

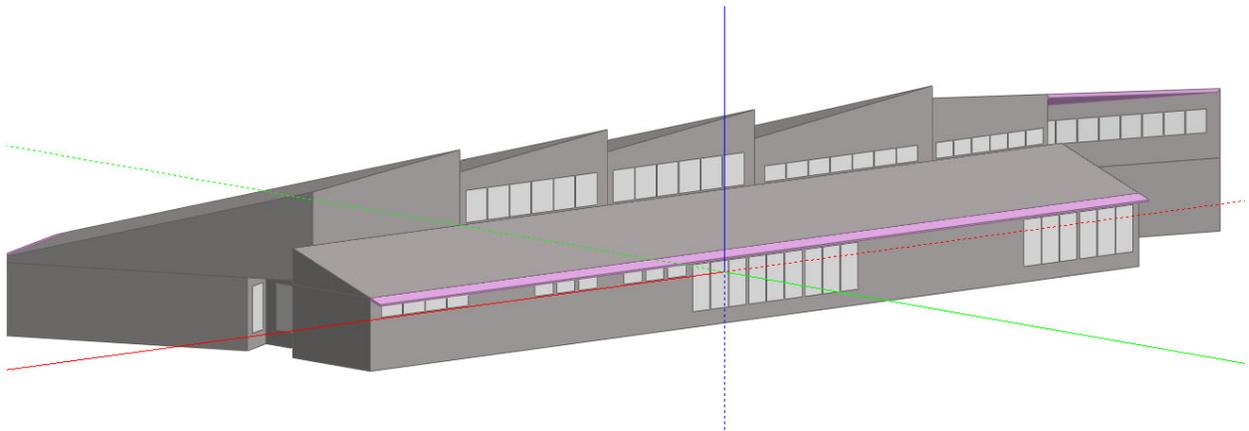
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Life Cycle Cost Analysis of the New NJMC Building

Final Report

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EXECUTIVE SUMMARY

The New Jersey Meadowlands Commission (NJMC) has recently completed a new 9,500 sq. ft. educational facility, which consists of three classrooms, a lecture room, laboratory space, administrative offices, and an observatory. This building is in the process of being certified to the standards set in the Leadership for Energy and Environmental Design (LEED)[™], and will most likely achieve a rating of at least Silver in this system. To better understand the costs and benefits that will accrue from the decision to make this a green building, the NJMC has contracted the Rutgers Center for Green Building (RCGB) to conduct a Life Cycle Cost Analysis (LCC) of the building using the building plans and specifications as inputs to the analysis.

The computer model constructed of the new NJMC building shows it to be extremely energy efficient, consuming only 16% of the natural gas and 54% of the electricity that similarly sized buildings in the same climate zone typically consume. In addition to modeling the building as it was designed, several different construction scenarios were modeled, and these reveal that the choices made in constructing the building were generally cost effective as well as energy efficient, when lifetime energy costs of the building are considered.

The NJMC also chose to install a 33 kW photovoltaic array on the roof of the new NJMC building. This array is projected to be able to supply over 50% of the electricity consumed in the operation of the building, but requires a significant initial investment to install. Unlike other design choices, the cost-effectiveness of the PV system is highly sensitive to assumptions about the future cost of electricity and the value of the State Renewable Energy Certificates. In general, a key distinction in the ensuing analysis is between design choices that are inherently cost-effective and those that are sensitive to factors exogenous to the building, such as commodity prices and state policies and incentives.

BACKGROUND

The New-Jersey Meadowlands Commission (NJMC) has been charged since its inception with the tasks of balancing economic development and environmental preservation throughout the Meadowlands, as well as with managing the landfill sites located within the Meadowlands. With this mandate, the NJMC has supervised remediation of wetlands, closed landfills to prevent further uncontrolled dumping, and initiated programs to capture landfill gas.

In this context, when it was determined that existing educational facilities would not meet future demands, the NJMC decided to build to rigorous environmental standards. Specifically, the new NJMC building was designed and constructed based on the Leadership in Energy and Environmental Design (LEED) standards, developed by the U.S. Green Building Council (USGBC). The new building is one of only a handful of LEED certified buildings that either is under construction or has been constructed in New Jersey. With the construction of this building, the NJMC has expanded upon its trend-setting role in natural preservation and pollution abatement.

The building under consideration in this study is a 9,500 sq. ft. educational facility. The building consists of three classrooms, as well as a lecture room, laboratory space, administrative offices, and an observatory. The observatory building, which is physically separated from the classroom building, has been excluded from consideration in both the Life Cycle Cost analysis and the Life Cycle Impact Assessment. The observatory is quite small, comprising only 5.5% of the total floor area of the project, and is responsible for very little energy use since it does not contain any office or classroom facilities and is not connected to the Heating, Ventilation, and Air Conditioning (HVAC) system.

The Life Cycle Cost (LCC) analysis provides an assessment of the costs of owning and operating the building over its expected lifespan. This analysis is accomplished by creating a detailed computer simulation model of the building based on its materials, plan, and equipment. This model tracks the heating, cooling, lighting, ventilation, and other energy flows of the building, which allows an extrapolation of the building's operating costs over its lifetime.

The results of this analysis provide a valuable tool for quantifying the benefits of green building. Combined with the Life Cycle Impact Assessment being conducted concurrently, this analysis provides a detailed understanding of the environmental and fiscal impacts associated with the choices made in constructing the new NJMC building. This understanding can be used to guide future policy making regarding the construction of green buildings throughout the Meadowlands, for the NJMC, and may prove useful to the U.S. Green Building Council's ongoing evaluation and revision of the LEED Standards.

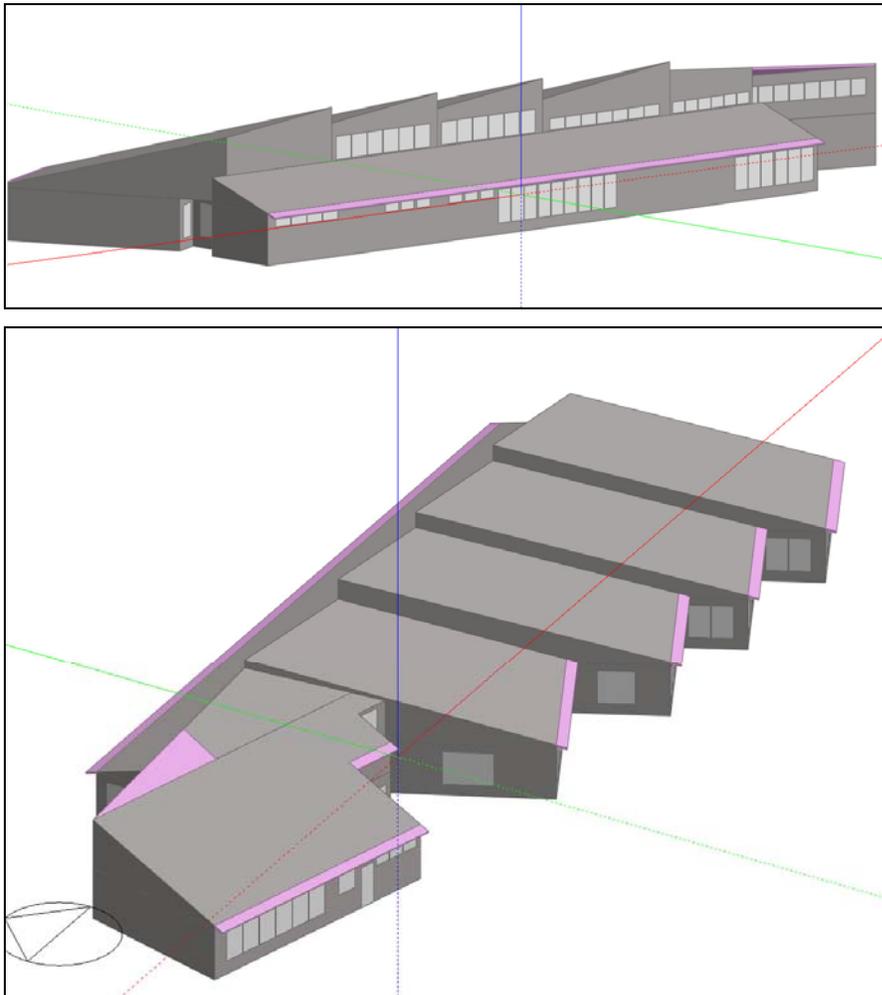
METHODOLOGY

The process of conducting the LCC has two main stages. In the first stage, a computer simulation model of the New Jersey Meadowlands Commission building is constructed. This model includes information on the materials and systems included in the actual building, architectural features detailed in three spatial dimensions, and allows the simulation of the energy flows through the building, including occupant activity. The second stage of the analysis consists of the Net Present Value (NPV) analysis. The NPV uses the estimated energy consumption from the computer model, along with energy price projections, to predict the cost of operating the new NJMC building over its lifespan.

Energy Modeling

For this study, the Rutgers Center for Green Building (RCGB) utilized *DesignBuilder* and *EnergyPlus* to simulate the structure and functioning of the new NJMC building. *DesignBuilder* is used to construct a three-dimensional architectural and engineering model of the New Jersey Meadowlands Commission building. This model contains information on all of the materials and systems included in the actual building, to the extent that the model will permit. Figure 1. shows an image of this model created using the *DesignBuilder* software.

Figure 1. Three-dimensional Model of NJMC Building from DesignBuilder



Once this computer model was constructed, *EnergyPlus*, an energy simulation program developed by the US Department of Energy, is used to simulate the weather conditions, energy use, heating and cooling needs, occupant activities, and all other pertinent variables in an attempt to create a virtual model of the building's structure and activity that is as close to that of the real building as possible. The output from this model provides an estimate of the annual energy consumption by system as well as the heat loss/gain throughout the building. After completing the base model according to the building as it was designed, multiple simulations were run, substituting in different equipment and materials. Models are useful tools for comparing alternate cases and are

generally better at showing the difference in energy use between cases than at forecasting actual energy use. These “what-if” scenarios allowed us to consider the effects of different materials, equipment and/or weather patterns. These simulations are useful tools for creating a building that will be both comfortable for its occupants and as energy efficient as possible.

Net Present Value Analysis

The net present value analysis uses the annual energy consumption in addition to the construction cost of the building, and projected energy prices to determine the lifetime cost of operating the building. In general, over 90% of the energy consumption of a building derives from its operation, rather than its construction, so examining the lifetime energy use of a building, and associated costs, is essential to understanding the effectiveness of any investments into its structure or mechanical systems.¹

The NJMC building contains superior insulation, highly efficient HVAC systems and a 33 kW photovoltaic array. These elements cost more to install than traditional elements, but they also have a significant impact on the lifetime cost of operating the building. These long-term benefits make it essential to examine these systems in terms of their overall cost rather than simply their initial cost.

The net present value (NPV) analysis was used to determine the opportunity costs associated with the decisions made in designing and constructing the new NJMC building. Opportunity costs help to clarify the costs associated with making certain decisions. For example, choosing to invest in more expensive HVAC systems in a building means that this same money can not be invested or spent in some other way, so the potential return from these alternatives is forgone. NPV analysis aids in understanding the relationship between money spent in the present and returns that will be received in the future.

The net present value analysis uses both projected energy costs and several different discount rates to determine the value of future returns and expenses in terms of current

¹ Scheuer, Chris, Gregory A. Keoleian, and Peter Reppe. (2003). “Life cycle energy and environmental performance of a new university building: modeling challenges and design implications.” *Energy and Buildings*. 35: 1049-1064.

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day dollars. Energy costs can be volatile, so it is essential to consider more than one possible cost projection. For this analysis we have included high, middle, and low costs of energy. These different cases allow the analysis to reflect the different potential realities that can occur.

The discount rates used in this analysis are 7%, 10%, and 15%. These rates represent a range of values for future money, which can model a variety of potential situations. The discount rates provide a way to examine the opportunity costs of the more innovative building systems that the NJMC chose to integrate into their building. The discount rate affects the analysis by decreasing the value of money that will be spent or received in the future, so future costs and returns are worth progressively less in terms of today's money.

With these two components of analysis complete, a base case was produced. This base case then became the comparison scenario for a series of "what-if" scenarios that allow for the extrapolation of the effects of changes in building materials and systems as well as changes in energy prices or discount rates. Models are excellent tools for comparing the effects of various scenarios, providing a relatively costless way to understand the impacts of the various choices that were involved in the design and construction of the new NJMC building, once the base case had been produced.

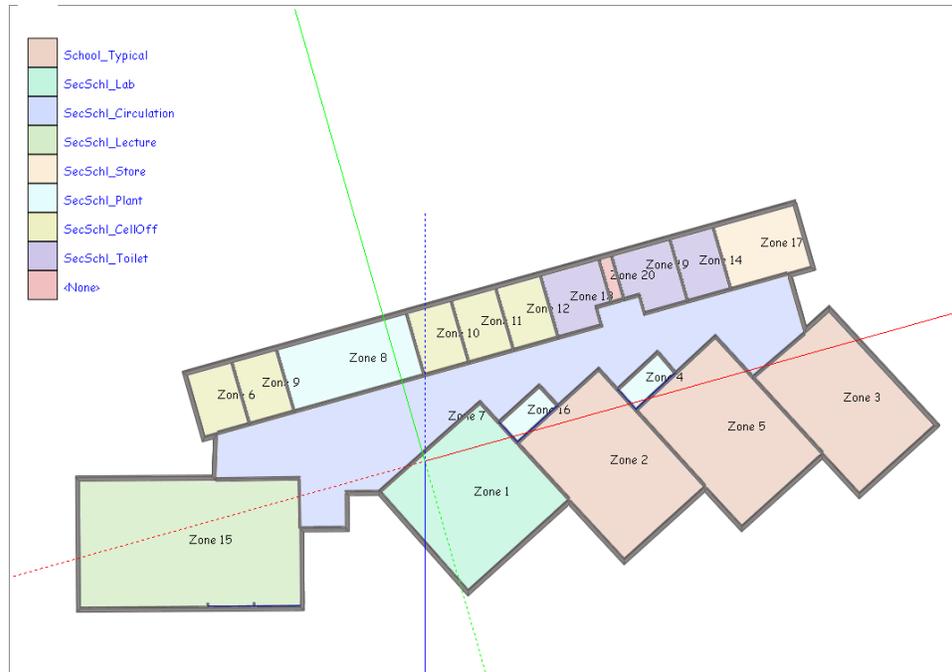
DESCRIPTION OF DATA

A wide variety of data was integrated into the models used in this analysis. The energy modeling is based on data on the construction and mechanical systems of the building as well as data on the weather and solar gain. This data was used to make estimates of energy consumption, heat gain, and energy loss throughout the building.

The energy modeling also takes occupant activity into account, so this activity must be assigned and modeled as well. Figure 2 below shows a plan view of the building with different activities assigned. Each assigned activity represents different data on occupancy levels and hours of activity, metabolic rates of occupants, and types of equipment that will be installed and used in each room. Occupant activity can have

significant effects on heat gain and loss inside a structure, and is a key input when modeling a building's energy use.

Figure 2. Occupant Activity



The net present value model uses the output from the energy modeling along with projected energy costs to estimate the total cost of operating the building over its lifespan. Figures 3 and 4 below show the projected costs of natural gas and electricity until 2030. These projections were based on the US Department of Energy's projections for national prices, which were then calibrated to current and historical NJ energy prices.² For each fuel type a high, medium and low case was calculated. This allowed us to examine a wide range of future situations. The other main input required for the net present value model is the discount rate. This rate represents the opportunity cost of assigning money to one activity instead of investing it or using it for some other activity. Discount rates of 7%, 10% and 15% were all modeled.

²USDOE. (2008). *Annual Energy Outlook 2008*. US Energy Information Administration.
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Figure 3. Projected Electricity prices through 2030

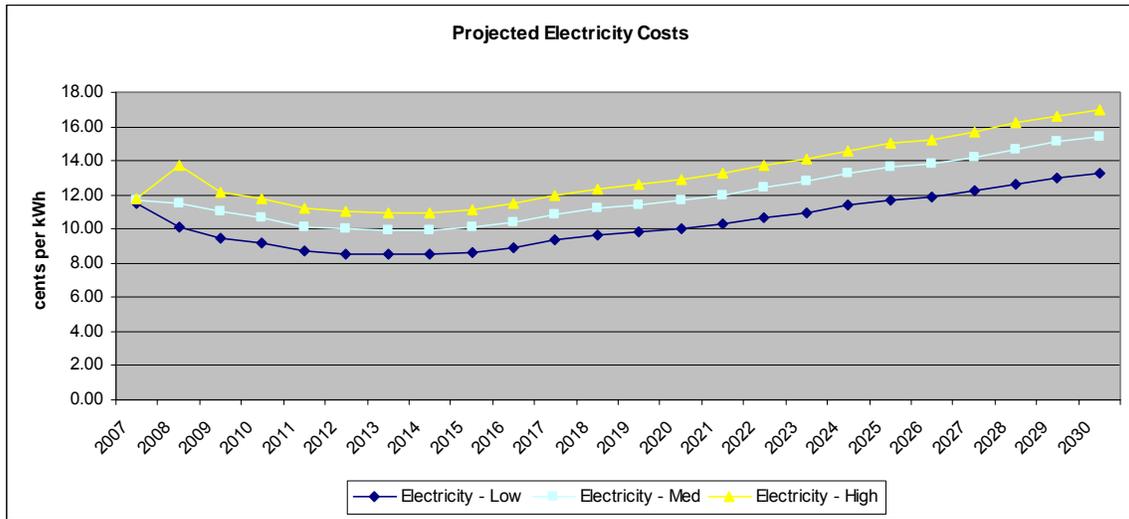
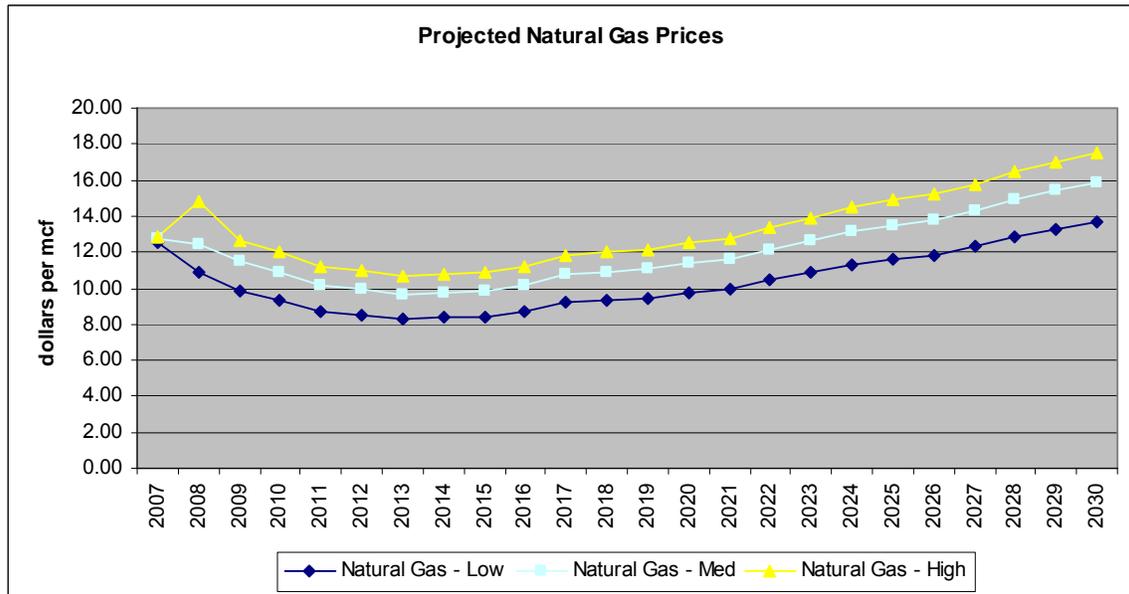


Figure 4. Projected Natural Gas prices through 2030

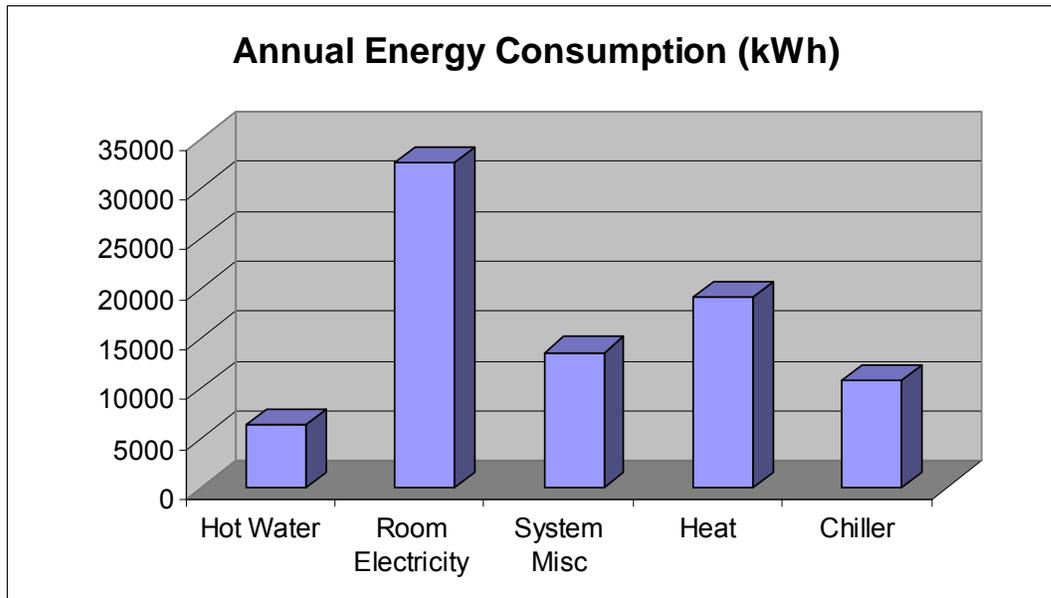


RESULTS

The results of the energy model provide an estimate of the energy consumed by each building system and also present data on how heat is lost and gained throughout the building. Figure 5 below shows the energy consumption, by system, of the new NJMC building. The total annual electrical consumption is only 56,901 kWh and the annual natural gas consumption is only 84,310 cu. ft.

The very high efficiency of the HVAC systems and building insulation ensure that the energy consumption for the new NJMC building is considerably lower than a similar building that used conventional systems. The Commercial Building Energy Consumption Survey (CBECS) collects data on the energy consumption of commercial buildings throughout the country. According to the survey, buildings in Climate Zone 2 (which includes the northern half of New Jersey) that are between 5,000 and 10,000 sq ft., consume an average of 54.9 cu. ft. of natural gas and 10.9 kWh of electricity per square foot.³ The new NJMC building is projected to consume only 8.8 cu. ft. of natural gas and 5.9 kWh of electricity per square foot. This is 16% of the natural gas and 54% of the electricity of the average building on a per square foot basis.

Figure 5. NJMC Building Annual Energy Consumption by System



³ CBECS. (2003) Table C20A. Electricity Consumption and Conditional Energy Intensity by Climate Zone for All Buildings, 2003

Net Present Value

This energy consumption data is then used as an input to the net present value model to create an estimate of the cost of operating the building both in present dollars and in annual cost. Table 1 below displays the present value of the annual electricity cost of operating the building for selected years between 2008-2058 using the medium energy price data. As can be seen from the table below, the farther into the future, the less the present value of money spent. This table also demonstrates the powerful effect that the discount rate has on the valuation of future money. At a 7% discount rate, money five years in the future is worth about 70% of its present value while at a 15% discount rate, money five years in the future is worth only 50% of its present value. This effect is even more dramatic in the distant future. By 2030, the present value of money with a 7% discount rate is only 23% and with a 15% discount rate it is only 5%. Thus, it is clear that costs and returns that occur in the present and near future are significantly more important than those occurring decades in the future.

Table 1. Effect of different discount rates using medium energy prices

	2008	2018	2028	2038	2048	2058
<i>Electricity Cost</i>	\$2,757.81	\$2,676.49	\$3,511.86	\$4,348.13	\$5,196.40	\$6,044.67
<i>Present Value 7%</i>	\$2,757.81	\$1,360.59	\$907.53	\$571.20	\$347.02	\$205.20
<i>Present Value 10%</i>	\$2,757.81	\$1,031.90	\$522.02	\$249.18	\$114.81	\$51.49
<i>Present Value 15%</i>	\$2,757.81	\$661.59	\$214.58	\$65.67	\$19.40	\$5.58

Lifetime Costs

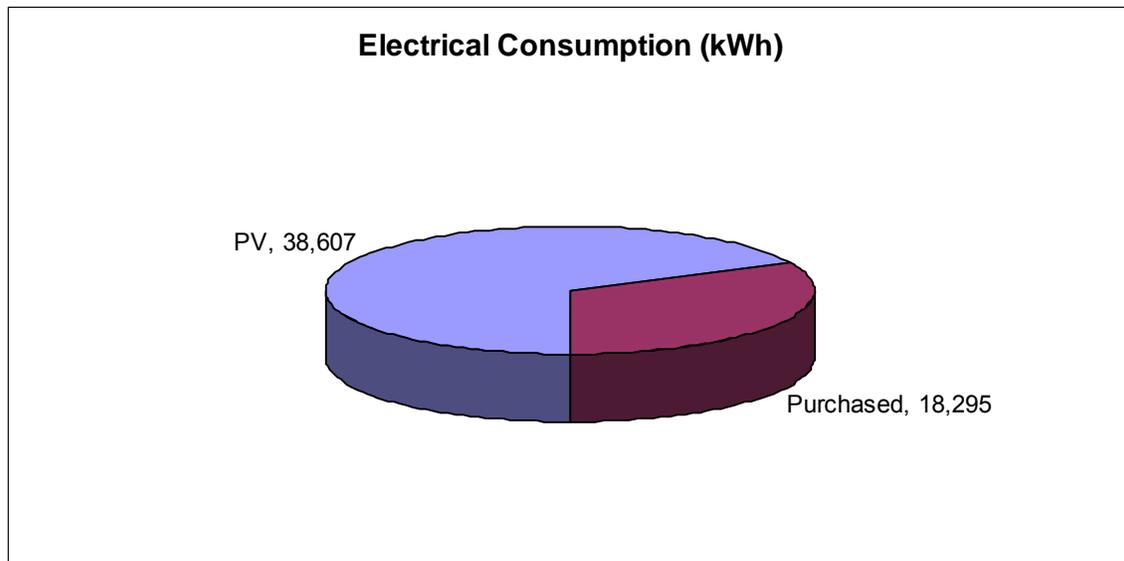
The assumed lifespan of the NJMC building is 50 years. Using this lifespan and the medium energy price scenario, the lifetime energy cost associated with the structure is \$557,784.11 (\$58.16 per sq. ft.) in actual dollars with a present value of only \$85,553.02 (\$8.92 per sq. ft.), using a 10% discount rate. Subtracting the value of the electricity provided by the PV array decreases this to \$229,519.74 (\$23.93 per sq. ft.) in actual dollars, with a present value of \$35,059.59 (\$3.66 per sq. ft.). When compared to the initial cost of \$3.5 million estimated for the construction of the building, this is an extremely modest sum. The combination of being well insulated, producing so much of its own electricity, and having highly efficient systems is likely responsible for this

unusual situation. These aspects of the building will be examined more closely in the following scenarios.

Photovoltaic System

Photovoltaic (PV) systems transform light energy into electrical energy, and so provide 'free' electricity once they are installed. The amount of electricity produced depends on the amount of sunlight that the panels receive. The panels are carefully oriented to receive as much sunlight as the site will permit. Data on the amount of sunlight that geographic locations typically receive is then used to estimate the total annual production of the PV system. The NJMC provided an estimate that the PV system will produce about 38,600 kWh annually. According to this estimate, the PV system will provide approximately 68% of the electricity required annually by the new NJMC building.

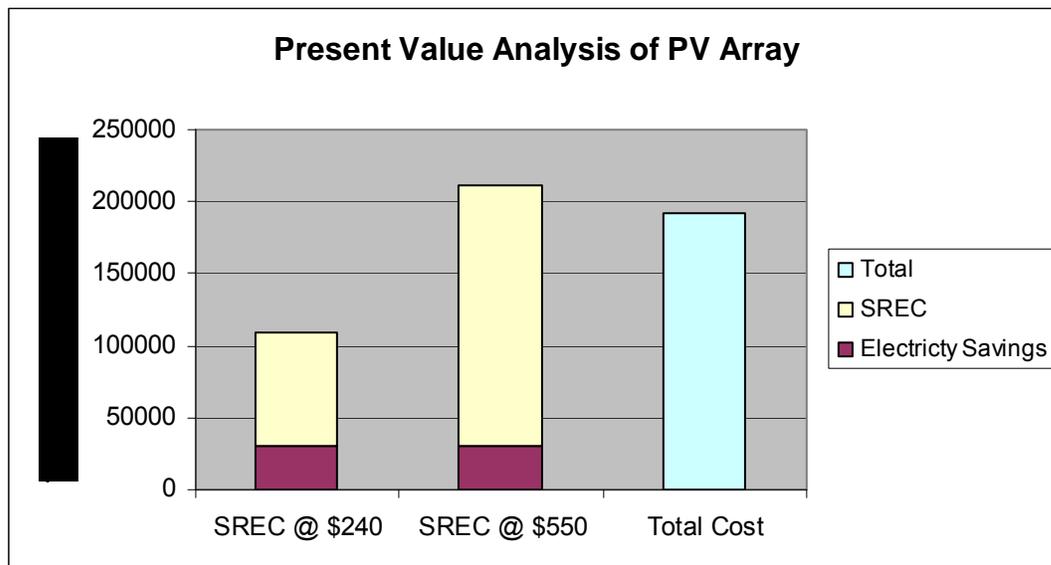
Figure 6. Percentage of Annual Electricity Provided by PV



The initial cost of the PV array is approximately \$192,000 for the panels, inverters, labor, and all necessary wiring and equipment. Using an assumed lifetime of 20 years, which is considered standard for PV systems, and a discount rate of 10%, the total value of the electricity produced by the array ranges in value from \$81,538.61 (\$8.50 per sq. ft.) to \$104,996.98 (\$10.95 per sq. ft.) in actual dollars and from \$35,107.51 (\$3.66 per sq. ft.) to \$45,371.45 (\$4.73 per sq. ft.) based on high and low energy cost projections. In addition to the income stream provided by the electricity itself, New Jersey also provides Solar Renewable Energy Certificates (SREC's). New Jersey has an aggressive

Renewable Energy Portfolio program, which seeks to ensure that 22.5% of the electricity sold in NJ is from renewable sources by 2021. SREC's are provided to generators of renewable energy for each megawatt hour (MWh) of renewable energy that they produce as a part of this system. The current value of these certificates is \$240, but they are expected to rise in value to approximately \$550 per MWh in the near future. The present value of these SREC's is the most volatile quantity in estimating the present value of the PV array. If the certificates remain at their current value of approximately \$240 per megawatt then the present value of the SREC's would be \$78,883, at a 10% discount rate. However if the SREC's increase in value to approximately \$550 per megawatt hour, as predicted, then the present value of the SREC's would be \$180,775, at a 10% discount rate. This results in a present value for the photovoltaic array, assuming a 10% discount rate, that ranges from -\$67,744. to \$34,147. Thus, under low energy price conditions, the PV array would have an overall net cost of \$67,744, while under high price conditions it would have a net value of \$34,147. These findings are in accordance with other studies of photovoltaics, which have found that there need to be significant incentives and high energy prices to make PV cost effective.⁴ Scenario V explores the costs and benefits of the PV array under varying energy prices and discount rates in more detail.

Figure 7. Present Value Analysis of PV Array

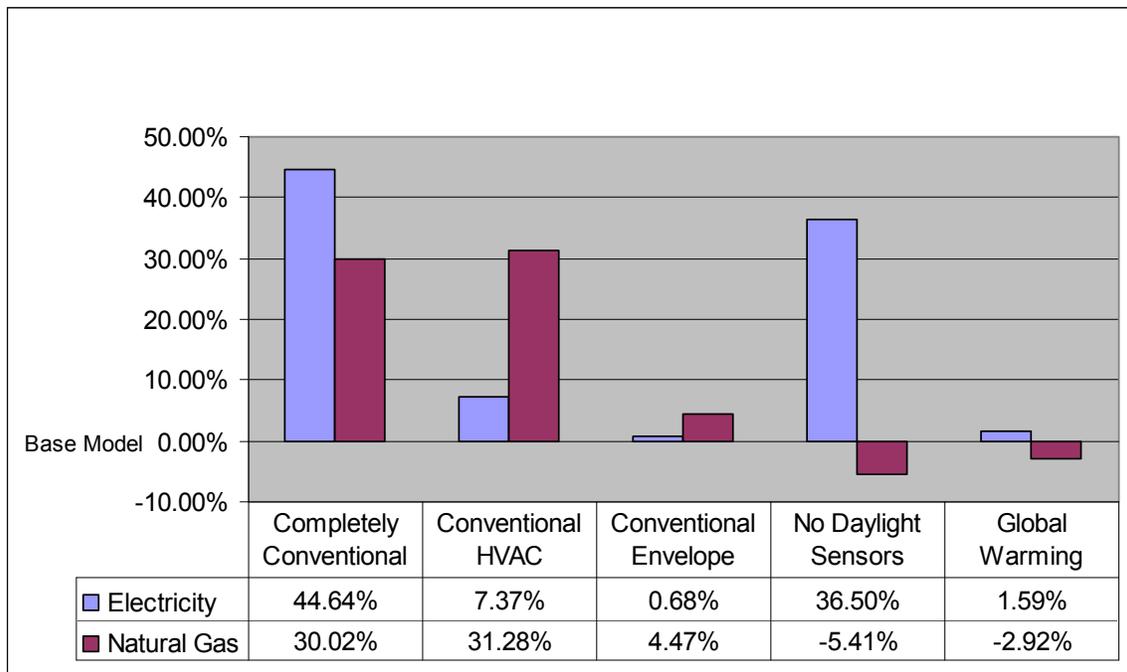


⁴ Simons, George. (2005). *Developing Cost-Effective Solar Resources with Electricity System Benefits*. California Energy Commission: CEC-500-2005-104
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WHAT IF SCENARIOS

The computer model of the new NJMC building was used to explore a series of scenarios to better understand the effects of the green investments that were made in the building. These scenarios modeled how the building would use energy differently if certain green practices used in constructing the building were replaced with conventional practices. Scenario I, Completely Conventional, explores the effects of using the minimum required insulation and HVAC systems as well as removing the daylight sensors. Each of these changes is also explored individually in scenarios II through IV. Scenario V has a detailed exploration of the effect of the photovoltaic array, and scenario VI explores the effects of projected climate change on the energy use of the building. Figure 8 below summarizes the differences in energy use between the base model and the various scenarios.

Figure 8. Difference in Energy Use Between Scenarios and Base Model



Scenario I. Completely Conventional

This scenario considers the effects of building a conventional version of the new NJMC building. The conventional version of the NJMC building would have standard HVAC equipment installed (SEER 12), the minimum required insulation (R-13), and would not have daylight sensors installed. The Seasonal Energy Efficiency Ratio (SEER) is a common measure of HVAC equipment efficiency; the higher the SEER, the more efficient the equipment. Similarly, R-value is a measure of the effectiveness of insulation (the ability to retard the flow of heat); the higher the R-value, the more effective the insulation. These choices represent the standard construction practices currently used in New Jersey. The HVAC equipment and insulation are both the minimum required by current building codes and typical buildings do not include the daylight sensors installed in the new NJMC building.

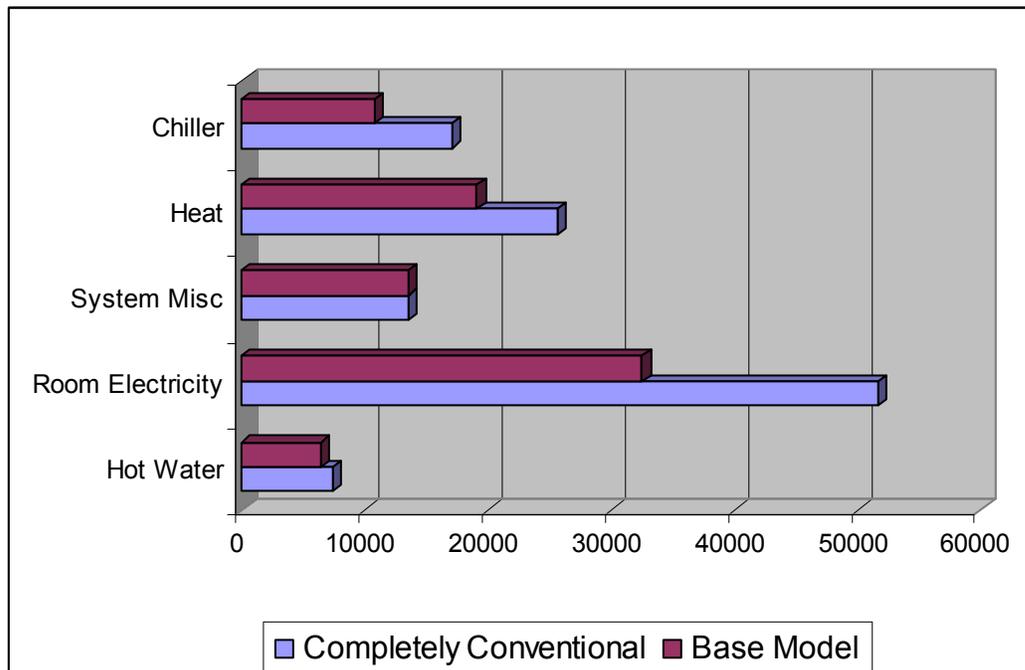
The difference between this model and the base model will best represent the difference in energy use and cost between the standard building practices and the highly energy-efficient practices used in the construction of the new NJMC building. The scenarios following this one explore the effects of the HVAC equipment, insulation, and daylight sensor separately.

The total energy consumption of the building with standard HVAC equipment, insulation, and no daylight sensors is over 33,000 kWh higher than it is under the current design. This is an increase of approximately 40%. The table below provides more detail on the savings associated with each discount rate and energy price estimate. The difference in cost between the conventional design and the current design of the new NJMC building is approximately \$22,000 (\$2.29 per sq. ft), while even at the lowest energy price and highest discount rate the savings attributed to the current design is \$20,794 (\$2.17 per sq. ft.), which demonstrates that the investments in energy efficiency included in the new NJMC building were a sound investment.

Table 2. Increased Operating Cost of Completely Conventional Scenario over the As-designed Base Model (50 year lifetime)

	Low Price	Mid Price	High Price
Not Discounted	\$204,521.55	\$238,175.17	\$262,854.01
per sq. ft.	\$21.33	\$24.84	\$27.41
7% Discount Rate	\$45,578.97	\$53,024.81	\$57,228.01
per sq. ft.	\$4.75	\$5.53	\$5.97
10% Discount Rate	\$31,446.65	\$36,562.41	\$39,979.40
per sq. ft.	\$3.28	\$3.81	\$4.17
15% Discount Rate	\$20,794.06	\$24,153.65	\$26,757.25
per sq. ft.	\$2.17	\$2.52	\$2.79

Figure 9. Comparison of Energy Use between the As-designed Base Model and the Completely Conventional Scenario



Scenario II. Conventional HVAC Equipment

This scenario considers the effect of installing conventional, rather than highly efficient, HVAC equipment in the new NJMC building. The conventional equipment modeled was assumed to have the same configuration but to be only 12 SEER, which is the minimum

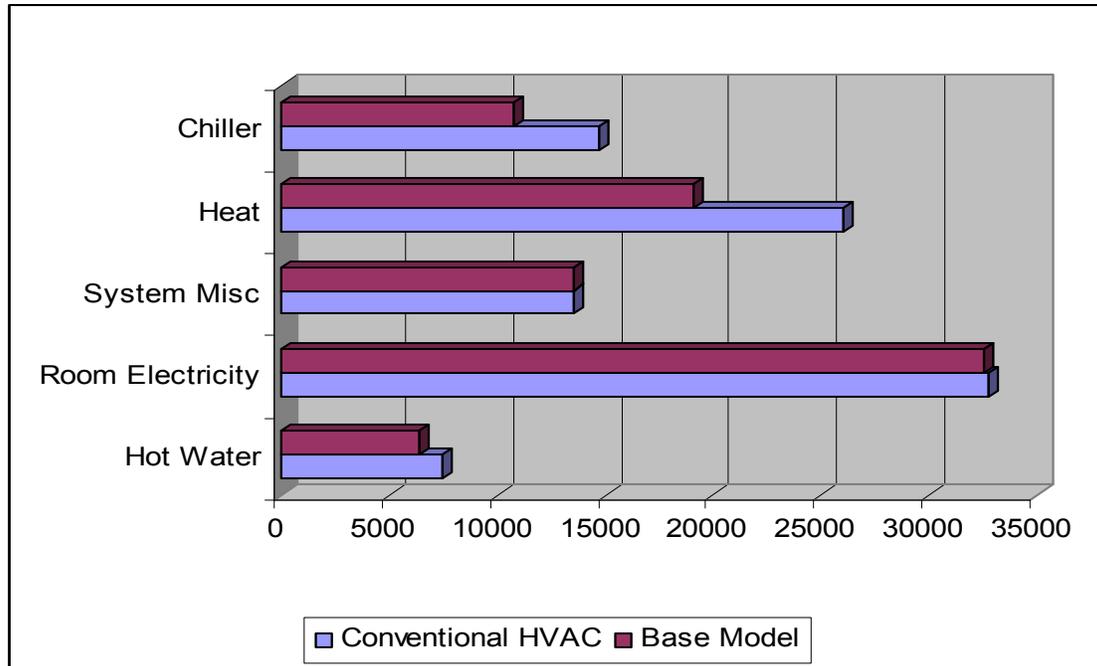
efficiency rating for such equipment in commercial buildings in New Jersey. The difference in energy consumption between the two systems can be seen in the graph below.

The total energy consumption of the building with standard HVAC equipment is over 12,000 kWh higher than it is under the current design; this is an increase of approximately 15%. The table below provides more detail on the savings associated with each discount rate and energy price estimate. The difference in cost between the conventional equipment and the highly efficient equipment purchased for the new NJMC building is approximately \$6,000 (\$0.63 per sq. ft), while even at the lowest energy price and highest discount rate the savings attributed to the equipment is \$5103 (\$0.53 per sq. ft.), which demonstrates that the high efficiency equipment purchased for the new NJMC building was a sound investment.

Table 3. Increased Operating Cost of Conventional HVAC Scenario over the As-designed Base Model (50 year lifetime)

	Low Price	Mid Price	High Price
Not Discounted	\$50,501.04	\$58,810.67	\$64,905.39
<i>per sq. ft.</i>	\$5.27	\$6.13	\$6.77
7% Discount Rate	\$11,190.80	\$13,018.64	\$12,847.02
<i>per sq. ft.</i>	\$1.17	\$1.36	\$1.34
10% Discount Rate	\$7,714.85	\$8,969.58	\$9,320.85
<i>per sq. ft.</i>	\$0.80	\$0.94	\$0.97
15% Discount Rate	\$5,103.11	\$5,927.28	\$6,443.60
<i>per sq. ft.</i>	\$0.53	\$0.62	\$0.67

Figure 10. Comparison of Energy Use between the As-designed Base Model and Conventional HVAC Scenario



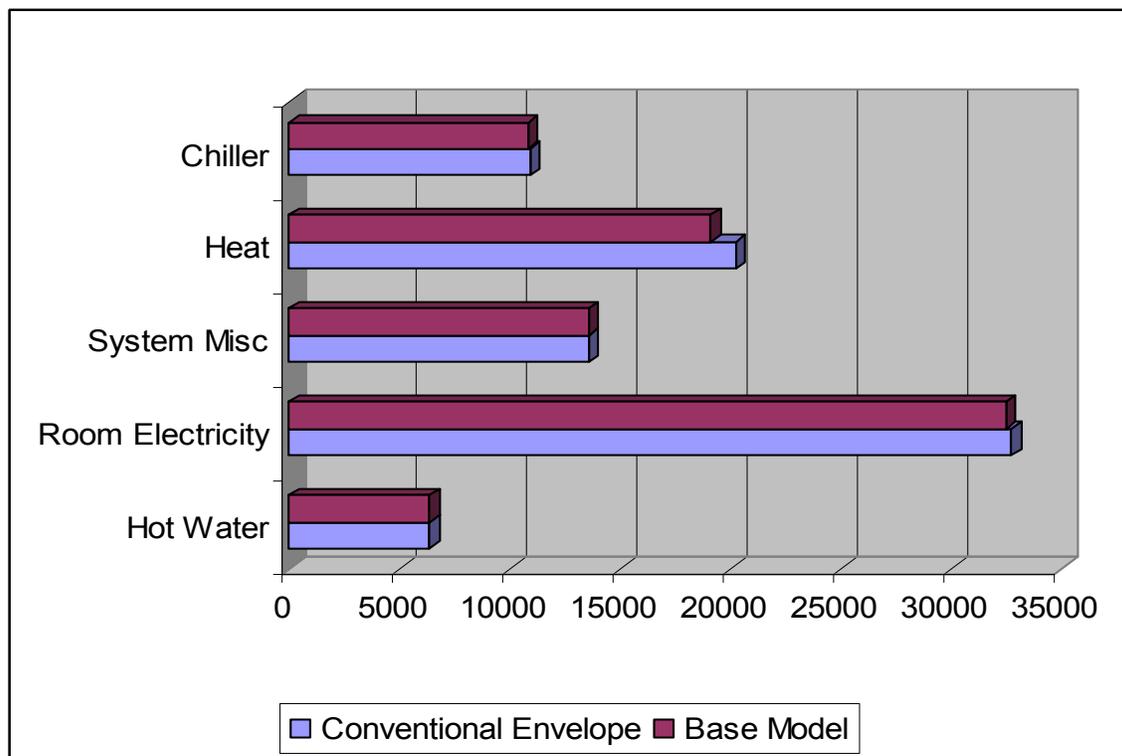
Scenario III. Conventional Envelope

This scenario considers the effect of installing the minimum required insulation (R-13), rather than the more effective (R-19) insulation installed in the new NJMC building. The difference in energy consumption between the two types of insulation can be seen in the graph below. The total energy consumption of the building with the minimum required insulation is over 1500 kWh higher than it is under the current design; this is an increase of approximately 2%. The difference in cost between the two types of insulation is approximately \$675 (\$0.07 per sq. ft). The table below provides more detail on the savings associated with each discount rate and energy price estimate. Investment in increased insulation is sound under all but the most unfavorable conditions.

Table 4. Increased Operating Cost of Conventional Envelope Scenario over the As-designed Base Model (50 year lifetime)

	Low Price	Mid Price	High Price
Not Discounted	\$5,681.66	\$6,616.53	\$7,302.26
<i>per sq. ft.</i>	\$0.59	\$0.69	\$0.76
7% Discount Rate	\$1,256.48	\$1,461.69	\$1,393.95
<i>per sq. ft.</i>	\$0.13	\$0.15	\$0.15
10% Discount Rate	\$865.96	\$1,006.79	\$1,026.59
<i>per sq. ft.</i>	\$0.09	\$0.10	\$0.11
15% Discount Rate	\$572.87	\$665.38	\$718.40
<i>per sq. ft.</i>	\$0.06	\$0.07	\$0.07

Figure 11. Comparison of Energy Use between the As-designed Base Model and the Conventional Envelope Scenario



Scenario IV. No Daylight Sensors

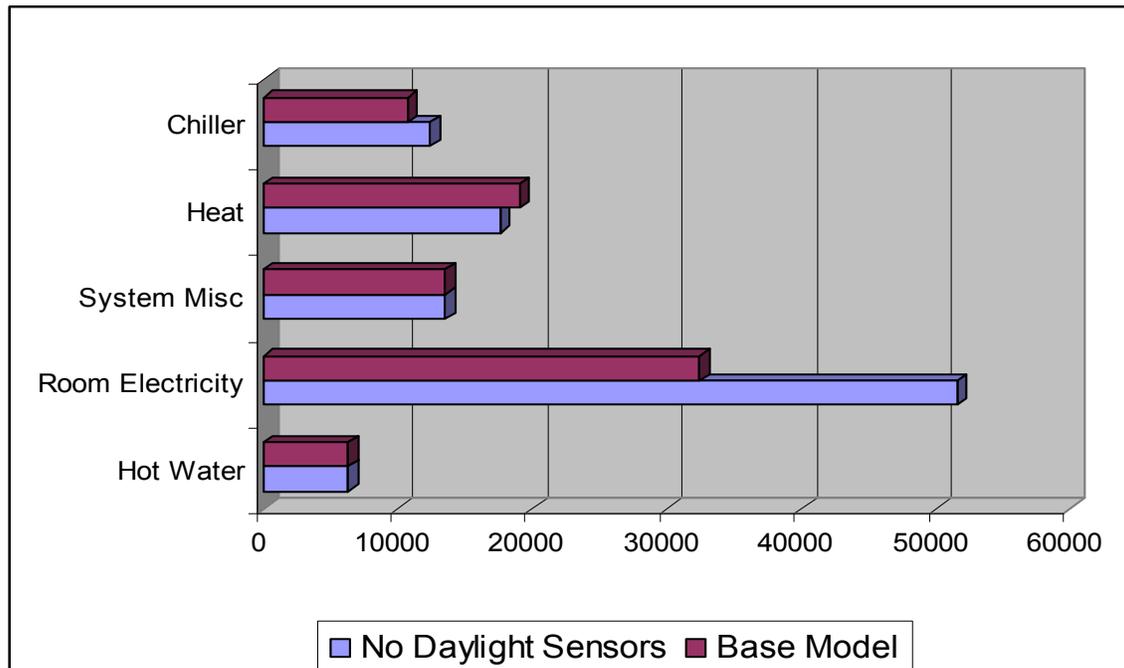
The new NJMC building includes daylight sensors which detect the level of light entering a room and control the output of the lighting fixtures so that a constant level of light is maintained. These daylight sensors save energy by reducing energy used on lighting,

which also reduces the heat gain from the lighting. This reduced heat gain lessens cooling load, but also increases the heating load. Figure 12 below shows the impact of the removing the daylight sensors on the energy consumption of the building. As is clear from Figure 12, the effect of the daylight sensors on the heating and cooling load comes close to balancing out, but the sensors create significant savings in room electricity. The lighting sensors decrease the electricity needed for lighting the building by approximately 19,000 kWh annually, which is close to 20% of the overall energy consumption of the building. Table 5 below translates this energy savings into lifetime cost savings. Even in the worst case scenario (high discount rate, low energy cost), the daylight sensors are responsible for over \$15,000 in savings. The cost of installing the daylight sensors was also \$15,000, which means that in the worst case considered, the daylight sensors were a break even feature, but under all of the other cases they provide a financial benefit in addition to the considerable energy savings they generate.

Table 5. Increased Operating Cost of No Daylight Sensors Scenario over the As-designed Base Model (50 year lifetime)

	Low Price	Mid Price	High Price
Not Discounted	\$148,213.25	\$172,601.68	\$190,484.94
<i>per sq. ft.</i>	\$15.45	\$18.00	\$19.86
7% Discount Rate	\$33,102.78	\$38,510.84	\$42,933.39
<i>per sq. ft.</i>	\$3.45	\$4.02	\$4.48
10% Discount Rate	\$22,845.81	\$26,562.74	\$29,599.47
<i>per sq. ft.</i>	\$2.38	\$2.77	\$3.09
15% Discount Rate	\$15,104.86	\$17,545.63	\$19,576.46
<i>per sq. ft.</i>	\$1.58	\$1.83	\$2.04

Figure 12. Comparison of Energy Use between As-designed Base Model and the No Daylight Sensors Scenario



Scenario V. NJMC Building Photovoltaic System

This scenario will consider the NJMC building as it has been constructed, but without the addition of the photovoltaic (PV) panels on the roof of the structure. These panels convert sunlight directly to electricity and so offset the electricity that needs to be purchased from the utility. Based on average weather conditions, it has been estimated that the panels will provide approximately 38,600 kWh of electricity annually. The revised model for this scenario will assume that all of this electricity is to be purchased directly from the utility.

In addition to the direct benefit of the produced electricity, PV panels also provide their owner with SREC's in the state of New Jersey. These certificates provide an additional income stream associated with the ownership of PV Panels. The value of these SREC's is somewhat variable, just as the value of the electricity produced is based on the current price of electricity. The costs of the PV system are comparatively static, however. The total cost of the PV system was estimated by the NJMC to be \$192,000 including the panels, supporting equipment, and labor. Using an estimated lifespan of 20 years, this

information provides the basis for our analysis of the effect of PV system on the overall cost and net present value of the building.

The present value of the PV system is based upon three variables: the discount rate, the cost of electricity, and the value of the SREC's. The chart below displays the present value of the PV system under the various conditions considered in this analysis. Where the value is negative the PV system's cost in net present terms, is greater than its benefits in net present terms. These results show that the financial viability of the PV system is very dependent on the value of the SREC's. At the current value of the SREC's, the PV system's financial benefits do not outweigh its costs at any discount rate or projected electricity cost. However, if the SREC's are valued at \$550 each, as is expected, the most favorable scenario shows the PV array adding just over \$88,000 to the value of the building, in net present terms.

Table 6. Present Value of the Photovoltaic Array (20 year horizon)

Discount Rate - 7%			
	Low Price	Mid Price	High Price
SREC's @ \$240	-\$50,540.35	-\$43,496.50	-\$37,948.80
SREC's @ \$550	\$76,250.61	\$83,294.46	\$88,842.16
Discount Rate - 10%			
	Low Price	Mid Price	High Price
SREC's @ \$240	-\$78,008.54	-\$72,315.08	-\$67,744.60
SREC's @ \$550	\$23,883.24	\$29,576.70	\$34,147.18
Discount Rate - 15%			
	Low Price	Mid Price	High Price
SREC's @ \$240	-\$107,579.27	-\$103,317.20	-\$99,782.60
SREC's @ \$550	-\$32,666.53	-\$28,404.46	-\$24,869.86

Scenario VI. Global Warming

A study on the impacts of global warming on the climate of the northeastern United States was recently released by the Northeast Climate Impacts Assessment (NECIA).⁵

⁵NECIA. (2006). *Climate Change in the Northeast United States*. NECIA. Available at: <http://www.northeastclimateimpacts.org>

This study models what the climate in various northeastern cities would be under high and low emission conditions at various points in the future. This study predicts that by the end of the century, the NYC region will have summers that feel like current summers in South Carolina under the high emissions condition, and like current summers in Virginia under the low emissions condition.

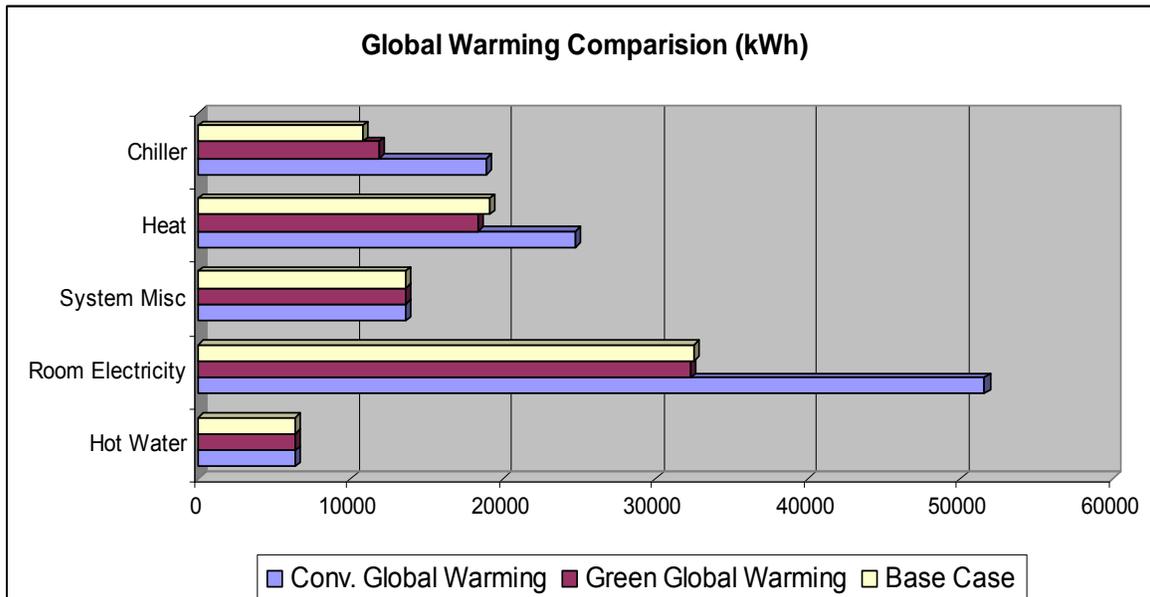
For this modeling scenario, the low emissions mid-century projections from the report were used. This includes a time period that will occur during the NJMC building’s expected lifespan, and provides a conservative estimate of the impact that global warming will have. According to the NECIA report, under the low-emission condition, the NYC region will have a climate similar to that of Washington DC between 2040 and 2069. The weather conditions in the energy modeling were altered accordingly and the results are summarized in Table 7 below.

Under the global warming scenario, the NJMC building consumes slightly more energy for cooling, but also consumes less for heating and room electricity. In total, under the global warming scenario the NJMC building uses only 160 kWh, or 0.2%, more electricity annually than it does under the current conditions. This is most likely due to the extremely efficient envelope and HVAC system, which shields the building from fluctuations in external environmental conditions. A conventional building would be much more vulnerable to increased energy costs under a global warming scenario, as Figure 13 demonstrates.

Table 7. Increased Operating Cost of Global Warming Scenario over the As-designed Base Model (50 year lifetime)

	Low Price	Mid Price	High Price
Not Discounted	\$4,749.06	\$5,530.54	\$6,103.44
<i>per sq. ft.</i>	\$0.50	\$0.58	\$0.64
7% Discount Rate	\$1,068.01	\$1,242.53	\$1,523.40
<i>per sq. ft.</i>	\$0.11	\$0.13	\$0.16
10% Discount Rate	\$737.79	\$857.86	\$1,011.82
<i>per sq. ft.</i>	\$0.08	\$0.09	\$0.11
15% Discount Rate	\$487.61	\$566.43	\$646.07
<i>per sq. ft.</i>	\$0.05	\$0.06	\$0.07

Figure 13. Global Warming Comparison Energy Consumption



This figure demonstrates the increased vulnerability that a conventional building has to the effects of global warming. Electrical and HVAC activity are considerably higher for the conventional building under global warming conditions, than they are for the new NJMC Building.

Scenario A. Effect of Energy Prices (High and Low Cases)

In recent years energy prices have been very volatile, and this volatility has contributed to the recent resurgence in the interest in energy efficiency. One of the major benefits of designing a highly efficient structure is that it insulates the owner of the building from energy price volatility. The NJMC building consumes significantly less energy than a standard comparable structure would, so energy prices make up much smaller percentage of the cost of owning and operating the building than would otherwise be the case. The table below demonstrates the lifetime energy costs at the three projected energy price cases (high, mid, and low) and the three discount rates.

Table 8. Lifetime Energy Costs of New NJMC Building

	Low Price	Mid Price	High Price
Not Discounted <i>per sq. ft.</i>	\$197,089.65 \$20.55	\$229,519.74 \$23.93	\$253,304.62 \$26.41
7% Discount Rate <i>per sq. ft.</i>	\$43,733.08 \$4.56	\$50,876.46 \$5.31	\$51,325.50 \$5.35
10% Discount Rate <i>per sq. ft.</i>	\$30,154.92 \$3.14	\$35,059.59 \$3.66	\$36,886.02 \$3.85
15% Discount Rate <i>per sq. ft.</i>	\$19,944.89 \$2.08	\$23,166.34 \$2.42	\$25,298.47 \$2.64

The very low lifetime energy costs associated with the NJMC Building create a situation where, even without discounting, the difference between high and low energy costs is only about \$65,000, while discounted the difference only ranges between \$11,000 and \$6,000. If this structure had been designed to current standards (completely conventional scenario, and no photovoltaic system) the energy consumption would be 40% higher and all the electricity would have to be purchased from a utility company, creating a situation where costs fluctuated much more based on energy prices. Table 9, below, displays the lifetime energy costs of the structure if it had been conventionally constructed. The gap between low and high energy costs widens considerably in this situation. With no discounting the difference in energy costs is approximately \$200,000, while with discounting this difference ranges between \$37,000 and \$20,000. The conventional structure is significantly more affected by changes in the price of energy than is the new NJMC building as it has been designed.

Table 9. Lifetime Energy Costs of New NJMC Building if Constructed Conventionally

	Low Price	Mid Price	High Price
Not Discounted <i>per sq. ft.</i>	\$683,492.26 \$71.27	\$795,959.28 \$83.00	\$878,434.90 \$91.60
7% Discount Rate <i>per sq. ft.</i>	\$152,241.49 \$15.88	\$177,111.47 \$18.47	\$189,653.45 \$19.78
10% Discount Rate <i>per sq. ft.</i>	\$105,029.56 \$10.95	\$122,115.43 \$12.73	\$132,922.02 \$13.86
15% Discount Rate <i>per sq. ft.</i>	\$69,452.75 \$7.24	\$80,673.47 \$8.41	\$89,217.01 \$9.30

Scenario B. Effect of Discount Rate (High and Low Cases)

The discount rate is the core of Net Present Value Analysis. It summarizes the opportunity cost associated with making a decision about how to spend money. Discount rates can be formulated as a purely financial factor, in which case the rate usually represents the return that could be received from investing a sum of money instead of spending it. However, discount rates can also be set with other factors in mind, e.g. a social discount rate to represent the consequences to society of making one decision rather than another.

In this analysis three different discount rates were selected, 7%, 10%, and 15%. These rates represent a range of potential costs associated with the decisions made in the construction of the NJMC building. As is clear from the previous scenarios, the discount rate has a powerful impact on the cost-effectiveness of various decisions. The higher the discount rate, the more necessary it is that a decision yield short-term benefits. The higher the discount rate the lower the value of future money. This effect is clear in the analysis of the PV Panels in Scenario V. Table 9 above shows the lifetime energy costs associated with operating the new NJMC building at all three discount rates as well as all three projected energy rates. As the discount rate increases the lifetime cost of operating the building decreases because the future costs, as well as future returns, are worth less than under a lower discount rate.

Scenario C. Building Lifespan

The lifespan of the building is important to consider when trying to analyze the life cycle cost of a structure. The usable life of a building has a significant impact on the acceptable payback period for investments in the building. If the developer of a building is only going to own it for a few years, it can be difficult for investments in certain systems, such as photovoltaics, to be cost-effective. However, these same investments can, over a longer term, become a cost-effective decision.

The lifespan of the new NJMC building was set at 50 years, after consultation with the NJMC. However, for this scenario, a 10 and 20 year lifespan will also be considered. These lifespan options will aid in an understanding of how the discount rate interacts

with the building lifespan in determining the cost-effectiveness of investments in building systems. Table 10 below shows the lifetime energy costs for the NJMC building using the medium price projection, but varying discount rates and building lifespans. As can be seen from the table, the undiscounted energy costs vary considerably, but as the discount rate increases the lifetime energy costs diverge less and less. Thus, in a net present value analysis the discount rate is a far more influential factor than the projected life of the building.

Table 10. Lifetime Energy Costs Using Medium Price Projection

	10 Year	20 Year	50 Year
Not Discounted	\$37,458.12	\$79,359.79	\$277,194.47
7%	\$27,446.65	\$42,164.04	\$61,508.98
10%	\$24,498.58	\$34,199.54	\$42,392.88
15%	\$20,729.36	\$25,757.49	\$28,010.36

CONCLUSIONS AND RECOMMENDATIONS

Table 11, below, presents the main green features that affect energy use that were incorporated into the new NJMC building. These features are arranged from those that are most dependably cost-effective (create a net savings under all modeled cases) to least dependably cost-effective. According to the model, the daylight sensors are the most clearly cost-effective green feature; they provide savings under all of the modeled situations and also provide the largest savings, excluding the PV array. The HVAC system is also projected to consistently provide savings, although of lower value than the daylight sensors. The insulation, on the other hand is modeled to provide savings under a majority of circumstances, but has a low return value in all cases. The cost-effectiveness of the photovoltaic panels is heavily dependent on the value of the SREC's, as discussed in Scenario V.

*Table 11. Net Costs/Savings of Green Features
(costs will appear as negative numbers in red)*

Green Feature	Least Cost-Effective (low energy price 15% discount rate)	Medium Case (med energy price 10% discount rate)	Most Cost-Effective (high energy price 7% discount rate)
Daylight Sensors	\$105	\$11,563	\$27,933
(per sq ft)	\$0.02	\$1.21	\$2.92
HVAC System	\$1,103	\$4,970	\$8,847
(per sq ft)	\$0.00	\$0.32	\$0.63
Insulation	-\$102	\$332	\$719
(per sq ft)	-\$0.01	\$0.03	\$0.08
PV Array w \$550 SREC	-\$32,666	\$29,576	\$88,842
(per sq ft)	-\$3.40	\$3.08	\$9.26
PV Array w/ \$240 SREC	-\$107,579	-\$72,315	-\$37,948
(per sq ft)	-\$11.22	-\$7.54	-\$3.96

Figure 14. Net Costs/Savings of Installed Green Features (50 year lifespan)

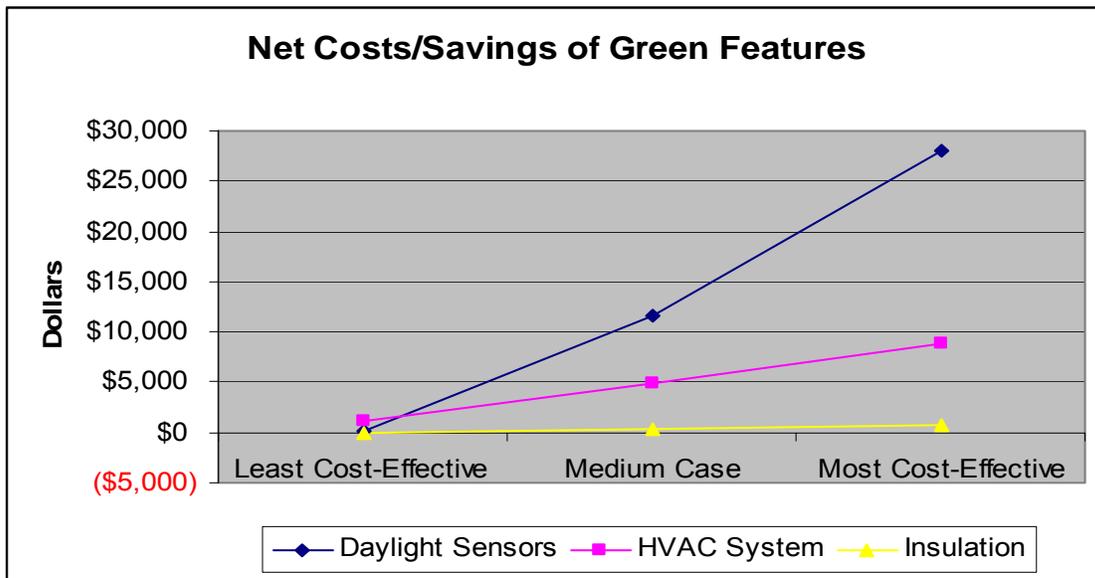


Figure 15. Net Costs/Savings of Photovoltaic System (20 year horizon)

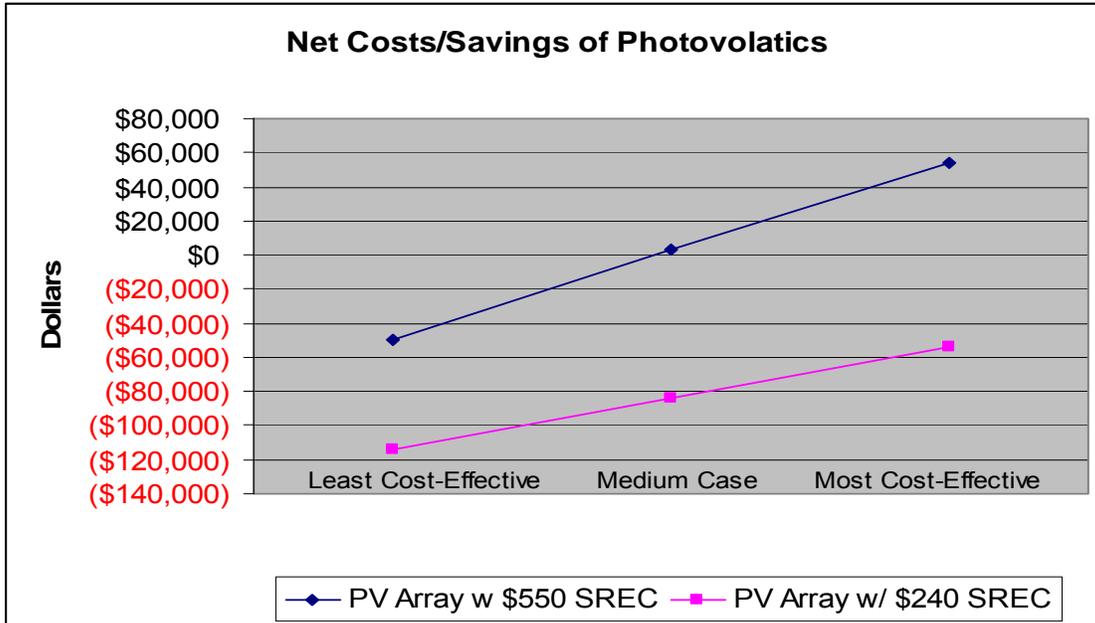


Figure 16. Effect of Discount Rates on the Net Savings/Costs of Green Features

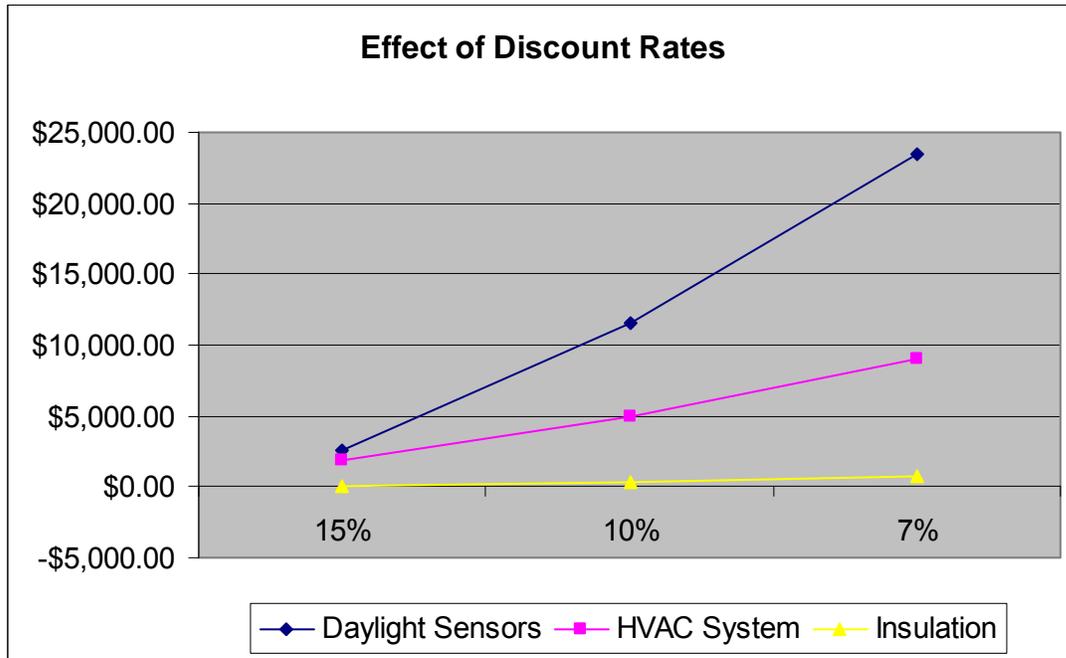
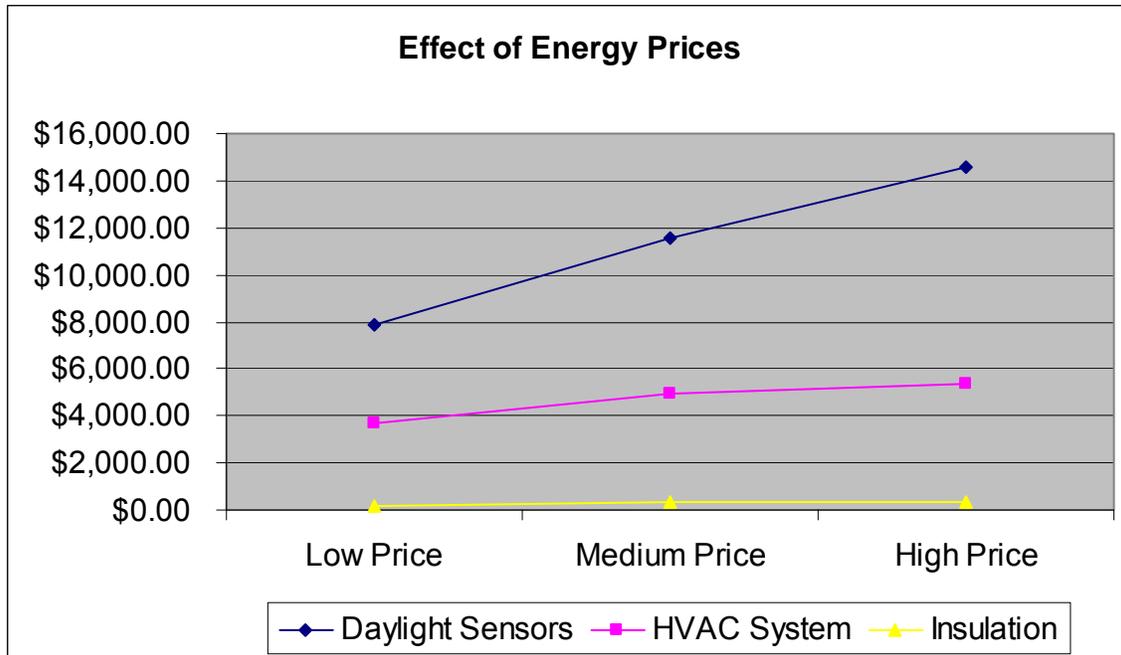


Figure 17. Effect of Energy Prices on the Net Savings/Costs of Green Features



This study also clearly demonstrates the usefulness of Life Cycle Costing in the design of a green building. If energy modeling is done early in the design process and combined with the LCC approach used in this study it can provide a powerful tool for choosing energy efficiency features for a project. The LCC offers insight into the long term costs and benefits that will arise from various choices and provides a relatively low-cost way to compare various design alternatives.

The incorporation of the LCC process into green building design will allow the construction of more energy and cost-efficient green buildings. Also, once a large number of LCC analyses have been conducted, general guidelines about which green features tend to be the most energy efficient and cost-effective will be available. This information could form the core of a set of green building guidelines.

However, it is important to remember that modeled results are not identical to actual results. For example, a recent study released by the New Buildings Institute (NBI) on the energy efficiency of LEED NC buildings found that the Energy Use Intensity (EUI) or (kBTU/sf/yr) for over ½ of the LEED NC projects in the study deviated by more than 25% from design projections, with 30% higher and 25% lower than the initial modeling projections.⁶ The authors noted that variations in results are likely to come from:

- Differences in operational practices and schedules
- Equipment performance
- Construction changes

In addition, systems such as the daylight sensors and HVAC systems are subject to the actions of the occupants, which can differ significantly from their modeled actions. Occupants may override the daylight sensors to increase the lighting level or may choose to set the HVAC system at temperatures that are not optimal for performance. For these reasons and other practical considerations, it is important to compare the results of modeling, such as was conducted in this study, to actual monitoring. Actual data would provide useful calibration for the model and would allow for more accurate predictions to be made in the future. It is also important to note the discrepancies

⁶ Turner, C, Frankel, M (2008) "Energy Performance of LEED for New Construction Buildings." New Buildings Institute.

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between modeled and actual performance to understand if there are flaws in the logic underlying the models.

Building Performance Evaluation (BPE) provides one method for acquiring the data necessary for such comparisons and also provides data on the effects of the building upon its occupants. BPE is a method of providing feedback on whether a building is performing as intended, and if so, whether it is performing optimally. To date, most BPE studies of green buildings have focused on more easily quantifiable criteria such as energy use, resource efficiency and physical measurements of environmental conditions. However, green buildings are being credited with improving occupant well-being, and productivity – improvements that have been linked to economic benefits. These claims about potential benefits to occupants make it essential to establish a solid foundation of understanding on how green buildings impact occupants. Building occupants represent a wealth of information about how well a building works. Surveys of occupant satisfaction allow designers, developers, owners, operators, and tenants to objectively gauge effectiveness of building design features and technologies. The information is especially useful for companies interested in optimizing employee productivity or for facility managers and building owners involved in acquiring, operating, and improving their building portfolios. Surveys can provide both diagnostic and benchmark data, helping to positively influence building performance for occupants of existing as well as future buildings and also inform the design community about the effectiveness of specific technologies and strategies.