CARBON DIOXIDE MONITORING
- 1 CONSTRUCTION ‘IAQ’ MANAGEMENT PLAN
- 1 LOW-EMITTING MATERIALS (ADHESIVES & SEALANTS)
- 1 LOW-EMITTING MATERIALS (PAINTS)
- 1 LOW-EMITTING MATERIALS (CARPET)
- 1 LOW-EMITTING MATERIALS (COMPOSITE WOOD)
- 1 INDOOR CHEMICAL & POLLUTANT SOURCE CONTROL
- 1 CONTROLLABILITY OF SYSTEMS (PERIMETER)
- 1 CONTROLLABILITY OF SYSTEMS (NON-PERIMETER)
- 1 THERMAL COMFORT (COMPLY W/ ASHRAE 55-1992)
- 1 THERMAL COMFORT (PERMANENT MONITORING SYSTEM)
- 1 DAYLIGHT & VIEWS, (DAYLIGHT 75% OF SPACES)

### INNOVATION & DESIGN PROCESS

- 1 INNOVATION IN DESIGN (SPECIFIC TITLE)
- 1 MINIMUM IAQ PERFORMANCE