INTEGRATING PHOTOVOLTAIC SYSTEMS INTO PUBLIC SECTOR PERFORMANCE CONTRACTS IN DELAWARE

FINAL REPORT

A Renewable Energy Applications for Delaware Yearly (READY) Project

Center for Energy and Environmental Policy
University of Delaware

February 2006

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A Renewable Energy Applications for Delaware Yearly (READY) Project

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1. Introduction

1.1 READY Project Mission

The purpose of the Renewable Energy Applications for Delaware Yearly (READY) project is "identifying high-value, high-visibility renewable energy applications; determining approaches to encourage renewable energy suppliers to enter Delaware markets; developing creative and effective education and consumer outreach regarding renewable energy technologies."

1.2 Photovoltaics in Performance Contracts: An Overview

This report explores the feasibility of using energy efficiency financing mechanisms to deploy solar energy systems on public buildings in Delaware.

2. Background

2.1 Performance Contracting

Performance contracting refers to the practice of financing energy services based on the savings stream that those energy services are projected to generate. To enter into performance contracts, facilities contract with private companies known as energy service companies (ESCOs) to finance and install energy conservation measures. The resulting utility bill savings are used over time to pay both the ESCO for its services and to pay back funds borrowed to finance the installations.

The institutional sector is the largest market for performance contracting services, and it is estimated that government agencies, universities, hospitals and schools invested between $15 and $19 billion in energy efficiency upgrades between 1990 and 2003 (Hopper et al., 2005). State government agencies, in particular, are increasingly taking advantage of performance contracting. State government projects accounted for 11% of the performance contracts before 1996, and 15% in the years since 1996 (Goldman et al., 2002). This increase occurred while the performance contracting market grew at an average annual rate of 24% (Hopper et al., 2005).

The expansion of state government performance contracts is attributable to several factors. First, the market for performance contracting has matured over the past two decades and has gained recognition as an effective tool for technology procurement. Second, the number of states with regulations enabling performance contracting for state agencies has expanded to 48 (Energy Services Coalition, 2005). Third, the advanced age of many state buildings, coupled with limited state funding for facility capital improvements has created opportunities for alternative financing arrangements. By using performance contracts, facility managers can correct operational inefficiencies without increasing their budgets. In addition, several studies have demonstrated that performance contracting can be a more cost-effective means for funding upgrades than direct appropriations, since a reliance on direct appropriations can delay the start of a project by several years (Hopper et al., 2005; Zobler & Hatcher, 2003).

Another important benefit of performance contracting, especially within the institutional sector, has been the ability to leverage operational savings (e.g., actions that lower energy or water billings) to finance capital investments with lengthy payback periods. In performance contracts, technologies with longer paybacks can be bundled with quicker payback technologies, such as lighting upgrades, to produce a blended payback term acceptable to the state. Many states encourage their agencies to use this dynamic to their advantage and to avoid "cream skimming," defined as the installation of only the quickest payback technologies (Raman, 1998; South Carolina Energy Office, 1998). During the past decade, there has been a distinct trend away from "cream skimming" in the institutional sector. Projects incorporating only lighting constituted 20% of the public sector ESCO market in the 1990s, but by 2004, only 7% of performance contracts incorporated only lighting. During the same period, the number of projects incorporating capital-intensive HVAC technologies rose from 16% to 27%, and the number of projects incorporating distributed generation systems rose from 2% to 9% (Hopper et al., 2005).

2.2 PV and Performance Contracting

Solar electric, or photovoltaic (PV), systems provide a wide range of non-commodity benefits[1] to facilities that employ them, to utilities, and to society as a whole. As an energy technology that generates electricity where it is consumed, PV reduces system-wide peak demand, reduces air pollution, natural gas prices, improves grid efficiency and reliability, and lowers investments in transmission and distribution infrastructure by decongesting lines during high-demand periods. Three recent studies that quantify these non-commodity benefits estimate that their added-value ranges from between 7.8 ¢/kWh and 35.2 ¢/kWh (Americans for Solar Power, 2005; Duke et al., 2005; Smeloff, 2005). Because many of these values are difficult to monetize, the high up-front capital costs of PV systems remain a barrier to widespread adoption of PV systems. With performance contracts, however, state agencies can advantageously bundle PV with energy efficiency technologies and install the systems at no up-front cost.

While blending photovoltaics into performance contracts was not widely practiced before 2000, recent research conducted by CEEP has revealed that the last three years has seen a sharp increase in such projects and that the model is increasingly gaining acceptance in different states and at different levels of government. The first projects, including a system analyzed by CEEP on behalf of the National Renewable Energy Laboratory (Byrne, Agbemabiese et al., 1999), were small and located in California. More recent projects have ranged up to 1.2 megawatts (MW) and have been successfully sited in New Mexico, Maryland, Connecticut, New York, and elsewhere. In 2003, performance contracts served as the vehicle for over 10% of US grid-connected PV installations, or approximately 3.4 megawatts (MW) of installed capacity (Rickerson, 2004).

The Federal government pioneered the use of performance contracts to install PV systems on its facilities. Executive Order 13123 from 1999 set a target of 20,000 PV installations on

[1] Commodity benefits include PV's generation of kWhs of electricity sold, through net metering, into the grid. Non-commodity benefits encompass services provided by PV such as non-polluting power, uninterruptible power supply (when storage is included with a PV system) and peak-shaving of a building's electricity demand (measured in kWs).

government facilities, and explicitly encourages agencies to bundle energy efficiency projects with renewable energy projects in performance contracts. Agencies are to "use savings from energy efficiency projects to pay additional incremental costs of electricity from renewable energy sources (Sec. 404.c.1)." In response to this emphasis on renewable energies, several facilities have incorporated PV into their performance contracts. Naval Base Coronado in San Diego, for example, installed a 750 kilowatt (kW) PV system as part of a $22 million contract. The PV system, which had a 38-year simple payback, was bundled with other energy conservation measures, including lighting and air compressor upgrades, for an overall simple payback of 9.8 years (Neeley, 2003).

2.3 PV Performance Contracting in Delaware

In 2003, Governor Minner's Delaware Energy Task Force (2003) concluded that distributed energy resources should be deployed on both private and public property in order to reduce the environmental impacts of energy use, increase energy security, and encourage economic development. One of the priority recommendations from the Task Force was to extend performance contracting authority to all state agencies. Prior to the release of the Task Force report, Delaware law provided for only a limited form of performance contracting for school districts. State facilities were therefore unable to use performance contracting as a vehicle for installing photovoltaic systems

Responding to the Task Force recommendations, the Delaware General Assembly passed Senate Bill (SB) 73, sponsored by Senate Majority Leader Harris B. McDowell, III in May 2005. In addition to providing state agencies with the authority to enter into performance contracting, SB 73 encourages state agencies to integrate renewable energy systems into their performance contracts. Section §6972 of SB 73 states that, "Where appropriate, agencies shall determine cost-effectiveness based on the life-cycle costs of combinations of conservation measures, particularly to encourage bundling of energy efficiency projects with onsite generation and renewable energy projects" (Delaware State Senate, 143rd General Assembly, SB no. 73, lines 81-83).

With the passage of SB 73, Delaware can now replicate the success of other federal and state agencies and use performance contracting to leverage renewable energy systems like PV on state buildings. Implementing performance contracts with PV would allow Delaware state facilities to install sources of reliable onsite power, while improving the overall energy performance of its buildings. Additionally, such projects would help achieve the goals articulated in Strategies 1, 2, 3, 4, 7 and 8 of the Energy Task Force Report (see Appendix).

3. Data and Methodology

3.1 Research Design

In anticipation of performance contracting authority being granted to state buildings in Delaware, CEEP proposed in its READY program (see p. 1 of this report) to analyze the feasibility of installing PV systems through performance contracts on several different Delaware public buildings.

This project was conducted in three phases. In the first phase, CEEP researchers worked with the Delaware Energy Office to identify state buildings that would be strong candidates for both performance contracts and for PV installations. In the second phase, CEEP collected data on energy consumption and the potential for both energy efficiency and PV installations at the target sites. In the third phase, CEEP used the *PV Planner* software package it developed under contract to the National Renewable Energy Laboratory to analyze the technical and economic performance of PV systems mounted on the target buildings in both peak shaving and emergency power applications. This section of the report describes the data collected during each phase of the project.

3.2 Phase 1: Identifying Candidate Buildings for Analysis

In selecting candidate buildings for analysis, CEEP worked closely with the Delaware Energy Office to survey Delaware's stock of 900 public buildings. CEEP eventually selected two buildings out of 12 potential candidates.

CEEP had previously conducted *PV Planner* analyses in 1999 (Byrne and Boo, 1999) for seven of the buildings under consideration. Under contract to the National Renewable Energy Laboratory and the Delaware Division of Facilities Management, CEEP researchers analyzed the economic performance of a PV system coupled with battery storage and configured to serve both a peak shaving and an emergency power function on seven State facilities. These buildings included the Wilmington Family Court, the William Penn Building, the Delaware Transit Authority building, the Division of State Services building, the Emily Bissell Hospital, the Governor Bacon Health Center, and the Stockley Health Center.

The other five buildings under consideration included Legislative Hall, the Jesse Cooper Building, the Townsend Building, the Highway Administration Building, and the Richards & Robbins Building. Using a grant received from the US EPA, the Delaware Energy Office commissioned formal energy audits for these buildings. 2rw Consultants, Inc., an engineering firm from Charlottesville, VA, audited the light and heating, ventilation and air-conditioning (HVAC) systems for each facility and identified the costs and savings of potential energy efficiency upgrades in their final report in 2004 (2rw Consultants Inc., 2004).

For the purposes of this project, the CEEP research team prioritized the buildings for which energy audits existed over those for which PV analyses had already been conducted. Since most of the audited buildings lay within the City of Dover's Historic District, CEEP also consulted the Dover Department of Planning and Inspections and determined that solar panels cannot be sited on buildings in the Historic District if they are visible from the street. Using the savings potential identified by 2rw, and the requirements of the Historic District as criteria, the CEEP research team selected the Highway Administration Building and the Richards and Robbins Building the analysis.

3.3 Phase 2: Data Collection

3.3.1 Delaware's Solar Resource

As has been frequently reported (Applied Energy Group, 2002; Byrne and Boo, 1999; Center for Energy and Environmental Policy, 2005), the solar resource in Delaware is adequate to support photovoltaic systems. As can be seen in Figure 1, Delaware's annual average solar radiation is above 4 kilowatt-hours on each square meter each day.

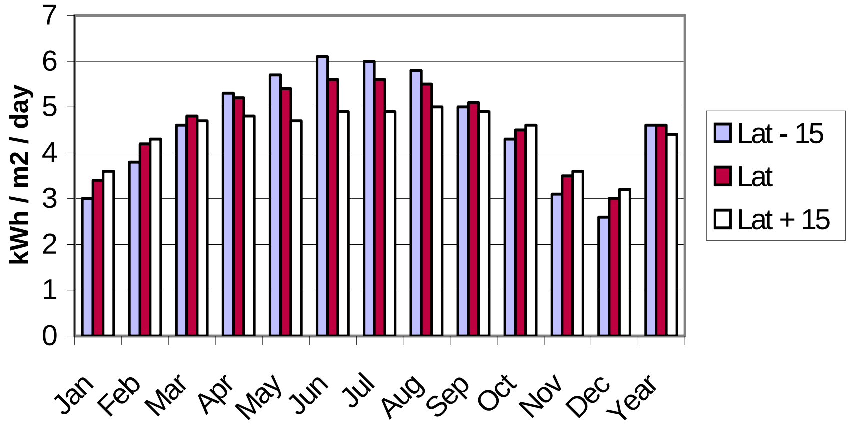

Figure 1. Average Solar Radiation on Stationary Solar Model at Varying Installed Tilt Angle
Source: (NREL, 1995)

The analysis in this report will focus not on whether there is enough sunshine, but how the technical performance of the PV system relates to the electricity rates paid by the buildings, how the PV system can best be configured to maximize economic performance, and how the savings generated by an onsite PV system can be blended into a performance contract with other energy conservation measures.

3.3.2 Dover Electricity Tariffs

Both of the selected facilities are sited within the service territory of the City of Dover Electric Utility and both are subject to the utility's Medium Commercial Service Classification rate structure (Table 1). This class is described as having monthly usage greater than 3,500kWh for at least two consecutive months, or having a measured demand greater than 300kW (City of Dover Electric Utility, 2005). As can be seen in Table 1, medium commercial customers are charged $0.052 per kilowatt-hour in summer, and $0.046 per kilowatt-hour (kWh) in winter. They are also charged $10.75 per kilowatt of demand in summer and $7.80 per kilowatt of demand in winter. These rates are significantly lower than the national retail average and pose challenges to PV economic performance as will be discussed in greater detail below.

Table 1. City Of Dover Medium Commercial Service

Charge	Summer (June-October)	Winter (November-May)
Customer Charge	$5.00	$5.00
Demand (kW)	$10.75	$7.80
Energy (kWh)	$0.0521	$0.0460

Source: (City of Dover Electric Utility, 2005)

3.3.3 Data for the Richards and Robbins Building

The Richards and Robbins Building houses the Department of Natural Resources and Environmental Control (DNREC) whose stated mission is “to protect and manage the state's vital natural resources, protect public health and safety, provide quality outdoor recreation and to serve and educate the citizens of the First State about the wise use, conservation and enhancement of Delaware's Environment.” DNREC manages a wide range of programs related to Delaware’s natural environment including air and water quality control, waste management, State parks maintenance, fish and wildlife management, and soil conservation.

The Richards and Robbins Building houses approximately 310 state employees. It is divided into three sections: Sections A and B, which house the administrative offices of DNREC and are two stories tall; and Section C, which houses the DNREC environmental laboratory and is one story high. The building was initially constructed in 1882, but was significantly renovated an expanded in 1983. The current facility is 105,000 square feet.

Energy Consumption
CEEP worked with 2rw and the Delaware Energy Office to collect historical electricity usage data for the period 2002 to 2004. Data from the Delaware Electric Utility shows that the Richards and Robbins Building consumed an average of 3,340,800 kWh each year, and experienced load growth of 5.21%. The facility’s demand varied from 468 kW-month to 678 kW-month. Hourly load data were not available.

Audit Results
The 2rw energy audit identified several lighting and HVAC measures that could be undertaken at the Richards and Robbins Building including: new energy efficient lighting, new lighting controls, the installation of a new air handling unit (AHU), HVAC temperature setting modifications, HVAC unit cleaning, and HVAC unit testing, adjusting and balancing (TAB).

Lighting
The 2rw audit determined that the Richards and Robbins Building’s lighting is a mixture of old and new technologies. While the laboratory sections of the building are equipped with energy efficient T-8 florescent lights, the offices are lit predominantly with less efficient T-12 florescent tubes. The recommended upgrades include replacing T-12 florescent lights with T-8 lamps and ballasts, and replacing incandescent bulbs with compact fluorescent lights (CFL). The lighting upgrades are projected to cost $95,663 with a simple payback of 7.4 years. The audit also recommended the installation of lighting occupancy sensors for $30,172 with a simple payback of 10.2 years.

HVAC

The 2rw audit recommended four energy conservation measures for the heating, ventilation, and air-conditioning (HVAC) system of the Richards and Robbins Building.

New air filters: To combat poor air quality in the Richards and Robbins lab, DNREC staff replace air distribution grille filters once each week. 2rw determined that the poor air quality results from missing filters in the main air handler unit. It recommends that the ventilation system be thoroughly cleaned, that the missing air handling unit filters be replaced, and that a filter monitoring system be installed. These measures are projected to cost $7,318 with a simple payback of 1.3 years.

Night setback: 2rw concluded that allowing the temperature in the Richards and Robbins Building to drop from 72º F to 68º F during unoccupied hours in the winter would save $5,037 per year with no upfront cost.

New air handler unit: The current air handling unit in the Richards and Robbins lab uses 100% outside air. Conditioning outside air is costly, and a smaller air handling unit could ventilate the lab by using a lesser amount of outside air. 2rw recommends installing a new, smaller AHU in parallel to the existing AHU. The new AHU would be the primary ventilation system while the existing AHU system would serve as a back-up. While the new air handling unit will cost $31,742, it will save $59,134 per year and pay itself back within the first year of operation.

Testing/adjusting/balancing and recommissioning: Airflows, indoor temperature, and staff comfort have been difficult to balance at the Richards and Robbins Building. 2rw recommends that, after the other HVAC upgrades in place, the system should be exhaustively tested and adjusted so that the different components functioning properly as an integrated system. This process is projected to cost $60,091 with a payback of 16.8 years.

The cost and projected performance of the lighting and HVAC energy conservation measures for the Richards and Robbins Building are summarized in Table 2.

Table 2. Summary of Proposed ECMS at the Richards and Robbins Building

Energy conservation measure	Cost savings ($/yr)	Implementation cost	Payback (yr.)	Electricity reduction (kWh/yr)	Natural gas reduction (ccf/yr)	CO_2 reduction (tons/yr)
Lighting: replacements	$13,002	$95,663	7.4	169,396	-3,970	158.6
Lighting: controls	$2,969	$30,172	10.2	83,795	-1,964	78.4
HVAC: AHU cleaning & filters	$5,800	$7,318	1.3	0	0	0
HVAC: night setback	$5,037	$39	0	0	5,119	28.7
HVAC: install new AHU	$59,134	$31,742	0.5	248,597	45,111	518.6
HVAC: TAB & recommissioning	$3,578	$60,091	16.8	60,653	646	68.4
TOTALS	$89,520	$225,025	2.5	562,411	44,942	852.8

Source: (2rw Consultants Inc., 2004)

The proposed energy conservation upgrades identified by 2rw demonstrate the importance of bundling short-payback measures with longer-payback measures. With a simple payback period of 16.8 years, it is unlikely that the HVAC testing, adjusting, and balancing could be undertaken on its own through a performance contract. The reason is that Delaware performance contracting law caps performance contract duration at a 20-year maximum. When the costs of financing are taken into account, an energy efficiency measure with a 16.8 year payback could exceed this horizon.

By bundling the HVAC TAB with quick payback measures like the new air handler, and the night setback, however, the total project has a simple payback of 2.5 years. As will be discussed below, this dynamic could be leveraged to install PV on the Richards and Robbins Building.

Roof
A site visit conducted by a member of the CEEP research team collected basic characteristics of the building's roof to determine whether it was suitable for PV installations. The Richards and Robbins Building's roof (Figure 2) is flat and made of concrete slab, with a rubberized decking. The roof provides ample, unobstructed space for a much larger PV system than the size analyzed in this report.

Figure 2. Richards and Robbins Building Roof
Source: (CEEP, 2005)

3.3.4 Data from the Highway Administration Building

The Highway Administration Building houses the Delaware Department of Transportation. It has recently undergone major renovations, including a large addition, and interior renovations are ongoing. The original building was constructed in 1971 and is 168,494 square feet in size. It is divided into four wings. Originally, the building consisted of what is now known as the East and West Wings. After 2000, a South and North Wing were added to the building, while the West Wing was renovated. There have also been significant renovations to the ventilation and controls systems of the building during the last ten years. There are currently approximately 380 employees working at the Highway Administration Building.

Energy Consumption
The data supplied to CEEP on the historical electricity usage shows an average electric usage of 2,710,160 kWh/yr for the years 2003-2004. A load growth of over 10% is shown between these years, and may be attributed to the expansion and renovations at this site. The available data also shows a demand ranging from 347 kW-month to 508 kW-month. Hourly load data were not available.

Audit Results
Similar to the Richards and Robbins Building, 2rw identified opportunities for both lighting and HVAC upgrades, including efficient lights, lighting controls, and a revalving of the HVAC system water pumps.

Lighting
The Highway Administration Building has fewer opportunities for lighting efficiency improvements than the Richards and Robbins Building does. The recently renovated South and West Wings of the building are already lit by T-8 lamps, as is the newly constructed North Wing of the building. There remain many T-12 and incandescent fixtures in the East Wing of the building. As with the Richards and Robbins Building, 2rw recommends replacing all of the T-12 flourescent lights with more efficient T-8 lights and ballasts and replacing all of the incandescent bulbs with CFLs. Where there is adequate daylighting, 2rw also proposes installing sensors that would dim internal lighting when sufficient levels of sunlight are detected. 2rw also proposes installing occupancy sensors in several rooms that shut off lights when the rooms are unoccupied. The lighting replacements and lighting controls are projected to cost $17,390 and $2,716, respectively, with simple paybacks of 6.4 and 5.5 years.

HVAC
The HVAC system in the Highway Administration Building is relatively efficient and there were few opportunities for quick payback improvements. 2rw concludes, however, that the mechanical plant's chilled water pumps could operate more efficiently at variable speeds. While the system is capable of variable speed operation, it currently uses 3-way valves that only permit constant speed operation. 2rw proposes replacing the 3-way valves with 2-way modulating control valves to increase the efficiency of the pumps and achieve an annual savings of $9,554. The cost of the valve replacement is projected to be $76,676, for a simple payback of 8 years.

The overall cost of the lighting and HVAC measures would be $96,782, while the annual savings stream generated would be $12,781. The resulting simple payback for the entire project is 7.6 years. The costs and performance of the proposed energy conservation measures for the Highway Administration building are summarized in Table 3. Although the annual savings stream is not as significant as that of the Richards and Robbins Building, it is still sufficient enough to allow for properly-sized solar energy installations to be advantageously blended into a performance contract.

Table 3. Summary of Proposed ECMs at the Highway Administration Building

Energy conservation measure	Cost savings ($/yr)	Implementation cost	Payback (yr.)	Electricity reduction (kWh/yr)	Natural gas reduction (ccf/yr)	CO_2 reduction (tons/yr)
Lighting: replacements	$2,731	$17,390	6.4	54,374	-1,274	50.9
Lighting: controls	$495	$2,716	5.5	14,049	-329	13.2
HVAC: variable flow pumping	$9,554	$76,676	8.0	196,982	0	210.3
TOTALS	$12,781	$96,782	7.6	265,405	-1,604	274.4

Source: (2rw Consultants Inc., 2004)

Roof

The site visit to the Highway Administration Building revealed that it, too, has a large, flat, and unobstructed roof that could accommodate a sizable photovoltaic installation (Figure 3).

Figure 3. Highway Administration Building Roof
Source: (CEEP, 2005)

3.4 Phase 3: *PV Planner* Analysis Assumptions

Having gathered the requisite data on building energy consumption and energy efficiency potential, the CEEP research team used the *PV Planner* software package to model potential solar installations on each building and determine the optimal system configuration.

3.4.1 A Description of *PV Planner*

PV Planner is an analytical software program developed by CEEP (under contract to the National Renewable Energy Laboratory) to assess the resource and economic aspects of PV systems (Center for Energy and Environmental Policy, 1996). This software can simulate the performance of a PV system operating in a dispatchable mode (i.e., a system with battery storage) or as a direct or non-dispatchable system (i.e., without battery storage). Energy value (in the form of kWhs generated per hour per day) and demand value (in the form of peak kW-shaving with and without storage) are calculated for each configuration (rooftop or façade-embedded PV systems can be analyzed) and each type of PV technology (based on cell efficiencies) and associated (e.g., inverters and their efficiencies). Economic benefits and costs are assessed using the financial analysis methods employed by utilities and commercial enterprises. Economic performance is measured as net present value, and a payback period and benefit-cost ratio is calculated for each configuration. *PV Planner* calculates payback period in years as the time when cumulative cash flow (including annualized O&M costs) first becomes zero.

3.4.2 Parameters

Key model parameters are discussed below. A complete listing of assumptions can be found in the appendix.

Sizing of the PV system
The size of the PV system was chosen by trial and error experiments on a range of kW sizes with *PV Planner*. The PV system size with the best economic performance, in terms of positive net present value (NPV) was selected. For this study, the research team determined that a 1.4 kW system is optimal.

Costs of the PV system
Costs of the PV system vary for different manufacturers, type of PV systems and differences in installation costs. For analysis in this study, an installed cost of $6500/kW is assumed. This would include PV panels purchased at $3.00-$4.50 per Wp and is consistent with research findings (Solar Energy Industry Association, 2004; solarbuzz.com, 2006). This installation cost includes a SolarDock PV panel mounting system manufactured by McConnell Energy Solutions of Wilmington, Delaware. The SolarDock system is a ballasted aluminum rack that requires no roof penetration and therefore avoids concerns over leaks. While other commercially available, non-roof penetrating mounting systems are flat, the SolarDock system has a fixed tilt of 25º. Because this tilt is closer to the optimal tilt for energy generation at Dover's latitude, PV systems mounted on the SolarDock perform better than flat-mounted systems.

Maintenance Costs
Regular maintenance will ensure proper system performance. In this study, the following maintenance conditions are assumed for the system: for every 5 years, there is a regular PV maintenance; the cost is at 0.6% of PV system cost; for every 20 years, a power conditioning system overhaul is performed at $200/kW AC; battery replacement happens every 8 years, at a cost of $200/kW. Other maintenance costs are included in a maintenance contingency, which is assumed to be 3% of system cost (except for the PV panels, which do not need replacement for 30 years).

Evaluation Period
The system was analyzed over a life time of 30 years, which is consistent with research on the operating life of PV panels (Realini et al., 2002).

3.4.3 Policy Incentives

There are several policy incentives available to onsite photovoltaic systems that were taken into consideration: net metering, tax credits, solar rebates, and the renewable portfolio standard.

Net metering is a policy that allows solar system owners to sell their excess electricity back to the utility at retail rates. While systems of up to 25 kW are permitted to net meter in Delaware, the output of the 1.4 kW system will be absorbed by the building load, so there is little reason for either of the facilities would need to take advantage of the policy.

The recently passed federal corporate tax credit for solar energy installations was also considered. Currently, there is a tax credit equal to 10% of PV system cost available to commercial and industrial customers. The Energy Policy Act of 2005 (H.R. 6) expands that tax credit to 30% of PV system costs beginning in January, 2006. To be eligible for the 30% credit, the system must be installed between January 1, 2006 and December 31, 2007. Because both of the buildings in question are public entities that do not pay taxes, they are not directly eligible for the tax credit. As will be discussed in Section 4, however, certain types of performance contracts allow a private company called an ESCO (or energy service company) to maintain initial ownership of the PV system, take advantage of the tax credits, and pass the savings onto a public facility after the ESCO recovers its costs and expected rate of return.

The third policy is the solar energy rebate. In the Delmarva Power utility territory, a surcharge of $0.00178 is assessed for each kilowatt-hour of electricity sold to residential users. This surcharge is collected in a fund for alternative energy development administered by the Delaware Energy Office. Through this fund, the Delaware Energy Office offers a rebate of 50% of the installed cost of solar energy system.[2]

Because the buildings in this analysis are located in Dover Utility's territory, they are ineligible to participate in Delmarva Power's green energy fund (Burton and Gallagher, 2003). With the passage of Delaware's renewable portfolio standard (RPS) in 2005, however, the municipal utilities are permitted to opt out of the RPS requirements if they start an alternative energy fund with a surcharge equal to Delmarva Power's. While the municipal utilities have not formally announced plans to opt out of the RPS, Section 4 analyzes a case in which the municipal utilities opt out of the RPS, and institute solar energy funding at a level commensurate with the Delmarva Power green energy fund.

The fourth policy taken into consideration is the renewable portfolio standard. The RPS requires that 10% of the electricity sold at retail in the state come from renewable energy sources by 2019. The RPS is based on a system of tradable renewable energy credits (RECs) that utilities must procure in order to demonstrate RPS compliance. In most cases, each megawatt-hour of renewable generation is awarded a credit that can be sold on the open market. Solar PV systems in Delaware, however, are awarded triple credit for each megawatt-hour of electrical output.

[2] It should be noted that the 30% tax credit is calculated based on the after-rebate system cost. In other words, the 30% tax credit is calculated after the 50% green energy rebate has been deducted from the system cost.

At present, there are 11 RPS laws in the United States that utilize tradable credit mechanisms.[3] Credits trade on the open market for between $0.70 and $51.00 per megawatt-hour, with credit prices determined largely by the structure of the RPS (Evolution Markets LLC, 2005). For purposes of this analysis, we used New Jersey's current credit price of $7.00 per MWh since the structure of Delaware's RPS is similar to New Jersey's. With Delaware's triple credit multiplier, solar generators could sell their RECs for $21.00 per MWh, or $0.021 per kilowatt-hour in the RPS market. In our analysis, we round down to $0.02 per kilowatt-hour.

If the municipal utilities opt out of the Delaware RPS, then solar systems located within a municipal territory will be eligible to sell credits in the Delaware market. A second condition to opting out of the RPS, however, is that municipal utilities must give their customers the option to purchase green power instead of the municipal utility's standard generation mix. This requirement creates another opportunity for solar generators to sell renewable energy credits. Since Delaware's municipal utilities currently do not own any renewable generation, it is highly likely that they will have to purchase renewable energy credits from brokers and generators to supply their green power programs. While the voluntary REC market is less transparent than the market for RPS RECs, it is likely that solar RECs could be sold for between $0.01 and $0.03 per kilowatt-hour (Evolution Markets LLC, 2005; personal communication with Mainstay Energy, May 2005). Solar generators, therefore, could choose to sell either into the RPS market or into the voluntary green power market, depending on which market was more favorable.

4. Results of *PV Planner* Analysis

Using the assumptions and parameters described in Section 3 and the appendix, the CEEP research team developed a series of case studies to analyze the economic performance of the proposed PV system. Four distinct cases were considered using *PV Planner*: a base case system with tax credits, but without storage or other incentives; a dispatchable peak-shaving PV system; a dispatchable PV system configured to also supply emergency power; and a dispatchable peak-shaving system that takes full advantage of policy incentives that may become available in the near future. Table 4 shows the results of the *PV Planner* analysis. Each of these cases is described and analyzed in detail below. The environmental benefits of the PV installation are also estimated.

[3] These jurisdictions are: Connecticut, Delaware, Maine, Maryland, Massachusetts, Montana, New Jersey, Pennsylvania, Rhode Island, Texas, Washington, DC.

Table 4. Results of *PV Planner* Analysis

Initial Cost ($)	Emergency Power Avoidance ($)	Green Energy Fund ($)	O & M Cost ($)	Net Present Value ($)	Benefit-Cost Ratio	Payback Period (years)
Base Case PV Installation						
9,291.87	NA	NA	334.27	-3,597.19	0.68	NA
Dispatchable Peak Shaving PV System						
10,449.42	NA	NA	2,020.57	-1,262.92	0.91	NA
PV System Configured to Supply Emergency Power and Peak Shaving						
10,449.42	2,020.57	NA	1,297.43	81.94	1.01	3.82
Dispatchable PV System with 50% Rebate and REC Sales						
10,449.42	1,297.43	4,634.79	2,020.57	3,806.47	1.52	2.72

4.1 Base Case (non-dispatchable configuration with tax credits, no other incentives)

For the base case, it was assumed that a 1.4 kW PV system is installed on the roof of each building without batteries and without the benefit of any policy incentives outside of the 30% tax credit. Because the PV system is not paired with battery storage, the PV system's output is consumed directly by the facility at the time of production. Forgoing storage reduces overall PV system cost. However, the potential peak-shaving and emergency power benefits of the PV installation are not fully captured in non-dispatchable systems.

As can be seen in Table 4, the non-dispatchable system does not perform well economically on its own. The benefit cost ratio of 0.68 indicates that the lifecycle costs of the system exceed its lifecycle benefits. The "N/A" value in the payback period cell indicates that the system does not pay for itself during its expected operating life. In other words, although a simple payback period for this system could be calculated, that payback period is longer than the assumed 30-year system life.

4.2 Peak Shaving Case (dispatchable configuration with tax credits)

The most obvious benefit of a PV system to an end-user is the reduction in the amount of retail electricity purchased from the grid. Most utility bills, however, consist of both a volumetric energy charge and a demand charge. The demand portion of the bill is typically a fixed fee based on a building's peak load. In the case of commercial or public buildings, this demand charge can represent a larger portion of the bill than the kilowatt-hour sales charge (Byrne et al., 1998). It is therefore advantageous for commercial customers to develop load management strategies. Studies conducted with satellite imaging have shown that PV output correlates well with the demand curves and peak prices of many utility service areas (Letendre et al., 2003). From an end-user perspective, this means that PV is likely to reduce demand charges by producing electricity when demand is at its highest.

This peak shaving capability is limited by the inherent intermittence of PV output. If a building's peak load occurs in the morning, instead of at noon when solar radiation is greatest, then a PV system will not optimally reduce demand charges. To address this problem, the Center for

Energy and Environmental Policy (CEEP) developed the concept of a dispatchable peak-shaving system that consists of a photovoltaic array coupled with a very small amount of battery storage. By diverting a portion of the PV output to charge the battery during off-peak hours, the battery can be discharged, or dispatched, at a time that corresponds to the building's peak demand. Dispatchable peak-shaving PV systems can thus be targeted to displace retail electricity when it is most expensive and fully capture the demand reduction benefits of PV. The economic performance of the dispatchable peak shaving system is summarized in Table 4 above.

As previously discussed, the addition of a modest-size battery system makes the initial cost of dispatchable PV systems higher than non-dispatchable systems. Operations and maintenance costs of dispatchable systems are also higher than non-dispatchable systems. Despite these additional costs, the savings achieved through dispatchable peak shaving more than offset the additional system costs. The dispatchable system's benefit-cost ratio (BCR) is 0.91 (compared to the BCR of 0.68 for the non-dispatchable system). Despite this improvement in economic performance, however, the lifecycle costs of the dispatchable system outweigh the benefits and the system does not pay itself back within its projected operating life.

4.3 Emergency Power and Peak Shaving (dispatchable configuration with emergency power capability and tax credits)

In many public buildings, uninterruptible power supply (UPS) systems are required to supply electricity during an outage. Many of these UPS systems rely on battery power. Because dispatchable, peak-shaving PV systems employ batteries, they can be configured to serve a UPS function as well (Byrne et al., 1998). When adding an emergency power function, we assume that the end-user has already justified the purchase of a conventional emergency power system based on avoided outage costs. The value of adding an emergency function to the DPS-PV is therefore equal to the avoided cost of a conventional UPS system (Byrne et al., 1997). *PV Planner* software can take this into consideration and Table 4 above shows the economic performance of a 1.4 kW dispatchable PV array configured with a UPS capacity.

When the UPS value is taken into account, the BCR for the 1.4 kW PV system becomes positive and the system pays for itself beginning in 3.82 years. The economic feasibility of dispatchable PV UPS systems has been modeled in numerous case studies (Byrne et al., 2000; Byrne and Schwartz, 1999; Byrne, Wicker et al., 1999; Hoff et al., 2005) and systems have has been successfully deployed around the country. In Montana, for example, a program to equip fire stations with dispatchable UPS systems has resulted in 13 2 kW dispatchable PV installations in 2 years, with another 7 coming online in the next few months. The systems have performed as expected and stations have maintained power during power outages caused by severe weather conditions (personal communication, R. Schott, National Center for Appropriate Technology).

4.4 Policy Incentives (green energy fund and RECs)

As discussed above, a PV system installed within Delaware may be able to take advantage of several renewable energy policies. While the buildings are not located within Delmarva Power's territory and can therefore not currently take advantage of the Green Energy Fund, we assume in this case that the municipal utilities will offer a PV rebate program as part of their plan to opt out of the Delaware RPS. It should be noted, however, that the 50% rebate applies only to the PV system itself and does not extend to the storage system. In addition, we assume that the 30% tax credit is calculated based on the after-rebate system cost. Finally, we assume that renewable energy systems in Delaware will be able to sell their renewable energy credits (RECs) – either through the RPS credit market or through the voluntary green power market – for $0.02 per kilowatt hour. The economic performance of a 1.4 kW peak shaving UPS PV system with these incentives taken into account is summarized below in Table 4.

As a result of these incentives, the system has a positive net present value of $3,806 and a payback period of 2.72 years.

4.5 Environmental Benefits

Deploying renewable energy technologies such as solar PV can reduce pollution associated with conventional fossil fuel generation. Table 5 shows typical pollutant emissions from power plants in Delaware, based on the emissions profile of Pepco Holdings.

Table 5. Emissions Data for Power Plants Serving Delaware

Emission Type	Rate (lbm/MWh)	Rate (lbm*/kWh)
CO_2	2,135.4	2.1354
SO_2	10.4	0.0104
NO_x	3.6	0.0036

* 1 lbm = 0.453592 kg.
Source: (CERES et al., 2004)

Using this data for calculation, Table 6 shows the environmental benefits for the above-mentioned scenarios.

Table 6. Environmental Benefits of PV Installation

Scenario	Annual Energy Savings (kWh)	Emission Reductions (lbm*/year)		
		CO_2	SO_2	NO_x
Non-Dispatchable	1,711	3,653.67	17.79	6.16
Dispatchable	1,418	3,027.00	14.75	5.10

* 1 lbm = 0.453592 kg

As can be seen in Table 6, there is a tradeoff between economic and environmental performance when evaluating dispatchable and non-dispatchable systems. The entire output of non-dispatchable systems can be directed towards displacing fossil-fuel generation from the grid. A portion of dispatchable PV system output, however, is directed to charge the battery system. As a result, dispatchable PV systems perform better economically, but offset slightly fewer air emissions than non-dispatchable systems.

5. Blending PV Installations into Performance Contracts

5.1 Types of Performance Contracts

Usually there several parties involved in a performance contact: the institution requiring the services; the performance contractor (ESCO) that identifies and installs the energy conservation measures; and a financial institution. There are several ways to structure a performance contract, and contract arrangements between these parties can be different, depending on the risks assumed and the sources of financing used (Thoma, 2005).

Under the first type of contract, known as the shared savings contract, the ESCO invests its own equity in the project, and installs energy conservation measures after securing the owner's agreement to "host" energy efficiency equipment on the company's premises (Rufo, 2001). Under shared savings agreements, the ESCO receives a share of savings generated by the equipment upgrades for a fixed term to cover its costs and make a profit. The client facility may also receive a percentage of the savings generated by the project while the ESCO continues to own the equipment. One of the advantages of the shared savings performance contract is that the ESCO effectively maintains ownership of the energy equipment for an initial period (typically 3-8 years) and can take full advantage of depreciation and tax credits.

Under the second type of contract, known as guaranteed savings contracts, the facility assumes the debt and the ownership of the equipment. The ESCO assumes the performance risk for the energy conservation measures it installs and guarantees the savings generated by the project. If the project does not perform as projected, the ESCO is held financially responsible. During the past two decades, guaranteed savings contracts have come to dominate the performance contracting market (Hansen, 2005).

Public buildings choose guaranteed savings agreement when they can use tax-exempt bonds to finance energy conservation projects at a lower cost of capital than available from private lenders. Under shared savings contracts, the ESCO must absorb the initial debt to finance the project or create an internal fund and invest its own equity. The costs of capital in a shared savings contract are therefore typically higher than the costs of capital from a municipal lease.

As discussed previously, however, PV systems are eligible for a 30% federal tax credit, which public facilities cannot take advantage of. In our analysis, we assume that both facilities will enter into shared savings contracts with an ESCO in which the ESCO maintains initial ownership of the PV system and energy conservation measures. By using a shared savings contract, the ESCO can take advantage of the 30% tax credit for the PV system and pass the savings on to the facilities. In our analysis, the value of the tax credit proved to outweigh the value of the lower cost of capital available through municipal financing.

To estimate the performance contract term, we assume that the financing period is twice long as the simple payback of the equipment. Therefore we need to estimate the blended simple payback for both buildings to find out the proper contract terms.

5.2 Selection of Energy Conservation Measures (ECMs)

As discussed earlier, the 2rw audit report recommends lighting and HVAC energy conservation measures (ECMs) for both buildings. The initial costs, savings streams, and payback periods of the different ECMs vary considerably. In considering which ECMs to include in our economic model, we eliminated those ECMs with the longest payback periods. While detailed information about proposed ECMs can be found in the appendix, Table 7 and 8 show the ECMs selected for the two buildings.

Table 7. Selected ECMs: Richards and Robbins Building

	ECM#2	ECM #8	ECM #9	ECM#10	ECM#11	HVAC#1-3	Total
Initial cost	**$6,583.00**	**$33.00**	**$836.00**	**$2,255.00**	**$836.00**	**$39,099.25**	**$49,642.25**
Total Annual Savings	**$1,094.00**	**$48.00**	**$1,659.00**	**$2,998.00**	**$1,855.00**	**$69,971**	**$77,625.00**
Electric Demand Cost Savings ($/yr)	$568.00	$10.00	**$298.00**	$496.00	$401.00		$1,773.00
Electric Energy Cost Savings ($/yr)	$891.00	$15.00	$467.00	$777.00	$629.00		$2,779.00
Cooling Energy Cost Savings ($/yr)	$79.00	$1.00	$42.00	$69.00	$56.00		$247.00
Heating Energy Cost Savings ($/yr)	-$461.00	-$8.00	-$242.00	-$402.00	-$325.00		-$1,438.00
Maintenance Cost Savings ($/yr)	$17.00	$30.00	$1,094.00	$2,058.00	$1,094.00		$4,293.00

Table 8. Selected ECMs: Highway Administration Building

	ECM #6	ECM #7	ECM #8	ECM #9	Total
Initial cost	**$1,577.00**	**$201.00**	**$2,313.00**	**$402.00**	**$4,493.00**
Total Annual Savings	**$442.00**	**$519.00**	**$419.00**	**$77.00**	**$1,457.00**
Electric Demand Cost Savings ($/yr)	$343.00	$96.00	$118.00	$20.00	**$577.00**
Electric Energy Cost Savings ($/yr)	$652.00	$183.00	$527.00	$99.00	**$1,461.00**
Cooling Energy Cost Savings ($/yr)	$58.00	$16.00	$47.00	$9.00	**$130.00**
Heating Energy Cost Savings ($/yr)	-$338.00	-$95.00	-$273.00	-$51.00	**-$757.00**
Maintenance Cost Savings ($/yr)	-$273.00	$319.00			**$46.00**

Using a stream analysis where the simple payback is defined as the point when the net cash flow turns from negative to positive, we calculated a 0.6 year payback for the Richards and Robbins Building and a 3.0 year payback for the Highway Administration Building.

5.3 Blending the Payback Streams of ECMs and Different PV System Configurations

After determining the blended simple payback of the ECM savings streams for each building, the capital costs and savings stream of the 1.4 kW PV system were added to the analysis. The overall payback of the ECM systems and the PV system is the simple payback that could be expected from a performance contract. Each of the different PV system cases described in Section 4 was analyzed for their impact on the economics of the performance contract. The results of this analysis are summarized in Table 9.

Table 9. Blending PV Installation into Performance Contract

Strategies	Simple Pay Back (yr.)	
	R & R building	Highway Admin. Building
ECM	0.6	3.0
ECM + non-dispatchable	0.76	3.8
ECM + Peak shaving	0.75	3.7
ECM + Peak shaving + UPS	0.75	3.3
ECM + Peak shaving + UPS + GEF + REC	0.69	2.9

In all four cases (except the last one for the Highway Administration Building), the PV system increased the simple payback of the performance contract. As would be expected, performance contracts that incorporate the non-dispatchable PV system have a longer simple payback than dispatchable systems paired with incentives. That said, none of the PV systems significantly increased the simple payback period of the performance contract.

To calculate the length of the performance contract, we assume that the total term of a contract is twice the length of its simple payback when financing costs are taken into account. The performance contract length for the Richards and Robbins Building is assumed to be 2 years under this scenario, and the performance contract for the Highway Administration building would be 8 years. Both contracts are well within the 20-year horizon established by SB 73 and well below the average contract length for state and local government buildings (Hopper et al., 2005).

5.4 Lifetime Economic Analysis

Simple payback analysis, while a useful tool, cannot give a full picture of energy project performance because it does not take equipment operational life into account. Different ECMs have different maintenance needs, and different operational lifetimes. As an example, a CFL light bulb, though efficient, would have to be replaced several times during the 30-year lifespan of a PV system. This section takes the operational lifetime and replacement costs of the different ECMs into account and analyzes the cash flows for both the ESCO and the State facilities over the 30-year life of the PV panel. In this section, we assume that the loan period is equal to the contract term (i.e., 2 years and 8 years, respectively). We also assume a 6%, interest rate, a 3.5% electric rate escalation, and 2.5% equipment cost escalation rate. We assume that the PV system is non-dispatchable. We also assume that there is an insurance fee for the PV panel of $1 per $10,000 of capital cost.

5.4.1 Richards and Robbins Building

Table 10. Maintenance and Operational Lives of Selected ECMs, Richards & Robbins Building

Lighting ECMs								
	Fixture Type	**Lamps per Fixture**	**Lamp Life (hours) (vendor)**	**No. of Fixtures**	**Operation (hr/yr)**	**Labor to change one lamp (hours) (means)**	**material cost to replace one lamp ($) (vendor)**	**maintenance cost ($/fixt/yr)**
ECM #2								
Existing	F4012/ES	4	20,000	61	3,500	0.09	2	$5.82
Proposed	F28T8/UM X-3-N/Ultra	3	18,000	61	3,500	0.09	2.8	$5.54
ECM #8								
Existing	60 W	1	1,000	2	3,500	0.05	2	$20.79
Proposed	CFL	1	8,000	2	3,500	0.05	7	$5.84
ECM #9								
Existing	75 W	1	750	50	3,500	0.05	2	$27.72
Proposed	CFL	1	8,000	50	3,500	0.05	7	$5.84
ECM #10								
Existing	85 W	1	2,000	75	3,500	0.05	11.57	$35.22
Proposed	CFL	1	12,000	75	3,500	0.05	16	$7.79
ECM #11								
Existing	100 W	1	750	50	3,500	0.05	2	$27.72
Proposed	CFL	1	8,000	50	3,500	0.05	7	$5.84
HVAC								
	Proposed Actions							**Lifetime (years)**
HVAC#1	Replace all filters at ceiling grilles in laboratory spaces							20*
HVAC#2	Establish night temperature setback schedule for the Laboratory							25*
HVAC#3	Reduce airflow in the laboratory to a minimum, and reduce outdoor air intake.							20*

Source: (Kirk & Dell'Isola, 1995)

The energy audit report for DNREC's Richards and Robbins Building recommends 11 lighting ECMs, 1 lighting control ECM and 4 HVAC ECMs. The total implementation cost for these ECMs is $225,025. Our selected ECMs are 5 lighting ECMs and 3 HVAC ECMs, with a capital cost $49,642 and a simple payback of 0.6 years. After blending with the non-dispatchable 1.4 kW PV system, the simple payback increases to 0.76 years. We assume that the performance contract term is 2 years, and that the ESCO shares its savings with the Richards and Robbins Building. We assume the same PV operational life and maintenance costs as before and we also assume a 3% maintenance cost for the ECMs. The operational lives and maintenance requirements for the ECMs proposed for the Richards and Robbins Building are listed in Table 10 above.

Based on our assumptions and analysis, the NPV for an ESCO to implement this project is $103,939, while the NPV for the state is $2,220,529. The cash flows for both the State and the ESCO are shown in Figure 4.

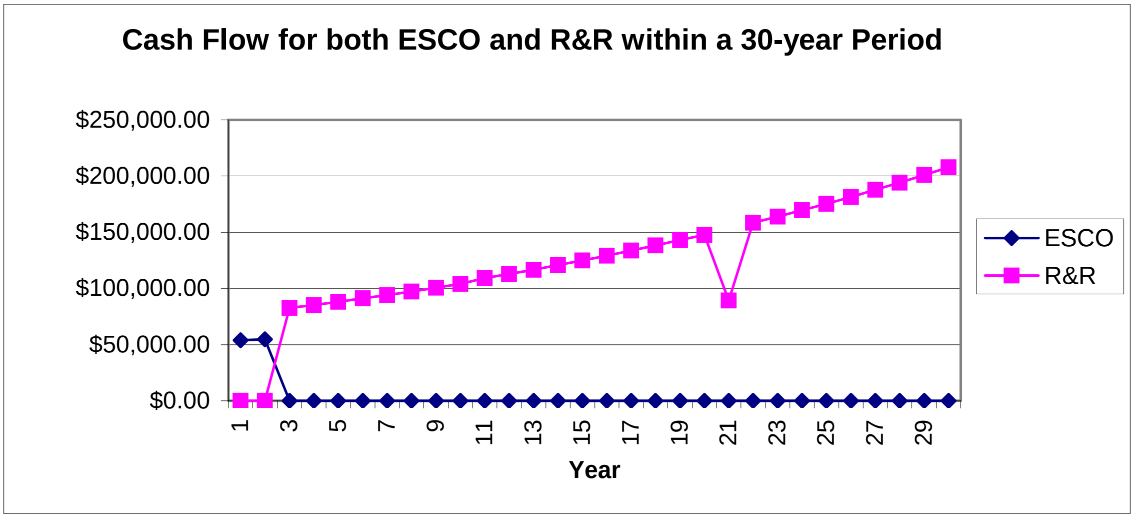

Figure 4. Performance Contract Cash Flow for ESCO and Richards and Robbins Building

5.4.2 Highway Administration Building

The 2rw energy audit report for the Highway Administration Building recommends 7 lighting ECMs, 2 lighting control ECMs and one HVAC ECM, with a total implementation cost of $96,782. The ECMs that we selected for our model performance contract include 4 lighting ECMs with a capital cost $4,493.00 and a simple payback is 3 years. After blending with the non-dispatchable 1.4 kW PV system, the simple payback is 3.8 years and the contract term is assumed to be 8 years. During this 8 year period, the ESCO finances, installs, and maintains the PV and ECMs and shares savings with the facility.

Equipment Maintenance and Operational Lifetimes
The assumed operational life of the PV system is 30 years. It is assumed that regular maintenance equivalent to 0.6% of the PV system cost is performed every five years. It is also assumed that the power conditioning system must be overhauled at a cost of $200/kW every 20 years. Finally, it is assumed that the battery must be replaced every 8 years at a cost of $200/kW.

The maintenance costs of the ECM equipment are estimated to be 3% of the total installed cost of the equipment. The different operational lives and maintenance requirements of the ECMs recommended by 2rw are listed in Table 11 below.

Table 11. Maintenance and Operational Lives of Selected ECMs, Highway Administration Building

Lighting ECMs								
	Fixture Type	Lamps per Fixture	Lamp Life (hours) (vendor)	No. of Fixtures	Operation (hr/yr)	Labor to change one lamp (hours) (means)	material cost to replace one lamp ($) (vendor)	Maintenance cost ($/fix/yr)
ECM #6								
Existing	135 W	1	2,500	34	4,250	0.05	2	$10.10
Proposed	CFL	1	10,000	34	4,250	0.05	26.75	$18.12
ECM #7								
Existing	100 W	1	750	12	4,250	0.05	2	$33.65
Proposed	CFL	1	8,000	12	4,250	0.05	7	7.09
Lighting Controls								
	Controls Lookup Code	No. of Controls 1 Units	Controls2 Lookup Code	No. of Controls 2 Units	Demand Contribution (%)	Existing Operation (hr/yr)	Proposed Operation (hr/yr)	Lifetime (years)
ECM#8	Wall OCC IR	23	N/A	0	10%	4,250	3,250	15*
ECM#9	Wall OCC IR	4	N/A	0	10%	4,250	3,375	15*

* Source: (McRae et al., 1998)

Based on our assumptions and analysis, the net present value (NPV) of the project for the ESCO is $9,227.07, and the NPV for the State of Delaware is $31,319.10. The cash flows for both the ESCO and the State is shown in Figure 5. The negative cash flow in the 16th year reflects the cost of replacing the lighting controls at the end of their operational lives as noted in the table above.

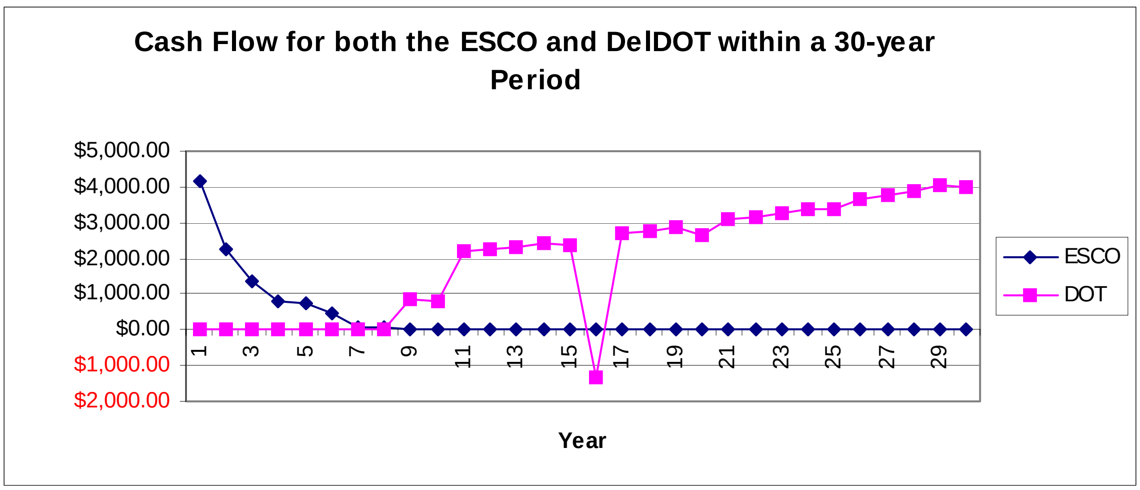

Figure 5. Performance Contract Cash Flow for ESCO and Highway Administration Building

5.5 Possible PV Capacity

Our analysis demonstrates that PV can be successfully blended into performance contracts without significantly affecting the economic performance of the project. A question arises as to the limit of the size of the PV array that could be integrated into the contract without crossing an acceptable payback threshold. Although PV system size has been optimized to provide the maximum peak shaving benefit in these analyses, the State may desire to use performance contracting to leverage larger PV installations. If the State of Delaware was to use performance contracting as a lever for PV installations – much as they might use performance contracting to leverage low-payback capital improvements like roof repairs – the possible PV capacity installation is potentially huge. When blended with the ECM savings streams listed above, a 30 kW PV system increases the blended simple payback from 3 years to 5 years for the Highway Administration Building, and from 0.6 years to 1.6 years for Richards and Robbins Building (Table 12).

Table 12. Potential PV System Size in Performance Contracts

Simple Payback (years)		
	R & R Building	Highway Administration Building
10 kW PV + ECMs	1.09	4.70
15 kW PV + ECMs	1.27	4.84
20 kW PV + ECMs	1.41	4.92
25 kW PV + ECMs	1.54	4.97
30 kW PV + ECMs	1.65	5.00

These economics only improve when peak shaving, uninterruptible power supply, and potential green power incentives are taken into account. Even at with a 30 k system and a 5 year simple payback, the resulting 10-year estimated performance contracting term is still far less than the 20-year limit imposed by Delaware law. Rather than calculating the size limit for non-dispatchable PV that could be integrated into a performance contract with a 20-year term, however, we will instead analyze performance contracts that include a modestly-sized 5 kW system in non-dispatchable, peak-shaving, and peak-shaving with UPS configurations. The results from this analysis are contained in Table 13.

Table 13. Simple Payback as Results of Performance Contract Blending

		R & R Building			Highway Administration Building		
		ND*	PS*	PS*+UPS	ND*	PS*	PS*+UPS
2 kW + ECMs	NPV ($)	2,322,779	2,325,112	2,326,738	35,403	37,735	39,362
	Simple Payback (yr.)	0.81	0.80	0.79	4.05	3.90	3.36
	BCR	2.94	2.99	3.24	37.01	37.92	38.10
3 kW + ECMs	NPV ($)	2,321,265	2,323,580	2,325,510	33,889	36,204	38,135
	Simple Payback (yr.)	0.90	0.87	0.87	4.32	4.12	3.64
	BCR	2.35	2.39	2.55	33.26	34.30	34.37
4 kW + ECMs	NPV ($)	2,319,750	2,321,318	2,323,247	32,375	33,942	35,872
	Simple Payback (yr.)	0.98	0.95	0.95	4.52	4.28	3.95
	BCR	1.99	2.04	2.12	30.20	31.06	31.45
5 kW + ECMs	NPV ($)	2,318,236	2,319,163	2,321,093	30,860	31,787	33,717
	Simple Payback (yr.)	1.06	1.02	1.04	4.67	4.39	4.17
	BCR	1.76	1.82	1.85	27.67	28.38	28.99

* Note: ND stands for Non-Dispatchable scenario; PS stands for Peak-Shaving scenario.

6. Discussion and Conclusions

This study's focus on performance contracting allows public facility managers to incorporate energy efficiency and renewable energy alternatives which would not have been otherwise available given traditional budgeting processes. Incorporating what are often considered to be "expensive" renewable energy alternatives in a blended performance format enables the public sector to cost-effectively provide leadership in deploying technologies that produce benefits not easily reflected in market prices.

As shown in the above analysis, PV installations could be economically blended with energy conservation measurements. Depending on the actual size of a PV system, the simple payback period of the performance contract could be slightly extended. If the PV system is small, its effect on ECM paybacks is negligible. Conversely, if the project analysis sets a payback period of 8-10 years, the PV system's size can increase considerably while meeting such a payback target.

Appendix 1. Assumptions

1. Technical Assumptions
    - Inverter DC to AC Efficiency: 94%
    - Battery Round-Trip Efficiency: 85%
    - Array Angle: 25°

2. Economic Assumptions
    - Installed Capital Costs (not including storage): $6500/kW
    - Installed Inverter Cost: $200/kW AC
    - Installed Battery Cost: $200/kWh
    - System Book Life: 30 years
    - Battery Replacement Cost: $100/kWh
    - Annual Maintenance Cost: 0.6% of initial costs (Sandia)
    - Evaluation Period: 30 years
    - Average Income Tax Rate: 38.5%
    - Discount Rate: 3%
    - Customer Debt Radio: 100%
    - Loan Interest Rate: 6%
    - Loan Period: 10 years
    - Equipment Depreciation Duration: 5 years
    - Escalation Rate for Electric Rates: 3.5%
    - Escalation Rate for Equipments: 2.5%

Appendix 2. Strategic Recommendations from the Delaware Energy Task Force

- Strategy 1: Reduce environmental and economic costs of energy consumption through improvements in end-use efficiency and conservation
- Strategy 2: Reduce the environmental impacts of electricity generation by encouraging clean and renewable energy generation
- Strategy 3: Reduce the economic impacts of transmission congestion
- Strategy 4: Promote clean distributed generation
- Strategy 5: Enhance availability of natural gas
- Strategy 6: Promote alternative transportation fuels
- Strategy 7: Promote economic development by encouraging advanced energy technology development
- Strategy 8: Implement energy efficiency, conservation and renewable energy in State government.
- Strategy 9: Continue the planning effort to insure that the long-term goals are met

Appendix 3. Proposed ECMs for Richards and Robbins Building (adopted from 2rw Audit Report)

Lighting Replacements. Table 14 lists the lighting groups for which replacement of lamps (for incandescent types) or lamps and ballasts (for fluorescent types) is recommended. Table 15 lists the proposed new lamps for the Richards and Robbins Building. Table 16 provides the savings and cost values for each new lighting group.

Table 14. Lighting Groups Recommended for Replacement, Richards and Robbins Building

Location	Existing Fixture Type	Existing Lamps per Fixture	Existing lamp life (hours) [Vendor]	Number of Existing Fixtures	Existing Operation (hr/yr)	Labor to change one lamp (hours) [Means]	Material cost to replace one lamp ($) [Vendor]	Existing maintenance cost ($/fix/yr)
ECM #1: Richards and Robbins Building-Alt	F40T12/ ES	2	20,000	719	3,500	0.09	2.00	$2.91
ECM #2: Richards and Robbins Building-Alt	F4012/ES	4	20,000	61	3,500	0.09	2.00	$5.82
ECM #3: Richards and Robbins Building-Alt	F40T12/ ES	3	20,000	88	3,500	0.09	2.00	$4.37
ECM #4: Richards and Robbins Building	F40T12U	2	20,000	26	3,500	0.10	2.00	$3.12
ECM #5: Richards and Robbins Building	F30T12	2	18,000	14	3,500	0.09	2.00	$3.23
ECM #6: Richards and Robbins Building-Alt	F40T12/ ES	1	20,000	8	3,500	0.09	2.00	$1.46
ECM #7: Richards and Robbins Building	F30T12	1	18,000	6	3,500	0.09	2.00	$1.60
ECM #8: Richards and Robbins Building	60W	1	1,000	2	3,500	0.05	2.00	$20.79
ECM #9: Richards and Robbins Building	75W	1	750	50	3,500	0.05	2.00	$27.72
ECM #10: Richards and Robbins Building	85W	1	2,000	75	3,500	0.05	11.57	$35.22
ECM #11: Richards and Robbins Building	100W	1	750	50	3,500	0.05	2.00	$27.72

Table 15. Proposed New Lamps, Richards and Robbins Building

Location	Proposed Fixture Type	Proposed Lamps per Fixture	Proposed lamp life (hours) [Vendor]	Number of Proposed Fixtures	Proposed Operation (hr/yr)	Labor to change one lamp (hours) [Means]	Material cost to replace one lamp ($) [Vendor]	Proposed maintenance cost ($/fix/yr)
ECM #1: Richards and Robbins Building-Alt	F28T8/UMX-2-N/Ultra	2	18,000	719	3,500	0.09	2.80	3.70
ECM #2: Richards and Robbins Building-Alt	F28T8/UMX-3-N/Ultra	3	18,000	61	3,500	0.09	2.80	5.54
ECM #3: Richards and Robbins Building-Alt	F32T8/XL/HL-2-H/Ultra	2	24,000	88	3,500	0.09	2.80	2.77
ECM #4: Richards and Robbins Building	F32T8U	2	20,000	26	3,500	0.10	2.00	3.12
ECM #5: Richards and Robbins Building	F25T8-2	2	20,000	14	3,500	0.09	2.00	2.91
ECM #6: Richards and Robbins Building-Alt	F28T8/UMX-1-N/Ultra	1	18,000	8	3,500	0.09	2.80	1.85
ECM #7: Richards and Robbins Building	F25T8-1	1	20,000	6	3,500	0.09	2.00	1.44
ECM #8: Richards and Robbins Building	CFL	1	8,000	2	3,500	0.05	7.00	5.84
ECM #9: Richards and Robbins Building	CFL	1	8,000	50	3,500	0.05	7.00	5.84
ECM #10: Richards and Robbins Building	CFL	1	12,000	75	3,500	0.05	16.00	7.79
ECM #11: Richards and Robbins Building	CFL	1	8,000	50	3,500	0.05	7.00	5.84

Table 16. Lighting Replacement Savings, Richards and Robbins Building

Location	Electric Demand Cost Savings ($/yr)	Electric Energy Cost Savings ($/yr)	Cooling Energy Cost Savings ($/yr)	Heating Energy Cost Savings ($/yr)	Maintenance Cost Savings ($/yr)	Total Cost Savings ($/yr)	Retrofit Installed Cost ($)	Simple Payback (yr)
ECM #1: Richards and Robbins Building-Alt	$2,415	$3,787	$337	-$1,959	-$564	$4,015	$71,187	17.7
ECM #2: Richards and Robbins Building-Alt	$568	$891	$79	-$461	$17	$1,095	$6,583	6.0
ECM #3: Richards and Robbins Building-Alt	$477	$748	$67	-$387	$140	$1,044	$8,687	8.3
ECM #4: Richards and Robbins Building	$93	$146	$13	-$75	$0	$176	$2,729	15.5
ECM #5: Richards and Robbins Building	$33	$52	$5	-$27	$5	$68	$1,278	18.8
ECM #6: Richards and Robbins Building-Alt	$17	$27	$2	-$14	-$3	$30	$733	24.7
ECM #7: Richards and Robbins Building	$7	$11	$1	-$6	$1	$15	$506	34.9
ECM #8: Richards and Robbins Building	$10	$15	$1	-$8	$30	$48	$33	0.7
ECM #9: Richards and Robbins Building	$298	$467	$42	-$242	$1,094	$1,659	$836	0.5
ECM #10: Richards and Robbins Building	$496	$777	$69	-$402	$2,058	$2,998	$2,255	0.8
ECM #11: Richards and Robbins Building	$401	$629	$56	-$325	$1,094	$1,854	$836	0.5

Lighting Controls. Table 17 lists the locations where the addition of new lighting controls is recommended. Table 18 provides the savings and implementation costs.

Table 17. Lighting Controls Recommendations, Richards and Robbins Building

Location	Controls1 Lookup Code	No. of Controls 1 Units	Controls2 Lookup Code	No. of Controls 2 Units	Demand Contribution (%)	Existing Operation (hr/yr)	Proposed Operation (hr/yr)
ECM #12: R & R Building	Wall OCC IR	152	Ceil OCC IR	54	10%	3,500	2,500

Table 18. Lighting Controls Savings, Richards and Robbins Building

Location	Electric Demand Cost Savings ($/yr)	Electric Energy Cost Savings ($/yr)	Cooling Energy Cost Savings ($/yr)	Heating Energy Cost Savings ($/yr)	Total Cost Savings ($/yr)	Retrofit Installed Cost ($)	Simple Payback (yr)
ECM #12: R & R Building	$834	$3,735	$333	-$1,933	$2,969	$30,172	10.2

HVAC: Proposed ECMs

ECM1: Service the filtration system for outdoor air, and establish a regular maintenance schedule.

Description:

Lab personnel have complained that dirty air is brought into the laboratory spaces via the HVAC system. As shown in the photo of Figure 3, filters have been installed on air distribution grilles to combat this problem. Personnel report that these filters quickly load up with contaminants and must be replaced each week. This approach only treats the symptom, not the cause of the problem, and has marginal results. The cause of the problem is missing filters in the main air handler, AHU-1. At the time of this energy audit, 20 of the 30 air filter panels had been removed from AHU-1.

Clean the interior of air handler AHU-1, including filter section, heating coils and cooling coils. **Install new filters in AHU-1**. Inspect ductwork to determine whether ductwork cleaning is required. Install a differential pressure sensor across the filter section in AHU-1 to measure pressure drop. Connect this sensor to the building automation system (BAS) and set up an alarm to display when pressure drop exceeds a limit, indicating that filters should be replaced. Establish a schedule for checking pressure drop via BAS and checking filters by visual inspection. Replace filters when needed.

Replace all filters at ceiling grilles in laboratory spaces. Monitor and replace as needed.

Figure 6. Add-on Ceiling Filters Showing Dirty Element, Richards & Robbins Laboratories.
Source: (2rw Consultants Inc., 2004)

Results:
Performing the service described would restore the filtration system to operable condition, and provide acceptable air quality for the laboratory. Cost savings would be achieved by virtually eliminating the need to replace filters weekly at ceiling diffusers. If there are 50 ceiling filters that must be replaced each week, the cost savings would be about:

50 filter changes/week x 52 weeks/yr x $5/filter = $13,000/yr

By comparison, if the filters in AHU-1 were replaced four times per month, the cost would be about:

30 filters x 4 changes /month x 12 months/yr x $5/filter = $7,200/yr

Thus, savings would be a minimum of $5,800/yr

Implementation:
The costs to implement this measure would include:
• Air handler cleaning,
• Pressure sensor installation and wiring,
• BAS programming

Per cost estimate provided in the Appendix, the cost of implementation is estimated to be about $7,318. Simple payback = $7,318 / $5,800 = 1.3 years.

Note: ECM1 should be accomplished regardless of the cost. Supplying dirty air to a laboratory space can negatively affect the results of testing procedures, and results in an unhealthy environment for the building occupants.

ECM 2: Establish night temperature setback schedule for the Laboratory.

Description:
The regular hours of operation at Richards and Robbins Building are approximately 7:00 am to 6:00 pm. The remaining hours of the day, the building is largely unoccupied. During unoccupied hours in winter months, allow temperature to drop from the daytime setpoint of 72 to 68 F. This would reduce the natural gas required for heating.

Energy modeling has shown that in the case of Richards & Robbins laboratories, during cooling season, establishing a set-up temperature (temperature setpoint higher than during occupied hours) would actually result in increased gas use for heating during unoccupied hours. Thus, this measure is recommended for heating season only.

Results:
Due to the unoccupied setback temperature, annual energy simulation showed that natural gas use would be reduced in the Laboratory from 54,107 ccf/yr to 48,988 ccf/yr. Estimated reduction is 5,119 ccf/yr. At the rate schedule cost of $0.984/ccf, annual savings would be $5,037.

Implementation:
Implementation would require modification to the control sequences. With the existing DDC control system in place at Richards and Robbins Building, this implies a simple change in software. We estimate changing temperature setpoints would take about 1.0 hr at $39.25/hr. Simple payback = $39.25 / $5,037 = virtually immediate.

ECM 3: Reduce airflow in the laboratory to a minimum, and reduce outdoor air intake.

Description:
As shown schematically in Figure 7, the laboratory HVAC system is set up for 100% ventilation (all airflow is made up with outdoor air). With the HVAC system as currently configured, minimum system flow is 23,210 cfm, all of which must be conditioned outdoor air. In winter, this conditioning requires a significant quantity of natural gas, and in summer, electricity for cooling. If airflow could be reduced, heating and cooling energy use and cost could be significantly reduced.

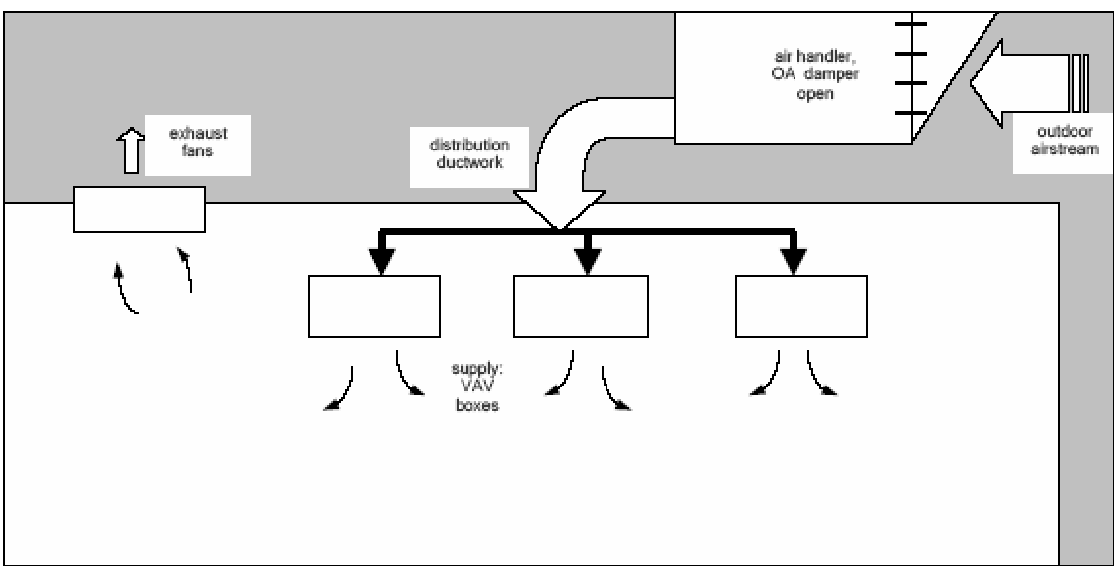

Figure 7. Existing Once-Through Airflow Scheme
Source: (2rw Consultants Inc., 2004)

According to the International Mechanical Code 1996, Table 403.3, laboratories require 20 cfm per person of ventilation air. Space types of similar use, such as darkrooms, printing shops and medical labs, require 0.5 cfm per square foot when occupied. Based on apparent occupancy of the laboratory during the energy audit, either of these methods would result in required ventilation rates that are significantly lower than the system is currently set up to provide. If occupancy were 50 employees, the required ventilation rate at 20 cfm per person would be 1,000 cfm. Using the 0.5 cfm per square foot value, the required ventilation rate would be about 10,000 cfm. By contrast, air handling unit AHU-1 can provide over 49,000 cfm, and according to system drawings, the HVAC system is set to reduce flow to 23,210 cfm.

We propose to install a new, 10,000 cfm air handling unit (AHU) with variable speed supply fan. This unit would be installed in parallel with the existing AHU-1, and supply air would be directed into the existing supply duct. Tight dampers would be installed at each AHU, such that only one unit would operate at a time, and the other would be shut off from the air handling system.

The new AHU would be operated as the primary unit. The control scenario would be as follows: thermostats control VAV boxes, which modulate open or AHU supply fan speed would be modulated by the VSD to maintain minimum supply pressure. If the maximum blower speed cannot provide minimum supply pressurization, the new AHU would be deactivated and the existing, large AHU-1 would be activated. When required supply pressurization is lower than can be provided by AHU-1, control would be returned to the new AHU. Whenever the building is unoccupied, the new AHU would be operated.

Note: to optimize savings, all unused exhaust fans, including all laboratory hoods, should be shut off whenever they are not in use. This reduces the make-up air requirement.

Results:
The model developed for existing conditions was modified to reflect conditions with a new air handler and minimum airflow. With night setback implemented, the hourly results of a whole building simulation for an entire year produced the following results.

Electricity savings from the AHU fan and chiller would be about 248,597 kWh/yr. Natural gas savings from the reduced heating requirement would be about 45,111 ccf/yr. Electrical demand reduction would be about 50 kW/month. The associated cost savings, obtained by applying the electricity and natural gas cost rates, would be about $12,057/yr for electricity, $44,389/yr for natural gas, and $2,688/yr for electrical demand. Some water savings can also be expected, due to reduced loads at the cooling tower. These additional savings have not been quantified here. Total annual cost savings would be about $59,134/yr.

Implementation:
Implementing this measure would require:

- installing a new, 10,000 cfm AHU,

• INSTALLING A LENGTH OF INSULATED DUCTWORK TO CONNECT NEW AHU TO EXISTING SUPPLY HEADER,

- installing new dampers in supply ducts from AHU-1 and the new AHU,
- making electrical connections,

• CONNECTING THE GLYCOL HEATING PLUMBING AND CHILLED WATER PLUMBING TO THE NEW AHU,

- installing new supply duct pressure transducers and connecting to the BAS,
- revised programming of BAS.

Per cost estimate provided in the Appendix, the cost of implementation is estimated to be $31,742. Simple payback = $31,742 / $59,134 = 0.5 year.

ECM 4: Perform test/adjust/balance (TAB) of all HVAC systems and recommission the building.

Description:
Field observations indicate that HVAC adjustments are needed to regain control of comfort conditions in the Richards and Robbins Building. Meeting temperature setpoints has become difficult and airflows are significantly out of balance.

A comprehensive re-commissioning of HVAC systems would improve the efficiency and controllability of the HVAC system while improving occupant comfort. This work should be performed after all modifications the HVAC systems are complete. The commissioning process includes testing/adjusting/balancing (TAB) work, but also incorporates protocols for exhaustive testing and confirmation of HVAC and controls operations for every system and piece of equipment in every control mode.

Note: since Richards & Robbins includes scientific laboratories, the air handling scheme in the building should be established such that the pressure in office spaces always exceeds that of laboratory spaces. This would prevent migration of odors and noxious gases into office areas.

Results:
The total extent of energy savings from commissioning depends on many factors, but FEMP data indicates that re-commissioning can reduce overall building utility usage by 8-20%. A conservative value of 5% of HVAC energy use was used for this analysis. The laboratory Section C of Richards & Robbins comprises about 20,000 square feet of a 148,550 square foot building. If we assume that the energy consumption of the laboratory is about 30% of the building's energy use, total electricity and natural gas consumption for the entire building, after HVAC improvements were made, would be about:

Estimated new annual total natural gas use: 12,923 ccf/yr
Estimated new annual total electricity use: 1,213,073 kWh/yr

If savings from TAB and commissioning results in 5% reduction in electricity and gas use, the energy and cost savings would be 646 ccf/yr or $636/yr for natural gas, and 60,653 kWh/yr. or $2,942/yr. for electricity. Total annual savings would be about $3,578/yr.

Implementation:
Per cost estimate provided in the Appendix, the cost of implementation is estimated to be $31,742. Simple payback = $60,091 / $3,578 = 16.8 years.

Note: Whenever 1.) the use of building spaces has been changed, 2.) an HVAC system has been installed, modified or replaced, or 3.) building systems have become deficient in their ability to control comfort conditions, TAB and commissioning are needed to ensure the building is operating according to the designer’s intent.

Appendix 4. Proposed ECMs for Highway Administration Building (adopted from 2rw Energy Audit Report)

Lighting Replacements. Table 19 lists the lighting groups for which replacement of lamps (for incandescent types) or lamps and ballasts (for fluorescent types) is recommended. Table 20 lists the proposed new lamps for the Highway Administration Building. Table 21 provides the savings and cost values for each new lighting group.

Table 19. Lighting Groups Recommended for Replacement, Highway Administration Building

Location	Existing Fixture Type	Existing Lamps per Fixture	Existing lamp life (hours) [Vendor]	No. of Existing Fixtures	Existing Operation (hr/yr)	Labor to change one lamp (hours) [Means]	Material cost to replace one lamp ($) [Vendor]	Existing maintenance cost ($/fix/yr)
ECM #1: Highway Admin Bldg East Wing-Alt	F40T12/ES	4	20,000	107	4,250	0.09	2.00	$7.07
ECM #2: Highway Admin Bldg East Wing-Alt	F40T12/ES	2	20,000	23	4,250	0.09	2.00	$3.54
ECM #3: Highway Admin Bldg East Wing-Alt	F40T12/ES	1	20,000	6	4,250	0.09	2.00	$1.77
ECM #4: Highway Admin Bldg East Wing	F40T12 U	2	20,000	2	4,250	0.10	2.00	$3.79
ECM #5: Highway Admin Bldg West Wing-Alt	F96T12	2	12,000	8	4,250	0.12	4.00	$9.26
ECM #6: Highway Admin Bldg East Wing-Basement	135W	1	2,500	34	4,250	0.05	2.00	$10.10
ECM #7: Highway Admin Bldg East Wing-Basement	100W	1	750	12	4,250	0.05	2.00	$33.65

Table 20. Proposed New Lamps, Highway Administration Building

Location	Proposed Fixture Type	Proposed Lamps per Fixture	Proposed lamp life (hours) [Vendor]	No. of Proposed Fixtures	Proposed Operation (hr/yr)	Labor to change one lamp (hours) [Means]	Material cost to replace one lamp ($) [Vendor]	Proposed maintenance cost ($/fixtyr)
ECM #1: Highway Admin Bldg East Wing-Alt	F28T8/UMX-3-H/Ultra	3	18,000	107	4,250	0.09	2.80	6.73
ECM #2: Highway Admin Bldg East Wing-Alt	F28T8/UMX-2-N/Ultra	2	18,000	23	4,250	0.09	2.80	4.49
ECM #3: Highway Admin Bldg East Wing-Alt	F28T8/UMX-1-N/Ultra	1	18,000	6	4,250	0.09	2.80	2.24
ECM #4: Highway Admin Bldg East Wing	F32T8U	2	20,000	2	4,250	0.10	2.00	3.79
ECM #5: Highway Admin Bldg West Wing-Alt	F96T8/ES-2-N/Ultra	2	18,000	8	4,250	0.12	5.60	7.29
ECM #6: Highway Admin Bldg East Wing-Basement	CFL	1	10,000	34	4,250	0.05	26.75	18.12
ECM #7: Highway Admin Bldg East Wing-Basement	CFL	1	8,000	12	4,250	0.05	7.00	7.09

Table 21. Lighting Replacement Savings, Highway Administration Building

Location	Electric Demand Cost Savings ($/yr)	Electric Energy Cost Savings ($/yr)	Cooling Energy Cost Savings ($/yr)	Heating Energy Cost Savings ($/yr)	Maintenance Cost Savings ($/yr)	Total Cost Savings ($/yr)	Retrofit Installed Cost ($)	Simple Payback (yr)
ECM #1: Highway Admin Bldg East Wing-Alt	$707	$1,347	$120	-$697	$36	$1,513	$11,547	7.6
ECM #2: Highway Admin Bldg East Wing-Alt	$77	$147	$13	-$76	-$22	$139	$2,277	16.3
ECM #3: Highway Admin Bldg East Wing-Alt	$13	$25	$2	-$13	-$3	$24	$550	22.6
ECM #4: Highway Admin Bldg East Wing	$7	$14	$1	-$7	$0	$15	$210	14.1
ECM #5: Highway Admin Bldg West Wing-Alt	$29	$56	$5	-$29	$16	$77	$1,028	13.3
ECM #6: Highway Admin Bldg East Wing-Basement	$343	$652	$58	-$338	-$273	$443	$1,577	3.6
ECM #7: Highway Admin Bldg East Wing-Basement	$96	$183	$16	-$95	$319	$520	$201	0.4

Lighting Controls. Table 22 lists the locations where the addition of new lighting controls is recommended. Table 23 provides the savings and implementation costs.

Table 22. Lighting Controls Recommendations, Highway Administration Building

Location	Controls1 Lookup Code	No. of Controls1 Units	Controls2 Lookup Code	No. of Controls 2 Units	Demand Contribution (%)	Existing Operation (hr/yr)	Proposed Operation (hr/yr)
ECM #8: Highway Admin Bldg North, East, West Wings	Wall OCC IR	23	N/A	0	10%	4,250	3,250
ECM #9: Highway Admin Bldg South Wing	Wall OCC IR	4	N/A	0	10%	4,500	3,375

Table 23. Lighting Controls Savings, Highway Administration Building

Location	Electric Demand Cost Savings ($/yr)	Electric Energy Cost Savings ($/yr)	Cooling Energy Cost Savings ($/yr)	Heating Energy Cost Savings ($/yr)	Total Cost Savings ($/yr)	Retrofit Installed Cost ($)	Simple Payback (yr)
ECM #8: Highway Admin Bldg North, East, West Wings	$118	$527	$47	-$273	$419	$2,313	5.5
ECM #9: Highway Admin Bldg South Wing	$20	$99	$9	-$51	$76	$402	5.3

HVAC Proposed ECMs:

ECM 1: Convert chilled water pumping systems from constant flow to variable by replacing 3-way bypass valves at coils with 2-way valves.

Description:

According to drawings provided by the facility manager at the Highway Administration Building and control documents provided by the controls contractor, chilled water and heating water pump systems in the new mechanical plant have been installed with variable speed drives. However, the cooling coils (in air handlers) and reheat coils (at VAV boxes) use 3-way valves with bypass to adjust flow and satisfy local thermostats. Because of this arrangement, pumps operate in constant flow mode. By replacing 3-way valves with 2-way modulating control valves at the coils, and installing a bypass for minimum flow in the mechanical room, significant pumping energy savings can be achieved.

Results:

From the annual whole building simulation model with variable flow waterside systems in place, annual electricity is estimated to drop from 1,659,268 kWh/yr to about 1,462,286 kWh/yr, for an estimated reduction of 196,982 kWh/yr. At the average annual electricity cost (per rate schedule) of $0.0485/kWh, annual savings would be about $9,554. Figure 1 illustrates estimated electricity use with variable flow systems.

Implementation:

Implementation would require:

- Replacement of 3-way bypass valves at cooling and reheat coils,
- Installation of minimum bypass plumbing circuit in mechanical plant,
- Installation of pressure sensors in conditioning water supply headers,
- Modification of control sequences in building automation software.

Using RS Means 2003, we estimate implementation would cost about $76,676.
Simple payback = $76,676 / $9,554 = 8.0 years.

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