Willingboro Township

Energy Savings Plan

Revision 4

June 28, 2023

Schneider Electric

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1.0 Executive Summary

Overview of the Energy Savings Improvement Program

The Energy Savings Improvement Program, or ESIP, was created in 2009 by the NJ legislature to reduce energy & operational costs, reinvest in infrastructure, and support the individual goals of public entities across the state. The ESIP program is a design-build financing mechanism that is regulated by the NJ Board of Public Utilities (BPU). Willingboro Township will implement a comprehensive ESIP that addresses building energy and infrastructure needs.

The energy conservation measures (ECMs) included in the ESIP were developed in partnership with the Township's team to meet the following project goals:

1. Reduce energy and operational expenses
2. Replace failing infrastructure that is beyond useful life
3. Improve indoor air quality and comfort inside the facilities
4. Make facilities more energy resilient
5. Create local green jobs

The ECMs in the Energy Savings Plan include building automation system upgrades, building envelope improvements and Heating, Ventilation, & Air Conditioning (HVAC) improvements. The following chart provides an overview of the sites and ECMs included in the ESIP.

Energy Conservation Measure	Kennedy Center	Municipal Complex	Library	DPW Site
Interior Environment				
HVAC Air-Side TAB and Retrocommissioning		●	●	
Air Sealing/Weatherization Improvements	●	●	●	●
Destraification Fans	●			●
Building Automation Systems				
BAS Scheduling and Setbacks	●		●	
Expand BAS to all RTUs and Boiler Plant	●			
Programmable Thermostats		●		●
Demand Controlled Ventilation	●	●		
Infrastructure				
New Heating and Cooling Central Plant			●	
Transportation Measures				
Diesel Engine Block Heater Controls				●
Nitrogen Tire Inflation System				●

2.0 Financial Analysis

2.1 Scope Summary

The intent of this project is to maximize savings for the Township, improve indoor air conditions, reduce maintenance and fund critical capital improvements. The following energy conservation measures have been reviewed with Township leadership.

FORM II

ENERGY SAVINGS PLAN (ESP):
ENERGY CONSERVATION MEASURES (ECMs) SUMMARY FORM
WILLINGBORO TOWNSHIP
ENERGY SAVING IMPROVEMENT PROGRAM

Number	ECM	Hard Costs	Annual Energy Savings
	Interior Environment		
1	LED Lighting	$ -	$ 29,627
3	Air Sealing/Weatherization	$ 120,851	$ 12,144
4	Destratification Fans	$ 56,467	$ 4,242
	Building Automation Systems		
5	BAS Scheduling/Setbacks	$ 13,117	$ 5,621
6	Expand BAS to incl older RTUs - JFK Center	$ 92,579	$ 10,511
7	New Programmable Thermostats - Muni Complex & DPW	$ 23,208	$ 6,962
8	Demand Controlled Ventilation	$ 12,399	$ 481
	Infrastructure		
9	New Heating and Cooling Plant - Library	$ 650,890	$ 11,734
10	Boiler and BAS Replacement - JFK	$ 55,110	$ 15,148
11	Boiler Replacement - DPW	$ -	$ 918
12	RTU Replacement - JFK Center	$ -	$ 16,872
13	RTU Replacement - Muni Complex	$ -	$ 73
14	Ground Mount RTU Replacement - DPW Main Bldg	$ -	$ 47
	Transportation Measures		
15	Diesel Engine Block Heater Controls	$ 1,451	$ 451
	Project Summary:	$ 1,026,072	$ 137,501

In order to achieve the above ECMs the following facility alteration is required. Specifically, this facility alteration will allow for the installation of a new mechanical room at the library to house new central plant equipment. This enables Willingboro to capture significant financial savings and incentives by removing the existing equipment which is at the end of useful life and requiring ever-increasing operations and maintenance costs.

Number	Facility Alterations	Hard Costs	Annual Energy Savings
9	New mechanical room for Library Central Plant	$ 267,015	
	Project Summary:	$ 267,015	$ -

Total Hard costs for ECMs and Facility Alterations = $1,293,088.

2.2 Financial Summary

The table below represents the total, turn-key cost of the ESIP based on the scope of work listed on the prior page and Form V from SE's RFP Response.

FORM V

ESCO's PRELIMINARY ENERGY SAVINGS PLAN (ESP):
ESCOS PROPOSED FINAL PROJECT COST FORM
WILLINGBORO TOWNSHIP
ENERGY SAVING IMPROVEMENT PROGRAM

ESCO Name: Schneider Electric

PROPOSED CONSTRUCTION FEES

Category	Cost	Percentage of Hard Costs
Estimated Value of Hard Costs (2):	$ 1,293,088	
Project Service Fees		
Investment Grade Energy Audit	$ 32,327	2.50%
Design Engineering Fees	$ 64,654	5.00%
Construction Management & Project Administration	$ 68,534	5.30%
System Commissioning	$ 19,396	1.50%
Equipment Initial Training Fees	$ 19,396	1.50%
ESCO Overhead	$ 58,189	4.50%
ESCO Profit	$ 84,051	6.50%
ESCO Termination Fee	$ -	0.00%
Project Service Fees Sub Total	$ 204,308	15.80%
TOTAL PROJECT COSTS:	$ 1,639,635	26.80%

2.3 Cash Flow Analysis

FORM VI
ENERGY SAVINGS PLAN (ESP):
FINAL PROJECT COST FORM
WILLINGBORO TOWNSHIP
ENERGY SAVING IMPROVEMENT PROGRAM

ESCO Name: Schneider Electric

Note: This energy savings plan is based on the following assumptions in all financial calculations:
(a) The cost of all types of energy should be assumed to inflate at 2.4% for Natural Gas and 2.2% for Electric.
1. Term of Agreement: 15 years
2. Construction Period (months): 14 months
3. Cash Flow Analysis Format:

ESIP Financing
Total Project Amount **$ 1,639,635**

Interest Rate Used: **3.80%**

Year	Annual Electric Savings	Annual Natural Gas Savings	Nat Gas Supplier Change	Annual O&M Savings (Boilers & Lighting)	Energy Rebates/ Incentives	Total Annual Savings	ESIP Financing Costs	Net Cash-Flow to Client	Cumulative Cash Flow
Installation	$ 20,428	$ 36,987				$ 57,416		$ 57,416	$ 57,416
1	$ 40,857	$ 73,975	$ 22,670	$ 8,500	$ 91,778	$ 237,780	$ 234,780	$ 3,000	$ 60,416
2	$ 41,756	$ 75,750	$ 22,670	$ 8,500		$ 148,676	$ 145,676	$ 3,000	$ 63,416
3	$ 42,674	$ 77,568	$ 22,670	$ 1,500		$ 144,412	$ 141,412	$ 3,000	$ 66,416
4	$ 43,613	$ 79,430	$ -	$ 1,500		$ 124,543	$ 121,543	$ 3,000	$ 69,416
5	$ 44,573	$ 81,336	$ -	$ 1,500		$ 127,409	$ 124,409	$ 3,000	$ 72,416
6	$ 45,553	$ 83,288	$ -			$ 128,842	$ 125,842	$ 3,000	$ 75,416
7	$ 46,556	$ 85,287	$ -			$ 131,843	$ 128,843	$ 3,000	$ 78,416
8	$ 47,580	$ 87,334	$ -			$ 134,914	$ 131,914	$ 3,000	$ 81,416
9	$ 48,627	$ 89,430	$ -			$ 138,057	$ 135,057	$ 3,000	$ 84,416
10	$ 49,696	$ 91,576	$ -			$ 141,273	$ 138,273	$ 3,000	$ 87,416
11	$ 50,790	$ 93,774	$ -			$ 144,564	$ 141,564	$ 3,000	$ 90,416
12	$ 51,907	$ 96,025	$ -			$ 147,932	$ 144,932	$ 3,000	$ 93,416
13	$ 53,049	$ 98,329	$ -			$ 151,378	$ 148,378	$ 3,000	$ 96,416
14	$ 54,216	$ 100,689	$ -			$ 154,905	$ 151,905	$ 3,000	$ 99,416
15	$ 55,409	$ 103,106	$ -			$ 158,515	$ 150,998	$ 7,516	$ 106,932
Totals	$ 737,284	$ 1,353,886	$ 68,009	$ 21,500	$ 91,778	$ 2,272,458	$ 2,165,526	$ 106,932	

2.4 Incentives and Rebates

A variety of incentive and rebate programs were evaluated during the development of the Project. Based upon the scope of this project, the following rebates are currently included:

Number	ECM	Estimated Rebates
	Interior Environment	
1	LED Lighting - Direct Install Scope	
3.1	Air Sealing/Weatherization	$ 26,267
3.2	Destratification Fans	$ 9,496
	Building Automation Systems	
4	BAS Scheduling/Setbacks	$ 13,805
5.1	Expand BAS to incl older RTUs - JFK Center	$ 24,417
6	New Programmable Thermostats - Muni Complex & DPW	$ 11,368
8	Demand Controlled Ventilation	$ 5,829
	Transportation Measures	
27	Diesel Engine Block Heater Controls	$ 596
	Project Summary:	$ 91,778

All rebates and incentives are subject to program terms, conditions, approvals, and availability of funds.

3.0 Facility Descriptions and Energy Conservation Measures

3.1 Facility Descriptions

Kennedy Center

The Kennedy Center, located at 420 John F Kennedy Way is a 189,950 square foot facility that was originally constructed in 1963 as a High School. It currently serves as a recreational and meeting facility for the community. It contains office spaces, conference and meeting rooms, a banquet facility, gymnasiums, a fitness center and a Senior Citizen Center. The auditorium is currently being renovated under a separate project.

Occupancy consists of approximately 15 to 20 employees, with varying levels of daily community visitors/users of the space. Recreational spaces are open to the public seven days per week. Some older classroom sections of the building are not routinely occupied.

The building is of masonry brick construction and some sections have two stories. The building has a flat black membrane built-up roof that was recently replaced. A large solar photovoltaic array is installed on the roof. There are many large rectangular shaped skylights on the roof, some of which are failing and have temporary tape used for sealing out rainwater. Some skylights have been permanently blocked from inside the space below and no longer provide daylighting. The building has mostly single pane windows and exterior doors, which lead to high levels of infiltration, though some sections were upgraded to double pane with a previous renovation.

Heating is provided to the building by a hot water boiler plant that is original to building construction. These boilers are well beyond useful life and one of the three boilers has been permanently removed from service. Some sections of the building receive heating and cooling by gas-fired rooftop units (RTUs) with DX cooling coils. Approximately twelve of these units are more than 20 years old and operate on R-22 refrigerant. Older classroom sections of the building use unit ventilators for heating and window units for cooling. The Senior Citizen Center uses a very efficient variable refrigerant flow system to provide heating and cooling.

Building automation control consists of a JACE supervisory controller and RTU controllers for the ten (10) RTUs installed in 2014. Trane VAV controllers were installed at the same time for the RTUs that are variable volume. Some space temperature sensors predate that installation. Standalone thermostat controls for the older RTUs appear to be original to the installation of those RTUs, dating between 1999 and 2003. Standalone controls associated with the boiler plant appear to be original to building construction.

Interior lighting in the facility is provided by a combination of LED fixtures, T8 linear fluorescent fixtures, incandescent fixtures and older T12 linear fluorescent fixtures.

Municipal Complex

The Municipal Complex is a 31,130 square foot facility located at 1 Salem Road. It was originally constructed in 1966 and has had several renovations since then. The facility serves as the main Township government office and houses government leadership and the police department.

Occupancy includes approximately 35 employees and varying quantities of community/citizen visitors. As it houses the police department, the facility is open every day of the year and sections are in use 24 hours per day.

The building is of brick masonry construction and has a flat white rubber roof in good condition. The building has three stories. There is a small solar photovoltaic system located on the roof. There are multiple tubular skylights on the roof that provide an abundance of daylighting to the spaces below. These skylights are in good condition with none that appear to be leaking. Windows are mostly single pane metal frame, operable in fair condition. Exterior doors are a mix of single pane and double pane metal frame.

Heating and cooling is mostly provided by gas-fired packaged rooftop units (RTUs) with DX cooling coils. These units range in age from 12 to 16 years old and are at or approaching end of useful life. One section of the building is served by small air handling units (AHUs) that provide heating and cooling. These AHUs contain hot water coils that are served by a small gas-fired boiler, which was recently replaced, and DX cooling coils.

The RTUs are operated by conventional, non-programmable thermostats installed when the RTUs were originally installed.

Interior lighting in the facility is provided mostly by T8 linear fluorescent fixtures though there is a small quantity of incandescent fixtures and older T12 linear fluorescent fixtures.

Library

The Township Library is located at 200 Willingboro Way and consists of 45,000 square feet. It is housed in a building that was formerly part of a retail establishment which was completely renovated into the library space in 2001. This facility is open to the public approximately 44 hours per week. Occupancy varies and includes 15 to 30 part-time and full-time staff and as many as 10,000 community visitors per month.

The building consists of open library book stack areas, offices, conference rooms, storage spaces, a computer/IT room and mechanical and electrical rooms located in the basement.

This one-story building is constructed of brick masonry exterior and has a flat white rubber built-up roof in good condition. There is a large solar photovoltaic array on the roof. Several rows of skylights provide daylighting to interior spaces below.

The HVAC system in the building consists of a direct-fired absorption (DFA) chiller/heater that provides both hot water and chilled water. The chiller section is water cooled and served by a cooling tower mounted on the roof. This Broad Spectrum DFA, Model BZ30N(k)CH_4, S/N 01092960, was manufactured in September 2001. As such it is original to library construction. While it may have originally been specified due to high performance energy efficient operation, this equipment is a source of constant maintenance and operational problems for the Township, and has been for many years. There are three large central air handling units (AHUs) with heating and cooling coils that serve VAV distribution boxes and associated ductwork throughout the building.

Building automation controls for this facility consist of a JACE supervisory controller installed in 2014, Trane controllers for the DFA and the AHUs which were also installed in 2014. VAV controllers include CSI controllers installed in 2000 and Distech controllers installed in 2006.

Interior lighting in the library consists of mostly T8 linear fluorescent fixtures and incandescent fixtures.

DPW Site

The Department of Public Works site is located at 25 Industrial Drive and consists of four buildings, three of which have conditioned, occupied spaces. The main DPW building consists of 8500 square feet and was built in 2010. The exterior is metal siding with a metal standing seam roof. There is a solar photovoltaic array installed on this roof. The windows and exterior doors are double pane in good condition.

This building is occupied approximately 45 hours per week. It consists of offices, meeting/conference rooms, a break room, locker rooms and a large high bay maintenance garage section.

HVAC is provided to the Main DPW building by two ground mounted packaged gas-fired units with DX cooling. This equipment is approaching end of useful life. These units are operated by conventional, non-programmable thermostats.

Lighting in the Main DPW building consists of T8 linear fluorescent fixtures.

There are two one-story cement block garage buildings at the DPW site that are occupied periodically throughout the day by about 20 people. Both garage buildings were built in 1960. Garage #1 consists of 6004 square feet and Garage #2 consists of 5490 square feet. These buildings have pitched roofs with asphalt shingles and appear to be in good condition. There are solar photovoltaic arrays on each of the garage roofs. Garage bay doors are mostly metal with only one or two remaining wood doors. They vary in condition from good to poor. The windows are single pane, metal frame in fair to poor condition.

Spaces in these garages are mostly used for equipment storage though some areas are used for maintenance as well as a sign shop. One section of Garage #1 has a restroom and locker room facility and a kitchen/breakroom area. These spaces are heated by hot water radiators and a hot water boiler that is well beyond useful life. Heating is provided to the garage bays and work areas with direct fired gas unit heaters, mounted in the ceiling.

Lighting in the garage buildings is mostly T8 linear fluorescent with a few incandescent fixtures.

3.2 ECM Descriptions and Facility Alterations

Please see the following descriptions of ECMs currently included in the project.

1. Lighting

Overview

This scope entails the installation of LED fixtures and lamps, replacing older inefficient fluorescent and incandescent lighting technology in the buildings.

Savings and Savings Methodology

Energy unit savings for the lighting upgrades were estimated using BPU accepted methods. Electric energy and demand savings were then run through Schneider Electric's rate tariff simulation tool to arrive at annual energy cost savings, rather than using a blended or average utility rate, resulting in a more accurate representation of cost savings.

2. Removed ECM.

3. Air Sealing Improvements

Overview

This ECM addresses the shell of the building and how well it is keeping conditioned air in and ambient air out. Our onsite testing and analysis of energy consumption indicate there is an opportunity to improve the indoor air quality, occupant comfort, and energy use by upgrading the existing air barrier systems. A tighter Building Envelope will provide the following advantages:

- Drafts will be reduced providing greater comfort for the building occupants. A tighter building envelope will lower the possibility of "hot" or "cold" spots brought on by unconditioned air infiltrating into conditioned spaces.
- Decreased Energy Consumption - Less conditioned air will be lost through the building envelope and the Heating and Cooling equipment will operate less to maintain the set point of the conditioned space. This will decrease the energy consumed and save on energy costs.
- Improved Air Quality – Decreasing infiltration of contaminated air promotes less humidity and greater air quality. This allows for the existing systems to run at peak performance and maintain the highest level of air quality for the occupants.
- Reduced Maintenance Costs – Reducing the "runtime" will increase the operating life of the heating and cooling equipment and increase the performance of new equipment.

Scope

The following is a breakout of the Building Envelope scope by facility:

Task	Kennedy Center	Municipal Complex	Library	DPW Site
Exterior Door Weatherstripping (units)	97	15	13	7
Overhead/Roll-up Door Weatherstripping (units)	4	1		28
Roof/Exterior Wall Intersection Air Sealing (LF)	1625			
Skylight Caulking/sealing (LF)	1828			

Savings and Savings Methodology

Savings for this ECM are derived by observing and measuring the size of openings or gaps in the building envelope and applying the ASHRAE 90.1 Crack Method. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

4. Destratification Fans

Overview

Stratification occurs because hotter air is much lighter than cooler air and tends to rise to the ceiling. With this stratification, a difference of 5 to 10 degrees can be measured from the floor to the ceiling. Destratification fans are an effective method of reducing heating loads by moving the hotter air from the ceiling down to the occupant area where it is beneficial. These fans provide the most benefit during the heating seasons in highly stratified areas, such as warehouses or other high bay areas, like large garage bays or gymnasiums.

The following highlights the key benefits of this solution:

- Reduce Energy Costs – Decreasing the thermal energy loss through stratification will reduce heating equipment run times in the wintertime and provide natural cooling effects during the summer months.
- Improve Occupant Comfort – Destratification fans will promote more uniform temperatures through large volume spaces, improving occupant comfort.

Example of Destratification Fans

Destratification fans reduce space conditioning loads by moving air from the ceiling downward to the occupant area.

Scope

Nozzle style destratification fans are included for the following locations:

1) Kennedy Center Main Gymnasium – quantity 8
2) DPW Main Building Garage Bay – quantity 2

Savings and Savings Methodology

Savings for this ECM is based on efficiency improvements identified from a theoretical computational fluid dynamics analysis performed for occupied spaces of the same approximate sizes as those listed above. Energy savings results from reduced run time and load on the existing HVAC system and also considers the additional electrical power required to operate the destratification fans. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

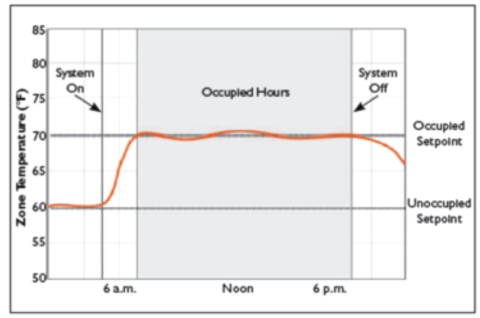
5. Building Automation System (BAS) Scheduling and Setbacks

Overview

Opportunities exist to improve the operation of space conditioning equipment. Some spaces are maintained at constant temperature set points throughout the year, regardless of occupancy. Energy savings potential exists from allowing the space temperature to drift during unoccupied periods, such as nights and weekends, in areas that are not temperature sensitive. Higher cooling and lower heating unoccupied set points will reduce air conditioning and heating demands on the system.

Energy Conservation Opportunities

The most effective way to save energy is to turn off equipment when it is not needed. For this reason, the scheduling feature of a BAS is often one of its most powerful energy conserving applications:



Result of Night Setback and Scheduling

Allowing space temperatures to drift during unoccupied periods saves energy and reduces equipment runtime.

- **Weekly**: Building operations usually fall into predictable patterns that may vary with the day of the week or with the seasons. A flexible Weekly Scheduling feature is able to start and stop a building's equipment to match the occupancy patterns throughout the space. Energy is consumed only when it is needed and only on the days that the space is utilized.
- **Holiday**: Holiday scheduling allows special schedules to be implemented on regularly occurring holidays. These days can usually be scheduled up to a year in advance. This feature prevents un-needed energy consumption from occurring when a holiday falls on a normal weekly scheduled day.
- **Special**: Exceptions to normal operations are a frequent occurrence. A BAS that can easily respond to these exceptions allows for maximum energy conservation. If special occasions can be quickly and easily addressed, then aggressive regular schedules can be implemented with the confidence that comfort can still be maintained when changes do occur.

The following highlights the key benefits of this solution:

- Reduce Energy Costs – Scheduling equipment drives energy savings potential.
- Automated Scheduling – Equipment scheduling is simple to implement, requiring no input from the user once schedules are set.
- Extends Equipment Life – With reduced run times, equipment wear and tear will be lessened.

Scope

This measure will be applied to the BAS systems at the Kennedy Center and the Library. For the Kennedy Center this includes the ten (10) existing to remain RTUs and the associated VAV boxes. Older classroom sections of the building that use unit ventilators for heating and window units for cooling are excluded from this scope. The Senior Citizen Center VRF system is also excluded. For the Library this includes the three (3) existing to remain AHUs and their associated VAV boxes.

Savings and Savings Methodology

Savings for this measure are derived by modifying unoccupied setback temperatures and equipment operating schedules within the building models created for each facility. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

6. Expand Building Automation System to older HVAC RTUs

Overview

Newer roof top HVAC units at the Kennedy Center are controlled by an existing Trane BAS system. However, the older RTUs, installed between 1999 and 2003 are controlled by standalone thermostats with limited to no ability to remotely control or monitor the equipment operation. Adding control of these RTUs to the existing BAS can greatly increase the efficiency of the building.

With the existing BAS, there are many opportunities to optimize building systems without sacrificing occupant comfort or safety, including:

- Set point control and monitoring,
- Scheduling of equipment,
- Identification and verification of issues with equipment,
- Implementation of advanced control sequences, and
- Trending and reporting features.

The key benefits of this solution are:

- Reduce Energy Costs – Control strategies use energy more effectively.
- Improve Occupant Comfort – New, calibrated system provide better temperature control.
- Better Visibility – Graphics, remote monitoring, and alarms help identify and prevent issues.
- Enhance System Performance – EMS will allow for new control strategies to be implemented.
- Extends Equipment Life – With reduced run times, equipment wear and tear will be lessened.
- Reduce Maintenance Costs – New, standardized control system will require less maintenance and replacement parts are more readily available.

Scope

Older HVAC RTUs at the Kennedy Center are being replaced. The Mechanical scope does not include connecting the new units to the existing BAS. That work will be performed by Schneider Electric as part of the ESIP scope of work. This totals (13) new HVAC RTUs that are not currently on the existing Trane BAS that will be added to the system after new RTUs are installed.

Savings and Savings Methodology

Savings for this measure are derived by modifying unoccupied setback temperatures and equipment operating schedules within the building models created for each facility. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

7. New Programmable Thermostats

Overview

Microprocessor-based programmable thermostats have built-in keypads and displays for programming and scheduling, and a 365-day time clock with two setback intervals per day. The thermostats have limited temporary set-point adjustment, definable in programming, and a local override button with remote override capability. This will allow occupants to adjust temperature settings for a temporary period without impacting night or unoccupied set points.

The ability to edit operating control parameters are password protected via a user-definable security access code. This ensures permanent set-points for unoccupied times are not comprised, thereby preserving future energy savings associated with unoccupied setbacks.

The following highlights the key benefits of this solution:

- Reduce Energy Costs – Scheduling and setback capabilities drive energy savings.
- Straightforward – The simplicity of the solution is easy to understand and implement.

Scope

The following equipment will receive new programmable thermostats:

1) Municipal Complex – (12) Rooftop Packaged HVAC units, (4) split system HVAC units, (1) ductless mini-split system
2) DPW Site Main Building – (2) Ground mounted Packaged HVAC units, (5) gas fired unit heaters, (1) ductless mini-split system

Note: some of the packaged HVAC units are being replaced as part of the program. However, that scope does not include programmable thermostats. These will be provided by Schneider Electric as part of the ESIP scope of work.

Savings and Savings Methodology

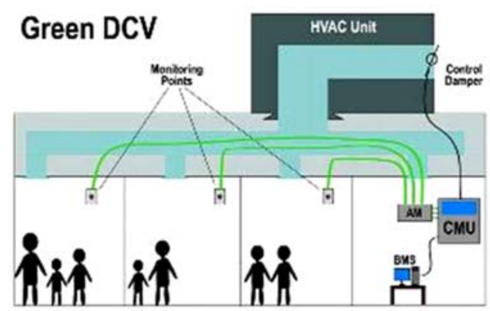
Savings for this measure are derived by modifying unoccupied setback temperatures and equipment operating schedules within the building models created for each facility. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

8. Demand Controlled Ventilation

Overview

Building ventilation management is one of the most cost-effective opportunity presenting itself in energy management and comfort control. Any space that uses more ventilation than its occupancy levels require results in excess energy consumption from conditioning unnecessary outside air. Air distribution systems are designed to provide a specified quantity of ventilation air corresponding to the maximum occupancy conditions for the space served. However, there are periods throughout the day when individual spaces within the building may be partially occupied or even unoccupied, yet ventilation rates are maintained as if the space was fully occupied. Demand Controlled Ventilation (DCV) can greatly reduce the energy consumed by the HVAC system by providing the right level of ventilation.

With this strategy, the measured amount of Carbon Dioxide (CO_2 is an indicator of occupancy) is used to vary the amount of outside ventilation air supplied to the space based on the actual occupancy. This strategy continuously adjusts the ventilation rate as dictated by code when the space is not occupied at full design level capacity. Good candidates for DCV control are systems that serve large, open spaces with variable and unpredictable occupancy and where CO2 can be measured effectively.



Example of Demand Controlled Ventilation

Demand controlled ventilation varies outside air rates based on building occupancy.

The following highlights the key benefits of this solution:

- Reduce Energy Costs – Less energy for heating and cooling is required by modulating outdoor air levels based on actual space occupancy.
- Improve Ventilation Control – Monitoring carbon dioxide levels will ensure the proper amount of outside air is introduced.

Scope

DCV will be implemented in the gymnasiums and the auditorium at the Kennedy Center as part of the RTU replacement being completed as well as the Board Room at the Municipal Complex, which will be included in this scope of work.

Savings and Savings Methodology

Savings for this measure are derived by modifying the volume of outside air delivered to the space within the building models created for each facility based on the anticipated variability of space occupancy. Annual energy and cost savings for this measure are listed by building in the Savings Table in Section 4.2 of this report.

9. New Heating and Cooling Central Plant

Overview

The existing direct-fired absorption chiller (DFA) located in the library basement, provides both hot water for space heating and VAV box reheat for dehumidification, and chilled water for space cooling. This unit is over 20 years old and as such has reached the end of useful life. Since its original startup, Township personnel report that the DFA has had many operational problems and has incurred ever-increasing maintenance costs.

Schneider Electric proposes to replace this unit with separate equipment for heating and cooling. This includes the installation of high-efficiency modular condensing boilers and high-efficiency modular water-cooled chillers.

Modular boiler and chiller plants maximize overall plant operating efficiency by taking advantage of running multiple, smaller pieces of equipment at full capacity to meet part-load conditions rather than operating one large peak-sized unit in a “turned-down” firing mode. The following are key benefits of this solution:

- Reduce Energy Costs – Switching from natural gas fuel for cooling, using the existing DFA, to electricity will save energy and reduce energy costs. Modular chillers and boilers operate at very high efficiencies, especially during part-load conditions, which make up the majority of operating hours.
- Reduce Operation & Maintenance Costs – Removing the DFA from service will result in decreased equipment maintenance costs, reduced need for emergency service calls and will greatly simplify plant operations. Replacement with new equipment avoids the increasing maintenance burden associated with repairing existing, aged equipment.
- Improve Reliability – An N+1 modular boiler and chiller plant arrangement allows for superior reliability should one or more pieces of equipment fail or be taken offline for maintenance.
- Address Aging, Failing Equipment Replacement – This measure will replace existing equipment which is at the end of its useful life.
- Controls Compatibility – Equipment will be selected to be compatible and incorporated with existing building automation and controls systems (BAS) at the library
- Staff Training – New equipment training ensures proper operation and maintenance practices.

Scope

The new boiler plant will consist of two (2) modular boilers and two new hot water distribution pumps with variable frequency drives (VFDs). By installing multiple boilers, each sized for part-load conditions, the new boiler plant will be able to operate at increased efficiencies while maintaining individual boiler redundancy and reliability. The new boiler equipment will be installed in the location where the existing DFA currently sits. A new stainless steel boiler flue vent pipe will be installed as the existing steel flue is not compatible with condensing boilers.

One (1) new modular chiller with two (2) modules, each rated at 50 tons, will be installed along with new chilled water pumps and new condenser water pumps. This equipment will be located in a new chiller plant equipment room to be built in the library basement. The new equipment room will have fire rated walls and access door to isolate the space from the rest of the library basement area that is currently used for storage. New electrical power circuits including conduit and wiring will be routed to the new basement chiller room from the existing main electrical room, also located in the library basement. New sprinkler piping and sprinkler heads will be installed as required for fire protection in the new equipment room.

All new major HVAC equipment will be incorporated into the existing BAS system.

Savings and Savings Methodology

Savings for this measure are derived by modifying the operating efficiency of the heating and cooling equipment within the Library building model. Annual energy and cost savings for this measure shown in the Savings Table in Section 4.2 of this report.

10. Boiler Replacement

Overview

New boilers will be installed at the Kennedy Center. Control of the new boilers and hot water pumps will be integrated into the existing BAS as part of this scope of work.

The boiler at the DPW Garage #1 will also be replaced.

Savings and Savings Methodology

Savings associated with the new boiler controls are derived by modifying equipment schedules within the Kennedy Center building model. Annual energy and cost savings for this measure are shown in the Savings Table in Section 4.2 of this report.

11. HVAC/RTU Replacement

Overview

As mentioned previously, rooftop units at the Kennedy Center and the Municipal Complex will be replaced. Additionally, the ground mounted HVAC units that serve the Main building at the DPW site will be replaced. Controls for all these units are included in this scope of work.

Savings and Savings Methodology

Savings associated with the RTU replacement are associated with equipment efficiency increases. Electric energy and demand savings were then run through Schneider Electric's rate tariff simulation tool to arrive at annual energy cost savings.

12. Diesel Engine Block Heater Controls

Overview

Engine block heaters are used to warm the block heater of a vehicle engine during cold weather seasons. The engine block heating process takes a few hours, but the heaters are typically left plugged in overnight for convenience. In order to save energy, the process can be automated to turn on the block heater circuits when appropriate.

The following highlights the key benefits of this solution:

- Reduce Energy Costs – Scheduling will limit the engine block heating time to only when needed.
- Automated Scheduling – Controls remove the guesswork out of heater scheduling.

Example of an Engine Block Heater Controller

Simple engine block heater controllers can automate the on/off heating cycle for engine block heaters with programmable schedules.

Scope

The model selected for this application senses outdoor air temperature and automatically adjusts the heating cycle. Two modes of operation are available:

- Ready the engine for a specific start time
- Maintain engine ready to start at any time

Six (6) of these control devices will be provided for the DPW site to be used in line with the electrical power outlets that are currently used for vehicle engine block heating.

Savings and Savings Methodology

Savings associated with the engine block heater controls are calculated by reducing operating hours of the heaters based on outside air temperature. Historical temperature information was analyzed using the Bin Method to arrive at the reduced operating hours. Annual energy and cost savings for this measure are shown in the Savings Table in Section 4.2 of this report.

Customer Performed Scope

All buildings included have other projects occurring. Schneider Electric reviewed the scope for each of the buildings. As part of the ESIP, Schneider Electric verified and re-estimated the energy impact of these projects.

Each of the buildings is receiving LED lighting. In addition, three buildings are receiving mechanical/HVAC upgrades, as shown below.

- Kennedy Center
    - Install (4) new modulating, condensing gas-fired boilers
    - Replace (13) packaged gas-fired rooftop HVAC units
- Municipal Complex
    - Replace (12) packaged gas-fired rooftop HVAC units
- DPW Site
    - Main Building - Replace (2) packaged gas-fired ground mounted HVAC units
    - Garage #1 – Replace (1) gas-fired boiler

3.3 Optional ECMs

The following opportunities have been identified during the Investment Grade Audit but are not currently included in the Energy Savings Plan.

1) **HVAC Air-Side Testing and Balancing and Retro-commissioning** - As buildings age, HVAC systems tend to fall out of calibration if there is no upkeep or focus on the function of the entire system. In some cases, the building was never properly balanced during construction. Unbalanced air-side systems contribute directly to unnecessary overheating or overcooling, outdoor air infiltration, occupant discomfort, complaints and maintenance requests, as well as excessive energy usage. Well balanced systems can reduce cooling and heating loads, as well as fan power consumption.
2) **Nitrogen Tire Inflation System** - Compressed air has traditionally been utilized to inflate vehicle tires. The use of compressed air can impact tire performance in several ways including corrosion from moisture and increased wear and tear from thermal expansion and contraction. An ideal medium to fill tires is an inert gas, such as nitrogen. Nitrogen used as a fill gas for tires will not corrode and will not significantly expand and contract with changes in temperatures. These advantages greatly reduce wear on treads, improve steering and handling, and also improving overall fuel economy of the vehicle since tire pressure will be held more constant.
3) **Cooling Tower Replacement** – The existing cooling tower is at the end of useful life and is recommended for replacement. The supporting steel structure could be reused, have rust removed and repainted to extend useful life. A new cooling tower could be set on this steel structure in the same location as the existing tower. It is also recommended that the exposed condensing water piping be prepared, primed and painted.
4) **Window and Exterior Door Replacement** – Most windows and exterior doors at the Kennedy Center are older single pane, metal frame without thermal breaks, leading to increased energy use to maintain interior comfort levels. These should be addressed as part of a larger building renovation.
5) **HVAC Upgrades** – Most of the original classroom wings at the Kennedy Center rely on older unit ventilators for heating and window units for cooling. Upgrading to more efficient HVAC systems such as that installed in the Senior Center would drive additional energy savings.
6) **Additional Solar PV and/or Remote Net Metering solar** – All roof mounted solar PV arrays are currently owned by a third party, from which the Township purchases power under a PPA. However, additional solar could be added under the municipal remote net metering program which could provide power to Township facilities not included in the ESIP, such as the new Fire Station and Township Parks.
7) **Combined Heat & Power –** Two sites, Kennedy Center and Municipal Complex, were evaluated for combined heat and power systems to reduce energy use and improve site resiliency. Hot water needs at the Kennedy Center are not sufficient to support the addition of a CHP unit when, nor is there a continuous need for electricity. In addition, the existing solar PV array often produces more electricity than is being

used in the building, so adding another source of energy production is not economically feasible. Economic and operating conditions are somewhat different at the Municipal Complex, where a portion of the facility is in use 24/7/365. However, it is still difficult to justify the addition of a CHP unit strictly on energy cost savings.

8) **Water Conservation Measures** – Water fixtures at the buildings are a mix of low flow and older higher flow and could benefit from recommissioning or replacement, however savings is not sufficient to cover the cost to perform such upgrades.
9) **Secondary Transformers –** This equipment at the Kennedy Center was evaluated for replacement as many transformers are original to building construction and at the end of useful life. Savings was insufficient to cover the cost to replace this equipment. This should be addressed as part of a larger building renovation.

4.0 Energy Savings

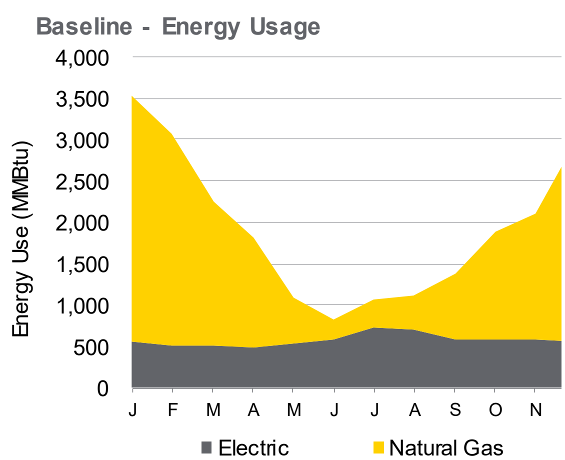
4.1 Baseline Energy Use

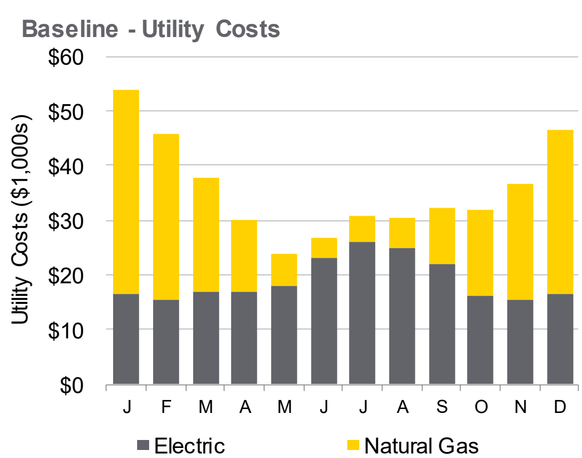
This baseline includes all facilities and was created by taking several years of utility data and utilizing the following:

- Prorating the usage into clean monthly bins
- Weather normalizing the baseline to represent a typical meteorological year

	Electricity			Natural Gas		Total	
Month *mmm*	Energy Use *kWh*	Energy Demand *kW*	Cost *$*	Energy Use *Therm*	Cost *$*	Energy Use *MMBtu*	Cost *$*
Jan	164,811	328	$16,708	29,802	$37,012	3,543	$53,720
Feb	146,344	334	$15,384	25,694	$30,556	3,069	$45,940
Mar	151,360	320	$16,848	17,229	$20,992	2,239	$37,840
Apr	140,041	321	$16,912	13,414	$13,115	1,819	$30,027
May	157,731	344	$18,139	5,515	$5,575	1,090	$23,713
Jun	170,646	382	$23,105	2,535	$3,537	836	$26,642
Jul	212,005	441	$26,081	3,513	$4,852	1,075	$30,933
Aug	209,050	432	$25,134	4,088	$5,477	1,122	$30,611
Sept	173,270	430	$21,868	7,867	$10,314	1,378	$32,182
Oct	170,167	407	$16,080	13,016	$15,797	1,882	$31,877
Nov	169,782	367	$15,360	15,367	$21,269	2,116	$36,629
Dec	166,544	326	$16,458	24,101	$30,158	2,979	$46,616
Year	**2,031,751**	**4,434**	**$228,078**	**162,140**	**$198,653**	**23,148**	**$426,731**

	Electricity			Natural Gas		Total	
Indices	**kBtu/sf**	**W/sf**	**$/sf**	**kBtu/sf**	**$/sf**	**kBtu/sf**	**$/sf**
	24.2	**1.5**	**$0.80**	**56.7**	**$0.69**	**80.9**	**$1.49**





The following charts depict the month-by-month energy baseline for each facility:

Kennedy Center

	Electricity			Natural Gas		Total	
Month	Energy Use	Energy Demand	Cost	Energy Use	Cost	Energy Use	Cost
mmm	*kWh*	*kW*	*$*	*Therm*	*$*	*MMBtu*	*$*
Jan	87,043	171	$8,252	20,879	$25,607	2,385	$33,860
Feb	77,179	180	$7,587	17,928	$20,699	2,056	$28,286
Mar	80,301	162	$8,770	12,119	$14,377	1,486	$23,148
Apr	70,713	161	$8,583	10,896	$10,104	1,331	$18,687
May	80,118	170	$8,838	4,638	$4,404	737	$13,242
Jun	84,658	188	$10,943	225	$385	311	$11,328
Jul	113,252	229	$12,765	217	$377	408	$13,143
Aug	113,790	219	$12,416	499	$623	438	$13,039
Sept	86,618	209	$10,350	4,404	$5,689	736	$16,039
Oct	83,494	207	$7,599	9,658	$11,475	1,251	$19,075
Nov	91,384	194	$8,236	11,506	$15,811	1,463	$24,048
Dec	92,247	173	$8,641	17,268	$20,910	2,042	$29,551
Year	**1,060,799**	**2,262**	**$112,982**	**110,236**	**$130,462**	**14,644**	**$243,444**

	Electricity			Natural Gas		Total	
Indices	kBtu/sf	W/sf	$/sf	kBtu/sf	$/sf	kBtu/sf	$/sf
	19.1	1.2	$0.59	58.0	$0.69	77.1	$1.28

Municipal Complex

	Electricity			Natural Gas		Total	
Month	Energy Use	Energy Demand	Cost	Energy Use	Cost	Energy Use	Cost
mmm	*kWh*	*kW*	*$*	*Therm*	*$*	*MMBtu*	*$*
Jan	33,112	65	$4,600	1,784	$1,759	291	$6,358
Feb	29,657	65	$4,344	1,539	$1,512	255	$5,855
Mar	31,434	65	$4,472	952	$928	202	$5,400
Apr	32,723	69	$4,594	458	$434	158	$5,028
May	37,323	85	$5,010	192	$193	147	$5,203
Jun	41,877	96	$6,270	100	$110	153	$6,381
Jul	50,499	105	$7,025	74	$87	180	$7,112
Aug	48,050	106	$6,861	87	$98	173	$6,959
Sept	39,787	100	$6,168	142	$148	150	$6,316
Oct	37,454	83	$5,005	474	$449	175	$5,454
Nov	32,686	66	$4,581	698	$671	181	$5,253
Dec	28,743	63	$4,270	1,125	$1,099	211	$5,370
Year	**443,346**	**968**	**$63,200**	**7,628**	**$7,489**	**2,276**	**$70,689**

	Electricity			Natural Gas		Total	
Indices	kBtu/sf	W/sf	$/sf	kBtu/sf	$/sf	kBtu/sf	$/sf
	48.6	3.4	$2.03	24.5	$0.24	73.1	$2.27

Library

	Electricity			Natural Gas		Total	
Month	Energy Use	Energy Demand	Cost	Energy Use	Cost	Energy Use	Cost
mmm	*kWh*	*kW*	*$*	*Therm*	*$*	*MMBtu*	*$*
Jan	34,753	62	$2,936	2,678	$4,250	386	$7,186
Feb	31,135	58	$2,638	1,940	$3,213	300	$5,852
Mar	31,713	65	$2,799	1,542	$2,569	262	$5,367
Apr	29,718	65	$2,992	595	$946	161	$3,938
May	32,306	65	$3,489	333	$604	144	$4,093
Jun	34,118	70	$4,661	2,006	$2,794	317	$7,455
Jul	36,155	75	$4,837	3,051	$4,165	428	$9,002
Aug	35,453	74	$4,416	3,333	$4,535	454	$8,951
Sept	36,777	77	$3,876	3,032	$4,141	429	$8,017
Oct	39,758	74	$2,519	1,626	$2,455	298	$4,973
Nov	37,201	67	$1,756	1,093	$2,228	236	$3,984
Dec	36,148	63	$2,734	1,872	$3,340	311	$6,074
Year	**415,235**	**814**	**$39,653**	**23,102**	**$35,238**	**3,727**	**$74,891**

	Electricity			Natural Gas		Total	
Indices	kBtu/sf	W/sf	$/sf	kBtu/sf	$/sf	kBtu/sf	$/sf
	31.5	1.7	$0.88	51.3	$0.78	82.8	$1.66

DPW Site

	Electricity			Natural Gas		Total	
Month	Energy Use	Energy Demand	Cost	Energy Use	Cost	Energy Use	Cost
mmm	*kWh*	*kW*	*$*	*Therm*	*$*	*MMBtu*	*$*
Jan	9,902	31	$920	4,462	$5,396	480	$6,316
Feb	8,373	32	$815	4,287	$5,132	457	$5,948
Mar	7,911	29	$806	2,616	$3,118	289	$3,924
Apr	6,888	26	$744	1,464	$1,630	170	$2,374
May	7,984	24	$803	351	$373	62	$1,176
Jun	9,993	28	$1,231	203	$248	54	$1,478
Jul	12,099	33	$1,453	171	$223	58	$1,676
Aug	11,756	33	$1,441	169	$221	57	$1,662
Sept	10,089	44	$1,474	289	$337	63	$1,810
Oct	9,462	44	$957	1,258	$1,418	158	$2,375
Nov	8,510	40	$787	2,069	$2,558	236	$3,345
Dec	9,405	28	$812	3,836	$4,809	416	$5,621
Year	**112,372**	**390**	**$12,243**	**21,175**	**$25,464**	**2,501**	**$37,707**

	Electricity			Natural Gas		Total	
Indices	kBtu/sf	W/sf	$/sf	kBtu/sf	$/sf	kBtu/sf	$/sf
	19.2	2.2	$0.61	105.9	$1.27	125.1	$1.89

4.2 Energy Savings

To estimate savings from the proposed project, Schneider Electric utilized energy modeling software and engineering formulas. Schneider Electric used Excel spreadsheets to accurately quantify savings for measures that have low interactivity. For measures that are significantly affected by interactions of different components, such as mechanical and BAS upgrades, Schneider Electric utilized energy simulation software called eQuest. eQuest was developed through funding by the United States Department of Energy (USDOE) and is the preferred tool for energy modeling in the energy performance contracting industry. Additionally, ELEMENT, a proprietary building modeling tool was used to develop baselines and savings for some builds. Using these modeling tool allows for the ability to model existing conditions and proposed retrofits to assess potential energy savings.

For detailed savings calculations for each ECM, please see the Appendix 6.1.

ECM Savings Summary by Site

ECM Detail		Total Energy Savings			Total Cost Savings			Detail Unit Savings			Detailed Cost Savings	
Site	ECM	Energy Savings	EUI Savings	Site % Savings	Cost Savings	ECI Savings	Site % Savings	Electric	Electric	Natural Gas	Electric	Natural Gas
Name	*Name*	*MMBtu*	*kBtu/sf*	*%*	*$*	*$/sf*	*%*	*kWh*	*kW*	*Therm*	*$*	*$*
Kennedy Center	Air Sealing/Weatherization Improvements	692	3.6	4.7%	$6,830	$0.04	2.8%	6,869	0	6,688	$224	$6,606
Kennedy Center	Destratification Fans	313	1.6	2.1%	$3,066	$0.02	1.3%	-3,600	0	3,256	-$150	$3,216
Kennedy Center	BAS Scheduling/Setbacks	476	2.5	3.2%	$4,227	$0.02	1.7%	12,545	0	4,329	$24	$4,203
Kennedy Center	Expand BAS to RTUs replaced	1,112	5.9	7.6%	$10,511	$0.06	4.3%	3,856	8	10,986	-$179	$10,690
Kennedy Center	Demand Control Ventilation	1,388	7.3	9.5%	$14,162	$0.07	5.8%	5,013	54	13,708	$792	$13,370
Kennedy Center	LED Lighting Upgrades	893	4.7	6.1%	$17,483	$0.09	7.2%	369,227	509	-3,675	$21,098	-$3,615
Kennedy Center	Boiler Replacement	1,540	8.1	10.5%	$15,148	$0.08	6.2%	0	0	15,400	$0	$15,148
Kennedy Center	RTU Replacement	187	1.0	1.3%	$2,710	$0.01	1.1%	54,876	123	0	$2,710	$0
DPW Site	Air Sealing/Weatherization Improvements	404	20.2	16.2%	$4,295	$0.21	11.4%	1,206	0	4,002	$93	$4,202
DPW Site	Destratification Fans	107	5.3	4.3%	$1,176	$0.06	3.1%	-500	0	1,085	-$38	$1,215
DPW Site	Diesel Engine Block Heater Controls	20	1.0	0.8%	$451	$0.02	1.2%	5,955	0	0	$451	$0
DPW Site	Programmable Thermostats	239	11.9	9.6%	$2,914	$0.15	7.7%	5,551	0	2,199	$410	$2,504
DPW Site	LED Lighting Upgrades	40	2.0	1.6%	$1,291	$0.06	3.4%	16,358	23	-163	$1,478	-$188
DPW Site	Boiler Replacement	80	4.0	3.2%	$918	$0.05	2.4%	0	0	797	$0	$918
DPW Site	RTU Replacement	2	0.1	0.1%	$47	$0.00	0.1%	517	0	0	$47	$0
Library	Air Sealing/Weatherization Improvements	26	0.6	0.7%	$347	$0.01	0.5%	0	0	257	$0	$347
Library	BAS Scheduling/Setbacks	139	3.1	3.7%	$1,394	$0.03	1.9%	1,803	6	1,326	-$327	$1,720
Library	New Heating and Cooling Plant	943	21.0	25.3%	$11,734	$0.26	15.7%	-13,542	9	9,894	-$1,287	$13,021
Library	LED Lighting Upgrades	262	5.8	7.0%	$3,242	$0.07	4.3%	81,550	112	-164	$3,469	-$227
Municipal Complex	Air Sealing/Weatherization Improvements	67	2.2	3.0%	$672	$0.02	1.0%	1,527	0	622	$113	$559
Municipal Complex	Demand Control Ventilation	42	1.3	1.8%	$481	$0.02	0.7%	2,373	0	334	$161	$320
Municipal Complex	Programmable Thermostats	243	7.8	10.7%	$4,049	$0.13	5.7%	43,902	0	936	$3,163	$886
Municipal Complex	LED Lighting Upgrades	238	7.6	10.4%	$7,612	$0.24	10.8%	98,306	135	-978	$8,532	-$920
Municipal Complex	RTU Replacement	0	0.0	0.0%	$73	$0.00	0.1%	0	6	0	$73	$0
Total Project Savings		**9,452**			**114,832**			**693,791**	**387**	**70,838**	**$40,857**	**$73,975**

In addition to the energy savings noted above, this Project will also provide O&M savings for the following scope items:

Scope Item	Annual O&M Savings	Years Claimed
LED Lighting	$ 1,500	5
Boiler & RTU Replacement & Library Central Plant Upgrade	$ 7,000	2
Total	**$ 8,500**	

4.3 Environmental Impact

The following table summarizes the environmental impact of the project:

Therms Savings	kWh Savings	Emission Type	Emission Reduction (tons/yr)
70,928	697,028	CO2	1,946
		NOx	1,168
		SO2	943

The emissions reductions are calculated based on the following factors, which comply with BPU guidelines:

- 1,292 lbs. CO_2 per MWh saved
- 0.83 lbs. NO_x per MWh saved
- 0.67 lbs. SO_2 per MWh saved
- 11.7 lbs. CO_2 per therm saved
- 0.0092 lbs. NO_x per therm saved

5.0 Implementation

5.1 Design & Compliance Issues

This project was developed using the proper Building Codes, Energy Codes, and Electrical Codes. Safety is of the utmost important to Schneider Electric, not only for our customers, but also for our employees and subcontractors. SE will comply with all the required safety codes and protocols to ensure a successful implementation.

5.2 Assessment of Risks

This assessment of risks is meant to provide Willingboro Township with an idea of the potential risks that lie within the ESIP project. By no means is this an effort to eliminate responsibility of the ESCO to provide an Energy Savings Plan that meets industry standards of engineering, energy analysis, and expertise. This is included to allow the Township to understand where potential failure points could be that would result in savings not being achieved or operational issues.

- If actual operation of the buildings deviates significantly from the parameters outlined in the Energy Savings Plan with respect to temperature set points and occupied times, energy savings associated with the building automation system and HVAC upgrades could be affected.
- Building Automation System sequences of operation must not be over-ridden or changed permanently. Overrides are permitted for maintenance or special occasions but must be reset to maintain energy savings.
- Lighting systems will require maintenance as they age. Replacement parts need to be of similar energy efficiency to maintain savings.

6.0 Appendices

6.1 Savings Calculations & Documentation

Below is a high-level summary of how savings were calculated for each measure included in this report. For further documentation of savings calculations, please see the Appendices Box folder.

Energy Analysis Methodology

Many tools and approaches exist for effectively analyzing energy conservation measures. Some ECMs are best analyzed in an individual spreadsheet calculation while other more comprehensive ECMs require higher levels of computer modeling to capture the entirety of their impact on energy consumption and demand. In general, the complexity of analysis tools escalates from spreadsheet calculations to, to more sophisticated computer software-based building simulation tools such as eQuest. Aspects such as total savings potential, influence on other ECMs, influence from weather, and overall complexity are all considered when selecting the analysis approach or tool for an ECM.

Below is a table displaying the ECMs and the analysis tool used for calculating the savings. Following the table are descriptions for each of the analysis tools and approaches used for calculating savings.

ECM Name	Analysis Tool
Air Sealing/Weatherization Improvements	Spreadsheet Calculations
Destratification Fans	Spreadsheet Calculations
BAS Scheduling/Setbacks, Expanding to RTUs	eQuest/ELEMENT
Demand Control Ventilation	eQuest/ELEMENT
Lighting Upgrades	eQuest/ELEMENT
Boiler Replacement	eQuest/ELEMENT
RTU/HVAC Unit Replacement	eQuest/ELEMENT
Diesel Engine Block Heater Controls	Spreadsheet Calculations
Programmable Thermostats	eQuest/ELEMENT
HVAC Airside TAB & Retro-commissioning	eQuest/ELEMENT
Nitrogen Tire Inflation System	Spreadsheet Calculations

Savings Methods – Spreadsheet Calculations

Schneider Electric utilizes a mixture of spreadsheet calculations and basic formula calculation tools. eCalc is a proprietary Microsoft Excel based spreadsheet calculation tool used for calculating energy consumption and savings for an ECM, rather than a comprehensive building analysis approach. Often an approach using eCalcs or other spreadsheet calculations is the most accurate and reasonable way of approaching ECMs in which their operation, situation, or contribution to the baseline is limited.

What separates eCalcs from other spreadsheet-based tools is its integration of bin weather data into many of its standard calculations. Equipment or infiltration often has fluctuating savings opportunity as outside air reaches new high and low average temperatures through different seasons. By capturing the quantity of hours inside specific temperature ranges, these ECMs can better replicate the demand on the system, run hours, and heating and cooling loads. Below is an example of an eCalc spreadsheet for calculating envelope improvement savings.

eCalcs: Energy Calculation Suite — Life Is On Schneider Electric

PC19P0001 - Municipal Complex

Infiltration

Building Data

Building Name	Municipal Complex
Weather City	PA, Philadelphia-International
Building Height, ft	15
Building Orientation, deg	0
Building L/W Ratio	3.0
Internal Draft Coefficient	0.7

Building Operating Conditions

Occupied Set Point Temp, oF	72.0
Cooling Setup Temp, oF	80.0
Percent of Building Cooled, %	100%
Cooling Seasonal Efficiency, %	290%
Heating Setback Temp, oF	60.0
Percent of Building Heated, %	100%
Heating Seasonal Efficiency, %	80%

Shelter Characteristics

Direction	Shelter Class	Terrain Category
See Reference Tables for Descriptions		
North	3	3
East	3	3
South	3	3
West	3	3

Building Crack Definitions

Penetration	Type	H	Qty	Length	Gap	% Open	Total Area	Wall Only
Name	*Select*	*ft*	*#*	*ft*	*inches*	*%*	*sqft*	*sqft*
Doors	Door	-4.5	1	300	3/32	100%	2.3	2.3
OH Doors	Door	-4.5	1	28	3/16	100%	0.4	0.4
Crack 3	Wall	0.0				100%	0.0	0.0
Crack 4	Wall	0.0				100%	0.0	0.0
Crack 5	Wall	0.0				100%	0.0	0.0
Crack 6	Wall	0.0				100%	0.0	0.0
Crack 7	Wall	0.0				100%	0.0	0.0
Crack 8	Wall	0.0				100%	0.0	0.0
Crack 9	Wall	0.0				100%	0.0	0.0
Crack 10	Wall	0.0				100%	0.0	0.0
Crack 11	Wall	0.0				100%	0.0	0.0
Crack 12	Wall	0.0				100%	0.0	0.0
Crack 13	Wall	0.0				100%	0.0	0.0
Effective H (Wall Only)		-4.5					2.8	2.8

Notes: H is the height difference between the crack and the neutral pressure level of the building.

Effective Building Coefficients

Shelter Coefficient	0.7
Wind Shear Exponent	0.14
Boundary Layer Thickness, ft	900
Wall Pressure Coefficient	0.11
Roof Pressure Coefficient	-0.30

Site Parameters

Average Wind Speed, mph	9.4
Site Corrected Wind Speed, mph	8.4
Model Wind Coefficient	0.22
Draft Factor	0.13
Volume Factor, ft/min (in-wg)^0.5	2,603

Energy Engineering Calculations

Temperature Bin Hours						Calculated Infiltration Rates				Energy Transfer		Energy Savings	
				JFK/Muni		Occupied Rates		Unoccupied Rates		Occupied	Unocc	Cooling	Heating
Mid Pt Temp	MCWB	Density	Enthalpy	Occupied	Unocc	Wall	Roof	Wall	Roof	Load	Load	Savings	Savings
oF	*oF*	*lb/ft3*	*Btu/lb*	*hrs/yr*	*hrs/yr*	*cfm*	*cfm*	*cfm*	*cfm*	*kBtu/yr*	*kBtu/yr*	*kBtu/yr*	*kBtu/yr*
9	6.5	0.085	2.8	4	18	491	0	420	0	-235	-673	0	1,136
13	10.1	0.084	3.9	7	31	469	0	394	0	-372	-1,010	0	1,727
16	14.0	0.083	5.1	20	57	446	0	366	0	-946	-1,582	0	3,160
20	17.4	0.082	6.3	28	81	422	0	336	0	-1,177	-1,898	0	3,844
24	20.3	0.082	7.3	67	175	397	0	305	0	-2,497	-3,418	0	7,394
28	24.1	0.081	8.7	106	245	370	0	268	0	-3,387	-3,740	0	8,909
31	27.7	0.080	10.0	206	305	341	0	227	0	-5,553	-3,443	0	11,245
35	31.1	0.080	11.3	138	282	310	0	177	0	-3,087	-2,151	0	6,548
39	33.8	0.079	12.5	166	350	277	0	110	0	-3,044	-1,434	0	5,597
43	37.4	0.079	14.0	208	298	238	0	91	0	-2,892	-807	0	4,624
46	41.4	0.078	15.8	175	342	189	0	171	0	-1,635	-1,234	0	3,587
50	44.7	0.077	17.5	139	273	126	0	222	0	-723	-810	0	1,916
54	47.7	0.077	19.0	198	321	59	0	262	0	-399	-528	0	1,159
58	52.1	0.076	21.4	248	392	160	0	301	0	-900	572	0	410
61	56.2	0.075	23.9	254	410	218	0	308	0	-625	0	0	781
65	59.1	0.074	25.8	168	271	259	0	307	0	-125	0	0	156
69	62.0	0.074	27.8	218	454	295	0	305	0	392	0	135	0
73	65.8	0.073	30.6	249	425	330	0	304	0	1,511	0	521	0
76	67.7	0.073	32.0	279	258	355	0	303	0	2,435	0	840	0
80	69.2	0.072	33.3	196	115	377	0	313	0	2,194	323	868	0
84	70.1	0.072	34.0	238	65	396	0	336	0	3,084	265	1,155	0
88	72.2	0.071	35.8	158	26	418	0	361	0	2,656	186	980	0
91	74.7	0.070	38.1	71	5	440	0	387	0	1,542	56	551	0
95	75.0	0.070	38.4	14	1	454	0	402	0	319	12	114	0
99	76.9	0.069	40.1	5	0	472	0	423	0	135	0	47	0
				3,560	5,200							5,211	62,193

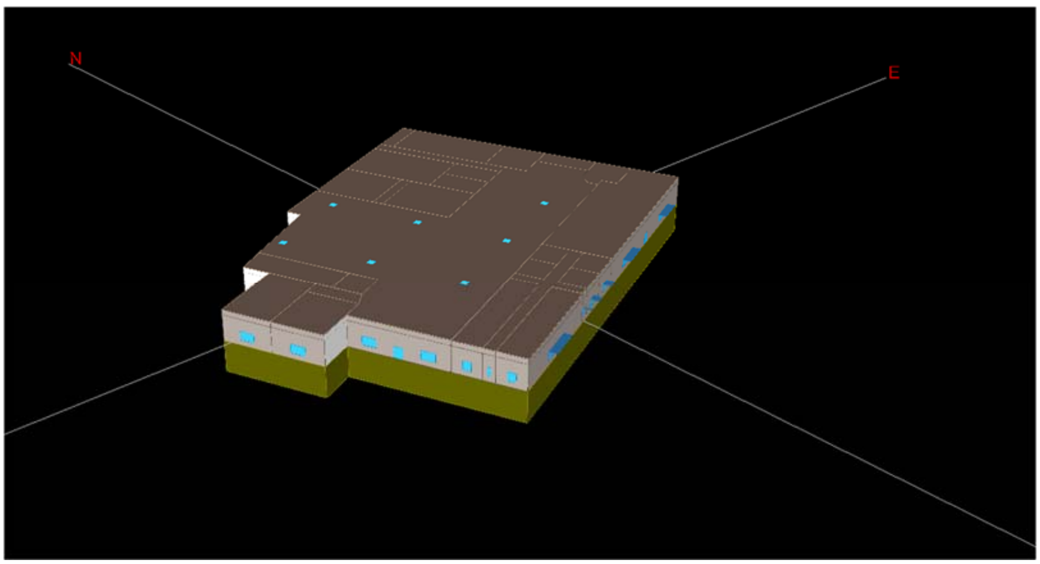
Savings Summary

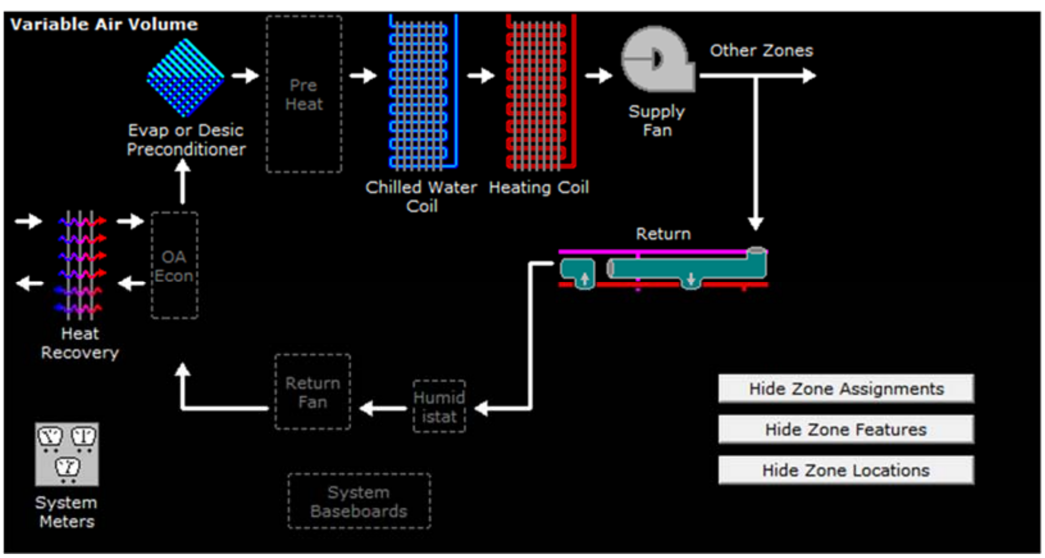
Type	Savings	Units	Utility Type
Cooling	1,527	kWh	Electricity
Heating	622	Therm	Natural Gas - Therm

Savings Methods – eQuest

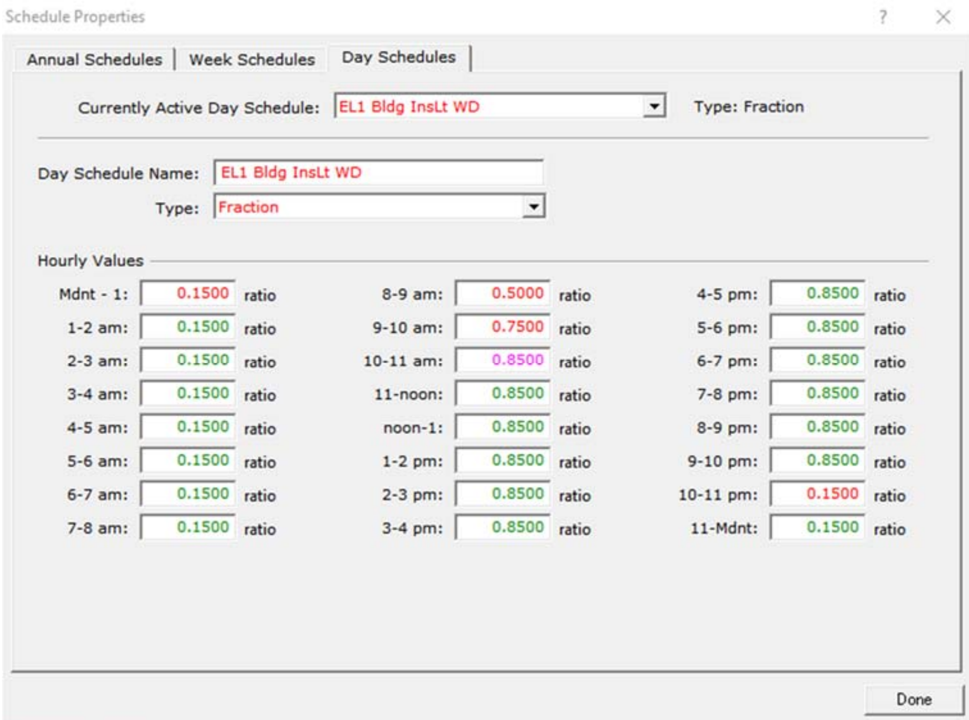
To estimate savings for key buildings, Schneider Electric modeled energy use of buildings using eQuest. eQuest was developed through funding by the United States Department of Energy (USDOE) and is used as the preferred tool for energy modeling in the industry. This modeling tool provides the unique ability to model current conditions, including combined heat and power, and proposed retrofits in order to assess energy savings.

Spaces are defined by their construction to determine thermal conductivity and mass for heat loss/gain calculations. Also included are ventilation rates, lighting, equipment, and occupant loads and schedules. Individual spaces or groups of spaces are assigned to thermal zones that are served by an air distribution system. A thermal zone is defined by the conditioned area that is served by one thermostat controlling one terminal device (if applicable). Systems may include either a central air handler or distributed equipment such as water source heat pumps. Systems are then assigned to a loop that serves heating and/or cooling coils. Loops can include chillers, cooling towers, boilers, ground source wells, and all associated pumps. Plants are then assigned to a building. Below are screen shots of the eQuest model for the Library:





Defining accurate schedules is imperative to creating an accurate model. Schedules are used to describe when and to what capacity the building is operated and occupied. Varying load levels and runtime for lighting, electrical equipment, occupancy, ventilation, fans, and temperature set-points are all modeled using schedules. Below are two screen shots showing a typical lighting schedule.



Calibrating the Model

To accurately predict the energy and demand savings of the project, the model must be calibrated to replicate closely the energy and demand use profiles of the baseline building. This is accomplished by first running the model as constructed. These results are then compared to the baseline energy consumption data described above to assess how closely the model matches the baseline. After examining the results, it becomes apparent where energy or demand is too high or too low and where adjustments may need to be made. The end goal is replicating all parameters such as electric energy, electric demand, and gas use to align simultaneously. These parameters typically involve adjusting operating schedules, internal loads, equipment efficiencies, and temperature set-points. The calibration process typically requires between fifteen and twenty iterations (possibly more for complex models) to achieve a satisfactorily calibrated model. The following graphic shows the output of the energy model vs. baseline for the Library.

Library - Baseline

eQuestrian Life Is On Schneider Electric

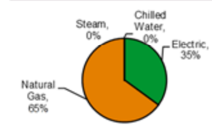
PC19P0001 - W Twp - Library - Baseline

Baseline | ECM01 | ECM02 | ECM03 | ECM04 | ECM05 | ECM06 | ECM07 | ECM08 | ECM09 | ECM10 | Update Results

Baseline Energy			
Fuel	Pre	Units	EUI
Electric	383,637	kWh	29.1
Electric	875	kW	-
Natural Gas	24,255	Therm	53.9
Chilled Water	-	Ton-hrs	-
Steam	-	klb	-
Total	3,734,900	kBtu	83.0

Calibration	
Previous	Current
-8%	-8%
8%	8%
5%	5%
-	-
-	-

Baseline Energy Chart



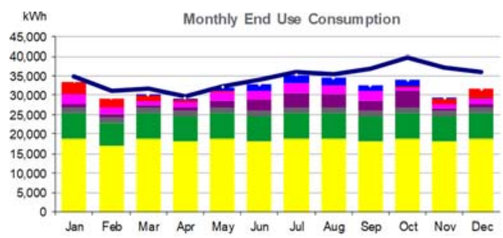
Electric Energy Data

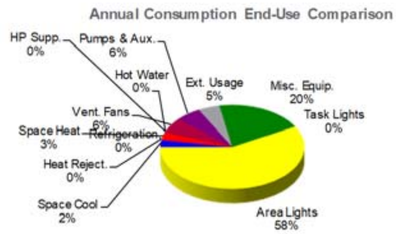
1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
	Electric Consumption												
Space Cool	0	0	9	312	966	1,717	2,177	1,963	1,390	1,525	10	0	10,070
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0
Space Heat	3,115	2,350	1,443	636	82	16	0	3	22	361	1,401	2,352	11,784
HP Supp.	186	108	33	2	0	0	0	0	0	0	37	77	443
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0
Vent. Fans	2,346	1,691	1,170	1,229	2,325	2,062	2,491	2,276	2,687	899	1,153	1,579	21,907
Pumps & Aux.	867	699	508	860	1,697	2,878	3,628	3,243	2,407	4,128	490	715	22,119
Ext. Usage	1,574	1,422	1,574	1,523	1,574	1,523	1,574	1,574	1,523	1,574	1,523	1,574	18,535
Misc. Equip.	6,442	5,821	6,447	6,268	6,452	6,243	6,462	6,467	6,228	6,462	6,213	6,442	75,948
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0
Area Lights	18,925	17,094	18,925	18,315	18,925	18,315	18,925	18,925	18,315	18,925	18,315	18,925	222,831
Total	33,456	29,185	30,109	29,146	32,021	32,756	35,258	34,452	32,572	33,875	29,144	31,664	383,637
Utility Baseline	34,753	31,135	31,713	29,718	32,306	34,118	36,155	35,453	36,777	39,758	37,201	36,148	415,235
Error	-4%	-6%	-5%	-2%	-1%	-4%	-2%	-3%	-11%	-15%	-22%	-12%	-8%

kWh 1	Model Checks Avg Hours	Max Hours	Load Factor
Space Cool	9,319	2,469	28.2%
Heat Reject.	0	0	0.0%
Refrigeration	0	0	0.0%
Space Heat	5,130	1,748	20.0%
HP Supp.	2,091	308	3.5%
Hot Water	0	0	0.0%
Vent. Fans	1,510	806	9.2%
Pumps & Aux.	10,984	3,498	39.9%
Ext. Usage	6,150	4,387	50.1%
Misc. Equip.	7,797	7,537	86.0%
Task Lights	0	0	0.0%
Area Lights	5,561	5,561	63.5%
Total Model	5,260	4,636	52.9%
Utility Baseline	6,124	5,362	61.2%
	-14%	-14%	-14%

10.65% Coefficient of Variation of the Root Squared Mean Error

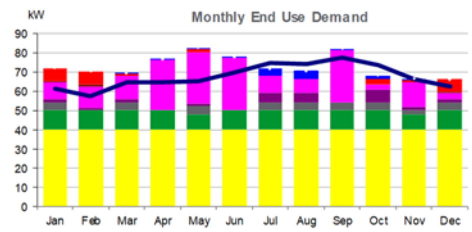
8.30% Normalized Mean Bias Error

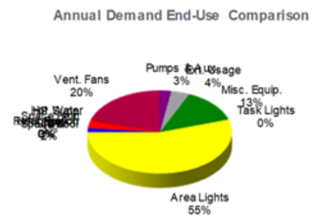




Electric Demand Data

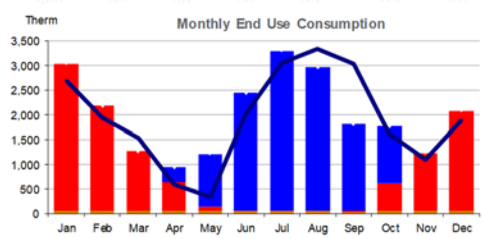
	Electric Demand													kW	Model Checks	
1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	1	Average	Max
Space Cool	0	0	0	1	1	1	4	4	1	2	0	0	13	Space Cool	1.1	4.1
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0	Heat Reject.	0.0	0.0
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0	Refrigeration	0.0	0.0
Space Heat	7	7	1	0	2	0	0	0	0	3	1	7	28	Space Heat	2.3	6.7
HP Supp.	1	1	0	0	0	0	0	0	0	0	0	0	3	HP Supp.	0.2	1.4
Hot Water	0	0	0	0	0	0	0	0	0	0	0	0	0	Hot Water	0.0	0.0
Vent. Fans	9	11	12	26	27	27	8	7	27	3	13	3	174	Vent. Fans	14.5	27.2
Pumps & Aux.	1	1	1	0	1	0	5	5	0	6	1	1	24	Pumps & Aux.	2.0	6.3
Ext. Usage	4	0	4	0	4	0	4	4	4	4	2	4	36	Ext. Usage	3.0	4.2
Misc. Equip.	10	10	10	10	8	10	10	10	10	10	8	10	117	Misc. Equip.	9.7	10.1
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0	Task Lights	0.0	0.0
Area Lights	40	40	40	40	40	40	40	40	40	40	40	40	481	Area Lights	40.1	40.1
Total	**72**	**71**	**70**	**77**	**83**	**78**	**72**	**71**	**82**	**68**	**66**	**66**	**875**	Total Model	72.9	82.7
Utility Baseline	62	58	65	65	65	70	75	74	77	74	67	63	814	Utility Baseline	67.8	77.4
Error	17%	22%	7%	19%	27%	11%	-4%	-5%	6%	-7%	0%	6%	8%		8%	7%
													13.32%	Root Squared Mean Error		
													-7.57%	Mean Bias Error		

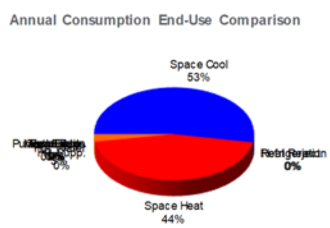




Natural Gas Energy Data

	Natural Gas Consumption													Therm	Model Checks		
1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	100	Avg Hours	Max Hours	Load Factor
Space Cool	0	0	0	313	1,063	2,374	3,259	2,920	1,748	1,149	0	0	12,826	Space Cool	2,700	1,116	12.7%
Heat Reject.	0	0	0	0	0	0	0	0	0	0	0	0	0	Heat Reject.	0	0	0.0%
Refrigeration	0	0	0	0	0	0	0	0	0	0	0	0	0	Refrigeration	0	0	0.0%
Space Heat	2,978	2,126	1,205	572	95	14	0	3	19	576	1,184	2,026	10,798	Space Heat	2,397	980	11.2%
HP Supp.	0	0	0	0	0	0	0	0	0	0	0	0	0	HP Supp.	0	0	0.0%
Hot Water	58	55	62	61	56	50	48	47	42	48	47	55	631	Hot Water	4,846	2,257	25.8%
Vent. Fans	0	0	0	0	0	0	0	0	0	0	0	0	0	Vent. Fans	0	0	0.0%
Pumps & Aux.	0	0	0	0	0	0	0	0	0	0	0	0	0	Pumps & Aux.	0	0	0.0%
Ext. Usage	0	0	0	0	0	0	0	0	0	0	0	0	0	Ext. Usage	0	0	0.0%
Misc. Equip.	0	0	0	0	0	0	0	0	0	0	0	0	0	Misc. Equip.	0	0	0.0%
Task Lights	0	0	0	0	0	0	0	0	0	0	0	0	0	Task Lights	0	0	0.0%
Area Lights	0	0	0	0	0	0	0	0	0	0	0	0	0	Area Lights	0	0	0.0%
Total	**3,036**	**2,182**	**1,267**	**947**	**1,214**	**2,438**	**3,307**	**2,969**	**1,809**	**1,773**	**1,232**	**2,081**	**24,255**	Total Model	2,584	2,085	23.8%
Utility Baseline	2,678	1,940	1,542	595	333	2,006	3,051	3,333	3,032	1,626	1,093	1,872	23,102	Utility Baseline	547	177	2.0%
Error	13%	12%	-18%	59%	265%	22%	8%	-11%	-40%	9%	13%	11%	5%		373%	1077%	1077%
													27.70%	Root Squared Mean Error			
													-4.99%	Mean Bias Error			





Savings Methods – ELEMENT

The ELEMENT tool was developed to provide transparency into the end use breakdown of energy consumption for each fuel type. The simplified building inputs and schedules are used in a powerful hourly load analysis to provide quick building calibrations. Energy saving scenarios can be run quickly to see the financial impact to the overall project and generate useful graphs for visualization and reports.

Introduction

ELEMENT is Schneider Electric's proprietary Microsoft Excel based spreadsheet calculation tool used for simulating building energy consumption. Its purpose is to allow a user with prior knowledge of a facility and its energy using equipment to simulate energy consumption, compare the outputs to historical utility data of the facility, breakout the calibrated baseline into its end use components and determine the energy savings of Energy Conservation Measures (ECMs).

The tool uses a variety of Excel functions and custom generated algorithms written in Visual Basic for Applications (VBA) to quickly simulate the energy consumption of a simple to moderately complex building. Heating and cooling loads are determined on an hourly basis (8,760 hours per year) using TMY2 or TMY3 weather data and the building definitions specified by the user. Loads are generated by the user inputs and key building variables are defined and adjusted to calibrate and predict energy impacts.

Calculations

The Element tool is an hourly load and energy analysis tool used for whole building energy models. The results show end use breakdowns of energy on a monthly basis while allowing for quick calibration to utility billing data. Energy conservation measures can be easily defined and reviewed using the ECM tab to redefine variables used in the baseline model. Each new ECM run is sequential and uses the variable last defined by the previously successful run. The savings are determined by the difference in runs by either actual, percent or minimum unit method, as described previously.

The hourly outdoor air conditions and solar data are imported from the National Renewable Energy Laboratories (NREL) typical meteorological year (TMY) data set. The building calendar defines up to four typical day types that occur throughout the year. These day types are used by the hourly load percentage schedules and HVAC schedules used to define the operation of internal and external building loads, as well as the fan operation of the HVAC system. All 365 days of the year are assigned a day type as defined by the calendar and each hour of the day has an hourly load percentage for each load schedule name and on or off status for each HVAC schedule name. The occupied and unoccupied set points are also driven by the on/off status of the HVAC fan. An algorithm determines if the system is in heating or cooling mode based on the user inputs and weather data in order to determine which occupied heating or cooling set point to use.

Zone and system loads are calculated using industry standard engineering equations (ASHRAE) as listed below based on the user defined building parameters described in the baseline calculation inputs section. The total sensible system load determines if heating or cooling energy is required (negative results for heating and positive values for cooling). Calculations are repeated for each hour of the year to determine the total annual loads and energy consumption.

The following is a sampling of the variables and equations used for calculations the building loads and energy consumption and demand.

Weather and Solar Data

Outdoor Air Dry Bulb Temperature, ^{o}F
Outdoor Air Density, lbm air/ft^3
Outdoor Air Humidity Ratio, lbm water/lbm air

Solar Direct Normal Irradiance, Btu/ft^2
Solar Diffuse Horizontal Irradiance, Btu/ft^2
Sol-air Temperature, °F

- $T_{SA} = T_{OA} + (\alpha \times I_N / h_o) - (\varepsilon \times \Delta R / h_o)$
  - α = wall or roof absorptivity of solar radiation based on surface color, dimensionless
  - I_N = direct normal solar flux on wall and diffuse horizontal irradiance on roof, Btu/hr-ft^2
  - h_o = the convective heat transfer coefficient on exterior wall or roof = 3.0 Btu/h-ft^2 °F
  - ε = hemispherical emittance of exterior surface = 1.0 Btu/h-ft^2
  - ΔR = long wave radiation incident on exterior surface and blackbody radiation
    - For vertical surfaces (walls), $\Delta R = 0$ (vertical surfaces)
    - For horizontal surfaces (roof), ΔR = 20.0 Btu/h-ft^2

Zone Loads

Sensible Zone Loads, Btu

- **Internal Heat Gains**
- Lighting, $Q_{S\_LTG} = L_{LTG} \times A_{BLDG} / 1000 \times HLP_{LTG} \times C$
- Equipment, $Q_{S\_EQUIP} = L_{EQUIP} \times A_{BLDG} / 1000 \times HLP_{EQUIP} \times C$
- People, $Q_{S\_PEOPLE} = n_{PEOPLE} \times HGF_{S\_PEOPLE} \times HLP_{PEOPLE}$
  - A_{BLDG} = building area, ft^2
  - C = conversion factor kW to kBtu = 3412 kBtu/kWh
  - HGF_{S_PEOPLE} = heat gain factor (sensible) based on activity level, (see Table 1), Btu/h-person
  - HLP = hourly load percentage of peak load based on assigned schedule, %
  - L = peak load density, W/ft^2
  - n_{PEOPLE} = number of people, persons
- **Envelope Loads**
- Wall, $Q_{S\_WALL} = 1/R_{WALL} \times (A_{WALL} - A_{WINDOW}) \times (T_{SA\_WALL} - T_{SP})$
- Roof, $Q_{S\_ROOF} = 1/R_{ROOF} \times (A_{ROOF}) \times (T_{SA\_ROOF} - T_{SP})$
- Window Conduction, $Q_{S\_WINDOW,C} = U_{WINDOW} \times A_{WINDOW} \times (T_{OA} - T_{SP})$
- Window Radiation, $Q_{S\_WINDOW,R} = A_{WINDOW} \times SHGC \times (1 - ES) \times I_N$
- Infiltration, $Q_{S\_INFIL} = \rho \times c_p \times q_{INF} \times A_{WALL} \times 60 \times (T_{OA} - T_{SP})$
  - ρ = density of outdoor air, lbm/ft^3
  - A_{ROOF} = roof area, ft^2
  - A_{WALL} = exterior wall area, ft^2
  - A_{WINDOW} = window area, ft^2
  - c_p = heat capacity of air = 0.24 Btu/lbm °F
  - ES = exterior shading, %
  - q_{INF} =infiltration rate per area of exterior wall, CFM/ft^2
  - R_{WALL} = R-value of roof, hr-ft^2-°F/Btu
  - R_{ROOF} = R-value of roof, hr-ft^2-°F/Btu
  - SHGC = solar heat gain coefficient based on window selection (see Table 2), dimensionless
  - T_{OA} = outdoor air dry bulb temperature, °F
  - T_{SA_ROOF} = sol-air temperature of the roof, °F
  - T_{SA_WALL} = sol-air temperature of the wall, °F
  - T_{SP} = indoor air dry bulb temperature, °F
  - U_{WINDOW} = U-value of the window based on window selection (see Table 3), Btu/h-°F-ft^2

Latent Zone Loads, Btu

- **Internal Heat Gains**
- People, $Q_{L\_PEOPLE} = n_{PEOPLE} \times HGF_{L\_PEOPLE} \times HLP_{PEOPLE}$
    - HGF_{L_PEOPLE} = heat gain factor (latent) based on activity level (see Table 1), Btu/h-person
- **Envelope Loads**
- Infiltration, $Q_{L\_INFIL} = \rho \times h_{fg} \times q_{INF} \times A_{WALL} \times 60 \times (\omega_{OA} - \omega_{SP})$
    - h_{fg} = latent heat of vaporization of water = 1054.8 Btu/lbm water
    - ω_{OA} = humidity ratio of outdoor air, lbm water/lbm air
    - ω_{SP} = humidity ratio of indoor space set point, lbm water/lbm air

Total Zone Loads, kBtu

- Sensible, $Q_{S\_ZONE} = (Q_{S\_LTG} + Q_{S\_EQUIP} + Q_{S\_PEOPLE} + Q_{S\_WALL} + Q_{S\_ROOF} + Q_{S\_WINDOW,C} + Q_{S\_WINDOW,R} + Q_{S\_INFIL}) / 1000$
- Latent, $Q_{L\_ZONE} = (Q_{L\_PEOPLE} + Q_{L\_INFIL}) / 1000$
- Total, $Q_{TOTAL\_ZONE} = Q_{S\_ZONE} + Q_{L\_ZONE}$

System Loads

Ventilation, CFM

- Ventilation Rate, $Q_{OA} = R_{PEOPLE} \times n_{PEOPLE} + R_{AREA} \times A_{BLDG}$
    - R_{PEOPLE} = outdoor air rate per person, CFM/person
    - R_{AREA} = outdoor air rate per floor area, CFM/ft^2

Ventilation Loads, Btu

- Ventilation Sensible, $Q_{S\_VENT} = \rho \times c_p \times 60 \times Q_{OA} \times (T_{OA} - T_{SP})$
- Ventilation Latent, $Q_{L\_VENT} = \rho \times h_{fg} \times 60 \times Q_{OA} \times (\omega_{OA} - \omega_{SP})$

Total System Loads, kBtu

- System Sensible, $Q_{S\_SYSTEM} = Q_{S\_ZONE} + (Q_{S\_VENT} / 1000)$
- System Latent, $Q_{L\_SYSTEM} = Q_{L\_ZONE} + (Q_{L\_VENT} / 1000)$
- System Total, $Q_{TOTAL\_SYSTEM} = Q_{S\_SYSTEM} + Q_{L\_SYSTEM}$

Energy Consumption

Electric, kWh

- Lighting, $E_{LTG} = L_{LTG} \times A_{BLDG} / 1000 \times HLP_{LTG}$
- Equipment, $E_{EQUIP} = L_{EQUIP} \times A_{BLDG} / 1000 \times HLP_{EQUIP}$
- Miscellaneous Electric Load 1, $E_{MISCE,1} = L_{MISCE,1} \times HLP_{MISCE,1}$ (typical of 3)
    - $L_{MISCE,1}$ = peak miscellaneous electric load 1, kW (typical of 3)
    - $HLP_{MISCE,1}$ = hourly load percentage of miscellaneous electric load 1 (typical of 3)
- Fans, $E_{FAN} = E_{C,FAN} + E_{P,FAN} + E_{V,FAN}$
  If the HVAC schedule is on or if the fan availability is enabled and there is a load on the system, then
    - Constant fan speed, $E_{C,FAN} = L_{C,FAN}$
    - Proportional fan speed, $E_{P,FAN} = L_{V,FAN} \times PL$
    - Variable fan speed, $E_{V,FAN} = L_{V,FAN} \times PL^{2.5}$
        - $L_{C,FAN}$ = constant fan load, kW
        - $L_{V,FAN}$ = variable fan load, kW
        - S_{MIN_FAN} = minimum fan speed, %
        - PL = percentage of load equal to the maximum of ($Q_{S\_SYSTEM} / Q_{HTG\_DESIGN}$), ($Q_{TOTAL\_SYSTEM} / Q_{CLG\_DESIGN}$), or ($S_{MIN\_FAN}$)

- Pumps, $E_{PUMP} = E_{C,PUMP} + E_{P,PUMP} + E_{V,PUMP}$ (typical of heating and cooling)
  If the HVAC schedule is on or if the pump availability is enabled and there is a load on the system, then
  - Constant pump speed, $E_{C,PUMP} = L_{C,PUMP}$
  - Proportional pump speed, $E_{P,PUMP} = L_{V,PUMP} \times PL$
  - Variable pump speed, $E_{V,PUMP} = L_{V,PUMP} \times PL^{2.5}$
    - $L_{C,PUMP}$ = constant pump load, kW (typical of heating and cooling)
    - $L_{V,PUMP}$ = variable pump load, kW (typical of heating and cooling)
    - S_{MIN_PUMP} = minimum pump speed, % (typical of heating and cooling)
    - PL_{HTG} = percentage of heating load equal to the maximum of (Q_{S_SYSTEM} / Q_{HTG_DESIGN}) or $S_{MIN\_PUMP,HTG}$
    - PL_{CLG} = percentage of cooling load equal to the maximum of (Q_{TOTAL_SYSTEM} / Q_{CLG_DESIGN}) or $S_{MIN\_PUMP,CLG}$

If the HVAC schedule is on or if the fan availability is enabled and there is a load on the system, then energy calculations will be done for heating or cooling depending on the polarity of the load (positive for cooling, negative for heating).

- Heating (Electric), $E_{HTG} = (-1) \times Q_{S\_SYSTEM} \times P_{HTG,E} / \eta_{HTG\_E} / 3.412$
    - $\eta_{HTG,E}$ = electric nominal heating efficiency, %
    - $P_{HTG,E}$ = percentage of load assigned to electric heat, %
    - Q_{S_SYSTEM} = hourly calculated heating load (negative values), kBtu
- Cooling, $E_{CLG} = Q_{TOTAL\_SYSTEM} / 12 \times \eta_{CLG\_PL} \times P_{CLG}$
  - Part Load Ratio, $PLR_{CLG} = Q_{TOTAL\_SYSTEM} / (Q_{CLG\_DESIGN} \times OF_{CLG})$, dimensionless
  - Energy Input Ratio, $EIR_{CLG} = a + b \times PLR_{CLG} + c \times PLR_{CLG}^2 + d \times PLR_{CLG}^3$, dimensionless
  - Cooling Part Load Efficiency, $\eta_{CLG\_PL} = \eta_{CLG} \times PLR_{CLG} / EIR_{CLG}$, kW/ton
    - a, b, c, d = cooling efficiency curve coefficients (see Table 4) based on system selection, dimensionless
    - η_{CLG} = nominal cooling efficiency, kW/ton
    - OF_{CLG} = oversize factor used to adjust calculated cooling design load, %
    - P_{CLG} = percent of building with cooling, %
    - Q_{CLG_DESIGN} = total cooling design load based on design day conditions, kBtu
    - Q_{TOTAL_SYSTEM} = hourly calculated cooling load (positive values), kBtu

Fuel, kBtu

- Miscellaneous Fuel Load 1, $F_{MISCF,1} = L_{MISCF,1} \times HLP_{MISCF,1} / \eta_{MISCF,1}$ (typical of 3)
  - $L_{MISCF,1}$ = peak miscellaneous fuel load 1, kBtu (typical of 3)
  - $HLP_{MISCF,1}$ = hourly load percentage of miscellaneous fuel load 1 (typical of 3)
  - $\eta_{MISCF,1}$ = miscellaneous fuel load 1 stand-alone efficiency, % (typical of 3)
    - Note: $\eta_{MISCF,1} = \eta_{HTG\_PL,F}$ if miscellaneous load is included on main boiler plant

The heating energy consumption of fuel is calculated and further broken down to provide more resolution into three main end use categories: Envelope, Infiltration, and Ventilation.

- Envelope, $F_{HTG\_ENV} = (-1) \times Q_{S\_ZONE} \times (1 - P_{HTG,E}) \times (1 - P_{INF}) / \eta_{HTG\_PL,F}$
- Infiltration, $F_{HTG,INF} = (-1) \times Q_{S\_ZONE} \times (1 - P_{HTG,E}) \times P_{INF} / \eta_{HTG\_PL,F}$
- Ventilation, $F_{HTG,VENT} = (-1) \times Q_{S\_VENT} \times (1 - P_{HTG,E}) / \eta_{HTG\_PL,F}$
  - Part Load Ratio, $PLR_{HTG} = Q_{S\_SYSTEM} / (Q_{HTG\_DESIGN} \times OF_{HTG})$, dimensionless
    - For miscellaneous fuel loads on the plant, Q_{S_SYSTEM} includes these loads.
  - Energy Input Ratio, $EIR_{HTG} = a + b \times PLR_{HTG} + c \times PLR_{HTG}^2$, dimensionless

- o Fuel Part Load Efficiency, $\eta_{HTG\_PL,F} = \eta_{HTG,F} \times PLR_{HTG} / EIR_{HTG}$, %
  - ▪ a, b, c = heating efficiency curve coefficients (see Table 5) based on system selection, dimensionless
  - ▪ $\eta_{HTG,F}$ = fuel nominal heating efficiency, %
  - ▪ OF_{HTG} = oversize factor used to adjust calculated heating design load, %
  - ▪ $P_{HTG,E}$ = percentage of load assigned to electric heat, %
  - ▪ Q_{HTG_DESIGN} = heating design load calculated on design day conditions, kBtu
  - ▪ $Qs_{\_SYSTEM}$ = hourly calculated heating load (negative values), kBtu
- o Zone Envelope Sensible Load, $Qs_{\_ZONE,ENV} = Qs_{\_WALL} + Qs_{\_ROOF} + Qs_{\_WINDOW,C} + Qs_{\_WINDOW,R}$
- o Percent of Zone Sensible Load attributed to infiltration, $P_{INF} = Qs_{\_ZONE,INF} / (Qs_{\_ZONE,ENV} + Qs_{\_INF})$

Energy Demand

Electric, kW

The tool determined the peak kW load of the month and displays the demand of each end use category component for that hour.

On the following page is an example of an Element model for Municipal Complex. The element model below was used to predict savings for modified BAS scheduling as well as other ECMs.

Baseline Breakout Analysis

Electric Consumption

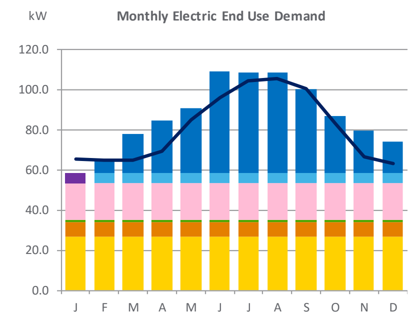
Month	Internal Loads		Miscellaneous Loads			Fans and Pumps			Heating and Cooling			
	Lighting	Equipment	Ext Lighting	rmer Baselin	0	Fans	Clg Pumps	Htg Pumps	Heating	Cooling	Dehumid	Reheat
	28.2%	8.9%	2.5%	2.0%	0.0%	36.5%	5.5%	4.5%	0.0%	12.0%	0.0%	0.0%
	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh
1	10,753	3,356	938	744	0	13,713	0	3,720	0	0	0	0
2	9,671	3,037	847	672	0	12,386	135	3,225	0	25	0	0
3	10,345	3,314	938	744	0	13,713	645	3,075	0	232	0	0
4	10,398	3,278	908	720	0	13,271	1,860	1,740	0	1,136	0	0
5	10,664	3,356	938	744	0	13,713	3,620	100	0	3,718	0	0
6	10,167	3,236	908	720	0	13,271	3,600	0	0	9,628	0	0
7	10,664	3,356	938	744	0	13,713	3,720	0	0	15,210	0	0
8	10,345	3,314	938	744	0	13,713	3,720	0	0	13,060	0	0
9	10,487	3,278	908	720	0	13,271	3,600	0	0	7,889	0	0
10	10,806	3,398	938	744	0	13,713	2,170	1,550	0	1,463	0	0
11	9,653	3,110	908	720	0	13,271	850	2,750	0	423	0	0
12	10,664	3,356	938	744	0	13,713	200	3,520	0	147	0	0
	124,617	39,392	11,041	8,760	0	161,464	24,120	19,680	0	52,932	0	0

Fuel Consumption

Month	Miscellaneous Loads			Heating			
	DHW	0	0	Envelope	Infiltration	Ventilation	Reheat
	12.7%	0.0%	0.0%	23.2%	22.9%	41.1%	0.0%
	kBtu	kBtu	kBtu	kBtu	kBtu	kBtu	kBtu
1	8,422	0	0	47,695	48,918	91,467	0
2	7,632	0	0	38,503	37,988	67,373	0
3	8,058	0	0	21,246	20,594	35,656	0
4	8,338	0	0	8,358	8,012	13,277	0
5	8,401	0	0	501	464	842	0
6	8,016	0	0	0	0	0	0
7	8,401	0	0	0	0	0	0
8	8,058	0	0	0	0	0	0
9	8,359	0	0	0	0	0	0
10	8,702	0	0	8,117	7,593	12,971	0
11	7,094	0	0	21,408	20,938	36,091	0
12	8,401	0	0	32,263	31,667	58,275	0
	97,882	0	0	178,090	176,175	315,952	0

Electric Demand

Month	Internal Loads		Miscellaneous Loads			Fans and Pumps			Heating and Cooling			
	Lighting	Equipment	Ext Lighting	rmer Baselin	0	Fans	Clg Pumps	Htg Pumps	Heating	Cooling	Dehumid	Reheat
	30.6%	8.6%	0.0%	1.1%	0.0%	21.2%	5.3%	0.5%	0.0%	32.8%	0.0%	0.0%
	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW	kW
1	26.6	7.5	0.0	1.0	0.0	18.4	0.0	5.0	0.0	0.0	0.0	0.0
2	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	5.9	0.0	0.0
3	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	19.6	0.0	0.0
4	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	26.1	0.0	0.0
5	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	32.3	0.0	0.0
6	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	50.8	0.0	0.0
7	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	50.1	0.0	0.0
8	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	50.1	0.0	0.0
9	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	41.9	0.0	0.0
10	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	28.2	0.0	0.0
11	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	21.2	0.0	0.0
12	26.6	7.5	0.0	1.0	0.0	18.4	5.0	0.0	0.0	15.8	0.0	0.0
	319	90	0	12	0	221	55	5	0	342	0	0



Modeling the ECMs

After the model has been calibrated, changes are made to the model, which represent implementation of the proposed scope conditions of the energy and water conservation measure. ECMs are implemented and run individually to assess the energy savings of each ECM. All ECMs are modeled with consideration to potential overlap inflating modeled savings. ECMs are run sequentially, building upon each other. This results in more accurate estimate of savings than if each ECM were run in comparison to the baseline.

6.2 Preliminary Mechanical Designs

Please see the Appendices Box folder for preliminary mechanical designs.

6.3 Local Government Energy Audit (LGEA)

Please see the Appendices Box folder for the Local Government Energy Audit reports.

6.4 Third Party Review & Approval Report

Please see the Appendix Box folder.

6.5 Board of Public Utilities (BPU) Approval

Please see the Appendix Box folder.