Guidebook for State and Local Government Facility Energy Assessments and Improvements

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Guidebook for State and Local Government Facility Energy Assessments and Improvements

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Disclaimer

Acronyms and Definitions

Acronym	Definition	Description
BAS	Building Automation System	a system that automates control over building electrical and mechanical equipment such as lights, HVAC, fire or security systems. May also be known as a Building Management System (BMS)
BEAP	Building Energy Assessment Professional	a validation of ability to assess building systems, analyze energy use and recommend improvements offered through American Society of Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE).
BTU	British Thermal Unit	British Thermal Unit
CBCP	Association of Energy Engineers Certified Building Commissioning Professional	a validation of ability to assess if new building systems operate as designed and make recommendations to improve where needed
CBECS	Commercial Buildings Energy Consumption Survey	a survey of a national sample of commercial buildings that collects information on the U. S. building stock, including energy-related building characteristics and energy use data.
CEM	Association of Energy Engineers Certified Energy Manager	a validation of ability to assess building systems, analyze energy use and recommend improvements offered through Assoc. of Energy Engineers
CFL	Compact Fluorescent Lamp	
CO2e Emissions	Carbon Dioxide equivalent emissions	a measurement of the total greenhouse gasses emitted
COP	Coefficient of Performance	a measure of energy efficiency of Btu thermal energy output divided by the Btu energy input. Higher values are more energy efficient. An electric resistance heater has a COP of 1 and is very inefficient. An electric heat pump may have COP typically between 2-4 depending upon outdoor conditions
DHW	Domestic Hot Water	hot water for washing or cleaning
EBCP	Association of Energy Engineers Existing Building Commissioning Professional	a validation of ability to assess if existing building systems operate as intended and make recommendations to improve where needed
ECM	Energy Conservation Measure	decreasing energy use by using something less
EEM	Energy Efficiency Measure	decreasing energy use by replacing equipment with an option with same output but less energy input for operation
EMS	Energy Management System	a system that measures, stores, analyzes, and reports energy usage of specific equipment
Energy Auditor	also known as "energy rater" or "energy consultant"	a professional who inspects buildings and equipment to identify areas of energy use waste
EPA	US Environmental Protection Agency	a national agency that establishes environmental safety standards and the voluntary ENERGY STAR energy conservation program covering appliances and building standards
ESCO	Energy Service Company	a company that help identify, plan, and implement energy conservation improvements for a client. ESCO compensation is typically provided through the energy savings over a long period of time.
ESPC	Energy Savings Performance Contract	contract establishing a partnership between an agency and ESCO. This typically does not require up-front costs for the agency and establishes payment for services to the ESCO through the energy costs saved
EUI	Energy Use Index	total annual energy use of a building normalized by the total building

Acronym	Definition	Description
		area. This is used to compare to other buildings of similar type and use
EV	Electric Vehicle	a vehicle capable of storing electric energy using batteries that need to be recharged at a charging station connected to an electric utility service
fc	foot candle	a measure of how much light falls upon a surface area. It is defined as an imperial system of measure of illuminance upon a surface equal to 1 lumen upon 1 square foot surface area. 1 fc = 10.76 lumens (lux)
HSPF/HSPF2	Heating Seasonal Performance Factor	higher values are more energy efficient. This provides a means of comparing the efficiency of different electric heat pumps using specific environment test conditions somewhat representative of heating season conditions. The HSPF2 designation accounts for a higher external static pressure assumed in the rating compared to HSPF
HVAC	Heating, Ventilating, and Air Conditioning	broad term covering space conditioning and mechanical ventilation equipment
Inverter		an electric device used to convert direct current electricity directly from solar PV panel into useful alternating current electricity used by a building
kW	kilowatt	a measure of power. May be associated with electric utility peak power demand used in billing on some accounts
kWh	kilowatt-hour	a measure of energy consumed over a period of time
LED	Light Emitting Diode	an electronic component used to generate visible light
Low-e	low emissivity	a material surface characteristic commonly associated with windows that helps limit heat transfer through glass. A thin near-clear coating of a metallic oxide is applied on one inner surface of a double or triple-pane window
lm	Lumen	a measure of luminous power emitted from a source such as a single lamp or a fixture. It is more formally defined as the metric SI system of measure of luminous flux. This is equal to amount of light (candela) emitted per second in a unit solid angle of one steradian from a uniform source of one candela
NPV	Net Present Value	a calculation used to determine whether or not an investment will be profitable in the future
OEM	Original Equipment Manufacturer	
O&M	Operations and Maintenance	a key component of maintaining reliable and efficient mechanical operations. This involves regular scheduled tasks such as inspections, cleanings, lubrication and OEM specified services
Peak Demand		is the highest amount of power (kW) used during a utility-specified period of time PV photovoltaic; semiconductor panel designed to convert solar radiated light into electricity
Renewable Energy		a natural energy source available where the usage does not deplete the primary resource. Wind, solar, biomass, geothermal, and hydropower are five examples
ROI	Return on Investment	a performance measure used to evaluate the efficiency of an investment

Acronym	Definition	Description
R-Value		unit of measure of heat resistance; higher R-value is better at resisting heat transfer, helps decrease heating and cooling energy use, and may help improve comfort
SEER/SEER2	Seasonal Energy Efficiency Ratio	a measure of estimated seasonal energy efficiency of air conditioners. Higher values are more energy efficient. This provides a means of comparing the efficiency of different air conditioners using specific environment test conditions somewhat representative of cooling season conditions. The SEER2 designation accounts for a higher external static pressure assumed in the rating compared to SEER.
SHGC	Solar Heat Gain Coefficient	This is the fraction of solar radiation transferred through a window, door or skylight. SHGC is a value from 0 to 1 where a lower value is better at restricting solar heat transferred through exterior windows. Lower values are desirable for cooling dominated climates
Therm		unit of energy used in natural gas billing. One therm = 100,000 Btu
U-value		U-value of window, door or skylight refers to how quickly thermal energy in air can pass through. The lower the value, the better the assembly resists energy transfer and improves energy conservation. A single pane of clear glass has a U-value near 1
ZEB	Zero Energy Building	(on-site def.) a building that produces enough renewable energy to meet all or more than the annual energy it consumes. (source site def.) a building that produces enough renewable energy to meet all or more than the annual energy it takes to generate and deliver to site.

Introduction

Many local governments and state agencies in Florida have adopted policies and developed programs related to sustainability, energy efficiency, and renewable energy across all operations. Because buildings are responsible for a significant portion of annual energy costs and environmental impacts, they are a natural target for improvement. Some cities and counties have set aggressive renewable energy targets and zero emissions goals to help mitigate the effects of climate change. Others are following at a slower pace. Both approaches can benefit from adopting a standard process for making decisions, beginning with setting goals and priorities, and ending with measuring improvement and evaluating the feasibility of on-site renewable energy (**Figure 1**).

IMPLEMENTING FINANCIALLY-SOUND SUSTAINABLE ENERGY IMPROVEMENTS AT PUBLICLY-OWNED FACILITIES:

- Is good stewardship of public resources
- Offers opportunity to showcase success
- Encourages the private community to adopt more energy sustainable practices.

Figure 1: Energy Audit Process. Adopt a streamlined decision-making process to reach and maintain facility sustainable goals.

The goal of this guidebook is to help a general manager successfully improve energy sustainable building operations and is particularly focused on the process of determining suitable energy conservation and efficiency measures. It also provides steps to consider the feasibility of on-site renewable energy.

The terms efficiency and conservation are sometimes used interchangeably to generally convey reducing decreasing energy usage, but they are technically different. Energy conservation measures (ECM) involve using something less by turning it off or using it less often. Using automated light controls that turn lights off when not needed is an example of an ECM. Another example is adjusting thermostat levels, which may result in less heating or cooling operation. ECMs should not decrease safety and they should not significantly reduce comfort. Reduced comfort may not only be unpleasant for employees, but may also decrease productivity. An energy efficiency measure (EEM) is the replacement of an item with something of equal output, but that consumes less energy. Upgrading from fluorescent to LED lighting is one example. Sometimes in this guide and in materials outside this guide, EEM and ECM may be used interchangeably to generally convey the concept of improvements that reduce energy use.

This guidebook is intended to provide a broad overview and basic understanding of what is involved in: energy auditing, establishing an energy baseline, selecting ECMs & EEMs, and determining the feasibility of potential renewable energy sites. Figure 1 shows the general steps towards the goal of implementing ECMs & EEMs. When considering purchasing on-site solar photovoltaic panels, energy reduction measures should be examined first so that the energy needs are as low as economically feasible before renewable generation needs are calculated. Lowering the energy needs will decrease the size and cost of PV panels required to meet the building needs.

Appendix A provides a list of the general information needed to get an energy audit started and are intended to help agencies better understand and be prepared for the details the energy auditor will be seeking to conduct an energy assessment.

Photo: Getty Images

1. Establish Energy Sustainability Goals

The pursuit of sustainability is creating and maintaining "the conditions under which humans and nature can exist in productive harmony to support present and future generations."[1] In buildings, an energy sustainability goal may be to reduce the building's energy use; or it may have a broader scope, such as targeting carbon dioxide equivalent (CO2e) emissions reductions. Renovation goals will also vary according to available resources and the baseline conditions of buildings. Before you can know how to meet energy sustainability goals, a starting point for the building energy use must be determined. This fundamental step is known as establishing the energy benchmark or Energy Use Index (EUI) which will be discussed in more detail later.

ENERGY USE INDEX

The EUI is a benchmark used to compare buildings of similar type and use. The total annual energy use of a building is divided by the total floor area.

Sustainability goals are usually ongoing; they should be established, considered whenever building upgrades are undertaken, and revisited. Energy sustainability goals may be general or more specific, such as:

Figure 2: Reduce facility CO2e emissions with on-site renewable energy. *Photo: freepik.com*

- To reduce energy use and cost
  - Reducing building energy use supports broader sustainability goals and may free up operating funds for other needs. Once the EUI is determined for a facility, it can be used to track energy reduction as improvements are made.
- To reduce the carbon dioxide emissions
- Carbon dioxide equivalent emissions (CO2e emissions) reduction can be achieved by reducing energy use or shifting use from non-renewable to renewable energy. However, emissions reduction is distinct from energy use reduction because the emissions per unit of energy delivered vary among the utility grid's various energy production sources. CO2e emissions can be reduced by shifting the time-of-day that the highest CO2 emitting fuel source is used.
- To become a Zero Energy Building (ZEB)
  - Zero Energy Buildings are designed to use as little energy as possible and use renewable energy to generate at least as much energy as the building consumes. The net effect is that the total annual energy consumed on site is no more than the amount of renewable energy produced over the course of a year. Since ZEB still consume energy, they are more accurately called net zero energy buildings[2]. To find out more about zero energy buildings, go to:https://www.energy.gov/eere/buildings/about-zero-energy-buildings.

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[1] https://www.epa.gov/sustainability/learn-about-sustainability

[2] Learn more about zero energy buildings at: https://www.energy.gov/eere/buildings/about-zero-energy-buildings

2. Determine Facility Priorities

Facility priorities must be considered along with energy sustainability goals to help establish how aggressive the discovery process should be. Facility needs typically outweigh available capital. Health and safety, building durability, comfort and productivity, and sustainability priorities can overlap, as demonstrated in **Figure 3**. Carefully prioritizing facility needs that are linked to sustainability efforts will help establish the best order and timing of improvements and avoid wasting resources or missed opportunities.

Health, Safety, Durability, Comfort

Building improvements necessary to maintain occupant health and safety and building integrity will have a higher priority than energy conservation improvements, however some building safety improvements can be leveraged with ECMs and may be an opportunity to reduce overall energy use if carefully considered at the right time. **Figure 4** shows a few health, durability, and comfort example priorities as potential opportunities to improve efficiency.

Figure 3: Four Primary Facility Priorities. Consider that sustainability goals that may align well with facility primary priorities.

Facility Needs	EEM Opportunity Examples
Improve outdoor safety	Install better quality and more efficient illumination.
Improve humidity control	Install more efficient equipment; Seal building leakage; Air balance building airflows across envelope.
Improve pest control	Seal building leakage holes and cracks. Replace Jalousie windows with insulated glass meeting new code.
Replace old roof	Consider low slope roof exterior surface with three-year aged solar reflectance > 0.55; Consider if roof choice is also good for solar installation.
Reduce facility labor burden	Install LED lights with longest lifetimes.

Figure 4: Example of How Facility Needs May be Opportunity to Consider EEM.

Sustainability Priority Considerations

Your agency will need to determine how aggressively it needs to improve facilities. There are different motivations, besides money, for how much is done at any given time. If LED lighting and new controls have not been implemented yet, consider evaluating the effectiveness of a specific measure in one building before adopting it in multiple buildings. On the more aggressive side, you may want to leverage the benefit of an EEM package that might allow smaller capacity heat and cool equipment to be installed and thereby save money. Implementing a package of EEMs is the best way to reduce EUI and prepare for future on-site renewable energy production.

Benefits of aggressive EEM facility packages over individual measures include:

- Greater impacts toward reducing facility EUI and increased movement toward energy use reduction goals
- Reduced energy use, size, and cost of on-site renewable equipment
- Down-sized HVAC equipment, reducing HVAC replacement costs
- Longer LED lights lifetime reduces maintenance labor and material wastes compared to older fluorescent lighting

3. Determine Energy Audit Level

An energy auditor is a professional who inspects buildings to identify areas of energy use waste and opportunities for improvement. An "energy auditor" may also be referred to as an "energy assessor" or "energy analyst." The process of assessing the current state of a facility's energy using systems, processes, and schedules is known as an energy audit. The term "energy assessment" is interchangeable with "energy audit".

There are three levels of energy audit available depending upon the detail and effort required. These audit levels are summarized in **Figure 5**.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) had developed a book, Procedures for Commercial Building Energy Audits that establishes what should be expected for each energy audit level. There is a progression of effort and outcome, with Level 1 being the most basic, up to Level 3 which includes Level 1 and Level 2 efforts plus more advanced analysis.

3 ENERGY AUDIT LEVELS

ASHRAE lists the three audit levels efforts as:

- Level 1 – Walk-Through Analysis
- Level 2 – Energy Survey Analysis
- Level 3 – Detailed Analysis of Capital-Intensive Modifications.

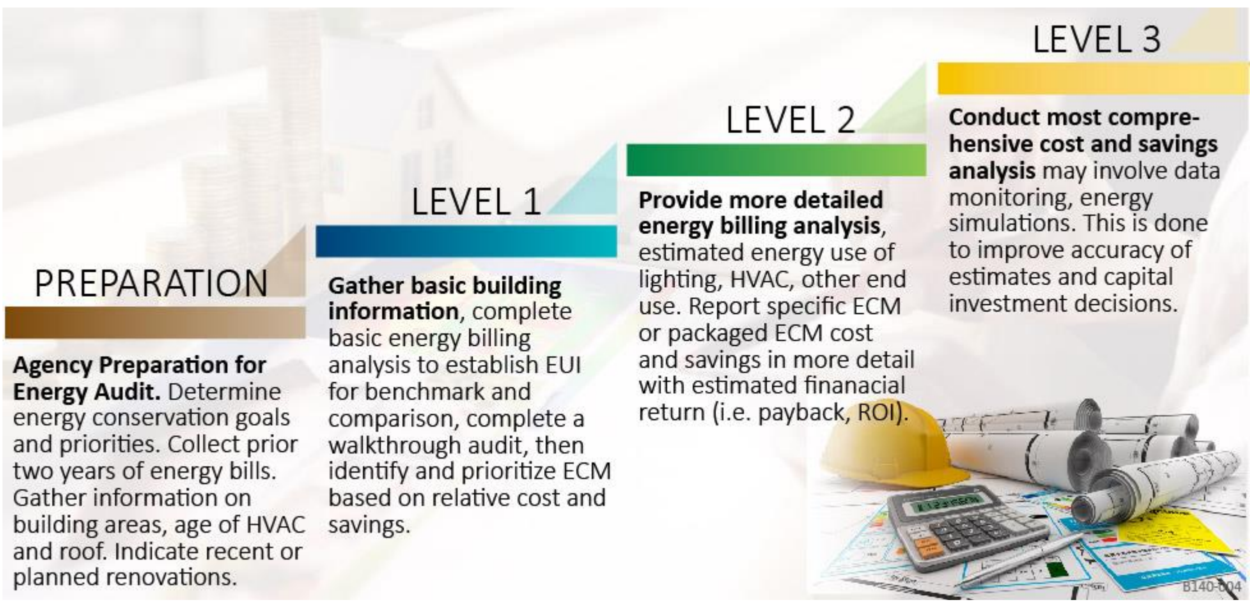

Figure 5: Energy Audit Levels. Understand ASHRAE's three energy audit levels before contacting an auditor.

Energy audits Level 1 involve:
1) using utility billing data to determine an annual energy use benchmark and look for excessive use trends; 2) conducting a brief on-site assessment of the building construction, business operations, and energy using systems; and 3) conducting basic analysis and reporting recommendations. The main goal is to list no-cost recommendations and prioritize the most cost-effective, relatively lower cost improvements.

Level 1 is less expensive to conduct due to less effort involved. Recommendations are usually limited to lighting and HVAC replacement or servicing. While a Level 1 audit does not include accurate cost estimates or ROI calculations, a good energy auditor may catch other important issues and help prioritize improvements. When more than one facility is audited during the same period, the auditor will indicate facilities with the highest improvement priorities. An EUI will be generated for each facility, enabling improvement impacts to be tracked allowing comparisons to EPA ENERGY STAR® benchmarks or other EUI targets.

LEVEL 2

Energy audits Level 2: include everything in Level 1 and go into more detail about a facility's specific energy use. Monthly energy end-use is estimated and additional audit detail is used to improve savings predictions. Selective lighting and HVAC measurements and monitoring may be conducted to better inform savings estimates. Approximate improvement costs may be used for a more detailed cost-benefit analysis. A Level 2 energy audit report should recommend prioritized EEMs based on the estimated savings and cost analysis. Potential financial incentives from utility providers should be noted and accounted for in analysis. Suggestions such as more capital-intensive projects may be provided for future considerations.

LEVEL 3

Energy audits Level 3 are the most in-depth assessment, designed to help guide capital investment decisions. This commercial energy audit considers much more comprehensive cost and savings data. The Level 3 audit takes the potential capital-intensive modifications identified in Level 2 and performs a deeper analysis to provide a more thorough look at the project's cost and savings. A whole-building computer simulation may be used to model a building's response to energy system or architecture changes to determine the complicated savings of a package of EEM improvements. Reporting should indicate benefits, costs, and performance expectations for system upgrades or retrofits for capital planning and personnel investments.

TARGETED AUDIT

A Targeted Audit is an assessment of a certain system or specific end use. It may be appropriate when a component is known to be near the end of its useful life and more efficient options and costs need to be evaluated. A targeted audit might specifically address one measure, such as lighting systems, packaged HVAC unit replacements, boiler replacement, or a building addition, when the broader scope of a Level 1, 2, or 3 audit is not necessary.

Determine the Energy Audit Level Needed

Before you decide on the energy audit level, keep longer-term planning in mind and be aware of all EEM opportunities.

A Level 1 energy audit is adequate if the facility:

1. has not had any energy audits in the past 5 years.
2. needs to identify and prioritize the top few ECMs and EEMs.
3. is only able to make a few improvements within the next 5 years.
4. needs to know the most cost-effective actionable improvements as soon as possible.

A Level 2 energy audit is a better choice than Level 1 when more confidence is needed in making decisions on how to best spend limited resources. A Level 2 audit would be appropriate when evaluating the performance of existing systems. For example, to determine if increasing energy use is due to bad control sensors or mechanical actuators.

Use Level 2 energy audit when you need:

1. an estimate of energy savings and costs to implement EEM.
2. to prioritize lighting or HVAC retrofits to address complaints.
3. to improve the performance of existing systems that may not need to be replaced.

A Level 3 audit is suitable for helping an agency prepare future budgets and establish priorities. It is also needed to perform a deeper economic analysis to determine savings estimates of several different EEM packages and on-site renewable energy requirements.

Use Level 3 energy audit when you need:

1. the most accurate estimated savings and costs of improvements.
2. to evaluate several EEM package options and prioritize them.

4. Prepare for Energy Audit

There are several things to consider before selecting or meeting with an energy auditor. Being prepared for the energy audit will help the agency avoid follow-up inquiry interruptions from the auditor. It will also help the auditor carefully consider the level of service required and to make the best overall recommendations.

AUDIT PREPARATION

Discuss your priorities with potential auditors at the beginning of communications so that the auditor will understand your needs and avoid proposing service that you do not want to pay for.

Establish Goals and Priorities

Preparation should start with clearly establishing the facility's energy sustainability goals, the audit level being requested, and the desired economic metrics for the cost-benefit evaluation of recommended improvements. Also indicate any known changes in occupancy or renovations that may impact energy use. If only a Level 1 Energy Audit is requested, do not expect detailed economic metrics to be reported. **Figure 6** provides examples of goals and priorities that could be shared with an auditor.

Type of goal or priority	Examples
Establish energy sustainability goals	• Reduce EUI similar to ASHRAE 90.1-2022 • Reduce all office facilities energy use to obtain EPA ENERGY STAR score of 75 or higher • Improve 10% of facilities to zero energy buildings within the next 5 years
List facility priorities	• This year: Demolish groundskeeping garage, replace fire station roof, increase HVAC capacity and ventilation to meet auditorium needs, complete energy audits in 10 facilities and prioritize by highest EUI • Within 5 years: Replace the fire station roof and implement cost-effective EEM
Determine level of energy audit required	• Conduct a Level 1 energy audit on 10 facilities and targeted audit of community center chiller
Indicate preferred method to determine cost benefit analysis	• Simple payback • Advanced life-cycle analysis of Net Present Value (NPV) • Return on Investment (ROI)

Figure 6: Examples of Established Priorities to Share with Energy Auditor.

Make Building Information Available

The energy auditor will need to collect a substantial amount of information. Facility staff should be prepared to make some information available before or during the audit, including the most recent two full years of energy utility bills. If the electric utility conducts the audit, gas utility data may need to be provided to the auditor. To better prepare your auditor for your site assessment, provide the gross floor area of the facility and type of business use for each energy utility account. Delivery of fuel such as fuel oil should also be included. Fuel used for transportation should be considered separately from site operations use.

Following is a list of several items to be supplied to the auditor. Your facilities O&M program may already track some of this information. Sharing this information prior to the site-visit will better prepare the auditor and shorten the time required on-site. **Figure 7** is a checklist of items needed for the Energy Auditor.

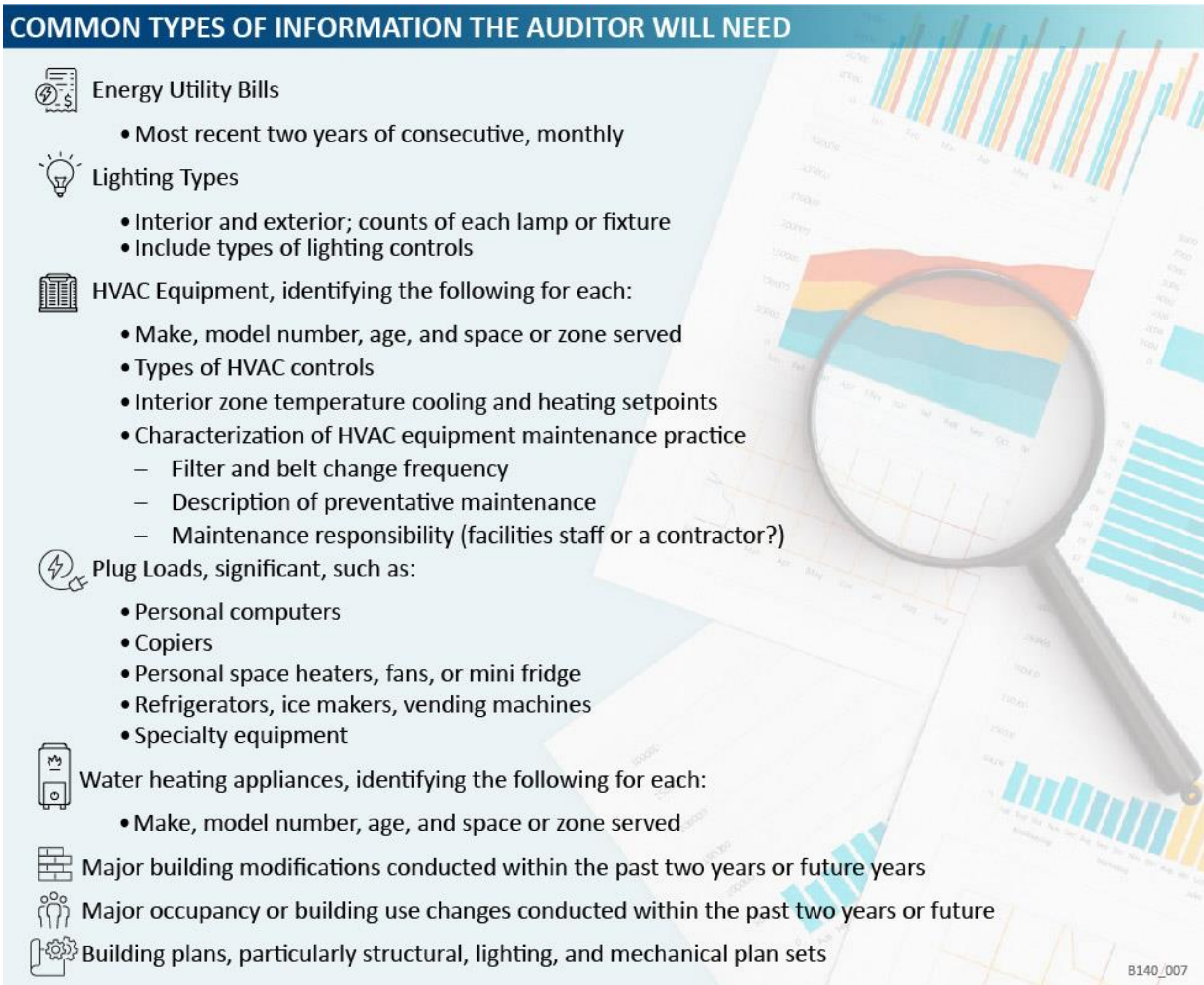

Figure 7. Common Types of Information the Auditor Will Need. Being aware of the basic information the auditor needs will help prepare your staff for the audit and may help shorten the auditor's time required on-site.

5. Find an Energy Auditor

Depending on the audit level depth, the energy auditor will assess the building envelope air leakage and insulation, HVAC systems including ductwork, lighting, refrigeration equipment, water heating, and motors. This section will provide some general qualifications to consider, where to start looking for an auditor, and cost considerations. For more information, see Finding an Energy Auditor in the Resources Organized by Topic section.

Auditor Qualifications

The energy auditor should perform energy audits according to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) *Procedures for Commercial Building Energy Audits*. Finding a qualified and experienced auditor is important. A professional engineer or other building professional may have several years of energy auditing experience, but it is recommended that they also have an energy auditing certification. Certifications for professionals with the knowledge of commercial building energy use and operations include:

- BEAP (Building Energy Assessment Professional ASHRAE)
- CEM (Certified Energy Manager Association of Energy Engineers)
- EBCP, CBCP (Existing or Certified Building Commissioning Professionals Association of Energy Engineers)

In qualifying an energy auditor for your needs, consider:

- Be sure that there is a match between the auditor's experience and the type of sites to be audited.
- How soon they can begin the audit and approximately how long will they need to prepare results.

Find a credentialed and experienced energy auditor.

Organizations with Energy Auditors

Energy auditors can be found from a variety of sources. One start is to ask for referrals from trusted sources. A list of other possible sources follows.

- **Local Utilities**
  Check with your utility representative to see if they can perform an energy audit.
- **Energy Service Companies (ESCOs)**
  An ESCO helps to identify, plan, and implement energy reduction measures for a client. The ESCO assumes the technical and performance risk for the project and is typically compensated through energy savings over a long period of time. See Finding an Energy Auditor or ESCO in the Resources section for more information about ESCOs and a list of DOE-qualified ESCOs.
- **Building Consultant Firms**

Minimal Energy Assessment Options When Energy Auditor is Not Available

Qualified energy auditors are critical to ensure comprehensive assessments. This guide strongly recommends using experienced energy assessors to increase the probability for successful outcomes. Your energy utility provider should provide at least a basic energy audit. However, it is recognized that in some cases, small governments in remote areas may lack adequate access to an experienced energy auditor. Lack of access to an available auditor may be more likely for rural areas or Fiscally Constrained Community Governments.

If an energy audit is not possible, and you are only evaluating an upgrade of older fluorescent lighting or small HVAC, (<60kbtu capacity), consider using contractor's savings estimates. Specify that estimates or bids should provide installed costs as well as realistic percent savings over existing equipment. Use of a contractor's estimates in place of an energy auditor is a last resort when a professional auditor is not available, and the authors do not endorse using general contractors in place of available experienced auditors. A contractor may be biased, selecting their preferred product or installation practice, which may be less efficient than other options, resulting in poorer financial return.

Energy Audit Cost Considerations

The cost of commercial energy audits can vary widely due to the complex differences of building types and uses. Auditor fees cannot be fairly simplified to a cost per square feet basis, even for the most basic audit. For example, a 10,000 ft^2 office building with seven rooftop package HVAC units will require substantially less effort than a 10,000 ft^2 laboratory building with four rooftop package units, but with several exhausts and air balance systems, and a more complex indoor environmental control system. The latter would require an auditor with industrial systems experience, capable of evaluating more complex systems and interactions. You may find various sources that cite estimated costs per square feet between $0.12/ft2 to $0.90/ft2 that are too wide of a range to be useful for serious planning purposes.

> **MISSED OPPORTUNITIES?**
>
> A targeted or Level 1 audit may cost less than Level 2 and Level 3, but the simplified effort may result in missed opportunities with good lifecycle savings and ROI.

Jim Kelsey, a co-author of ASHRAE-published Procedures for Commercial Building Energy Audits, claimed that if an agency requiring bidding out a “normalized” approach, it should ask for audit cost based on EUI or energy cost intensity. Energy cost intensity could be Btu/ft2, kWh/ft2 or $/ft2 (Kelsey 2021). Using one of these three bases for determining an audit cost would still require someone to calculate the annual or monthly energy or dollar cost and divide it by the represented total area of metered facility.

A targeted or Level 1 audit may cost less than Level 2 and Level 3, but the simplified effort may result in missed opportunities with good lifecycle savings and ROI.

Discuss your priorities with potential auditors at the beginning of communications so that the auditor will understand your needs and avoid proposing service that you do not want to pay for.

You may be able to get very basic Level 1 energy audits for free from your energy utility provider. Contact your service representative to find out more. Larger electric utilities have a website where an audit inquiry can be started.

6. Choose Efficiency Measures

Once you receive your audit report you will review the auditor's recommended measures and options. As you consider which measures or packages of measures to implement, determine the time frame needed to complete work and the length of time operations will be disrupted for each measure. You will also want to obtain quotes or bids for all ECMs being considered so you can update any cost estimates with actual costs. You should also contact your utility provider to see if any of the ECMs qualify for rebates and determine what the requirements are for any of those rebates. With the actual costs and any rebates figured in, project economics can be updated.

LED LIGHT LAMPS AND FIXTURES

There are many interior and exterior options of high-quality illumination with long lifetimes.

You may qualify for federal and state grant opportunities to assist in the ECM implementation costs. Potential governmental funding assistance sources are the US Department of Energy and within Florida, the Florida Department of Agriculture and Consumer Services. An application for such funding opportunities will likely require a business description, project narrative, scope of work, and budget plan to be prepared.

The energy audit report will likely include recommended ECMs and EEMs. ECMs are usually low to no cost actions that involve turning things off or reducing use when not needed. Turning lights off is a common measure. Raising thermostat levels during cooling is one example of an ECM that may reduce cooling energy use up about 8-10% per degree raised. There is no cost to implement thermostat setpoint changes, but if taken too far will increase comfort complaints and may reduce productivity, which would be more costly than the energy saved. These types of changes will work better at some locations than others. You are more likely to have success with ECMs if the work community is educated about the conservation goals and the measures are phased in slowly to allow occupants time to adjust to changes. Examples of ECMs having little impact on occupants are raising cooling setpoints, lowering heating setpoints, and turning lights off during non-business hours. If there is not any automated means to implement occupancy-related measures, appoint one person responsibility or set a policy of "last one out, first one in".

Exterior LED light is about 50% to 90% more efficient than HID lamps and should last about 4 to 8 times longer.
Photo: Charles Withers Jr.

Selecting EEM involve several possible priorities that will vary depending upon the facility. Besides financial consideration, there are other facility priorities mentioned earlier such as health and safety or equipment degradation to consider. For example, repairing building and duct air leakage may also reduce air pollutants and help maintain better humidity control as well as reduce energy use. Such a repair may have a higher cost or longer payback but could be considered a higher facility priority over a lighting upgrade with lower payback period. The combined benefit of selecting more than one EEM should also be weighed against simply choosing one. Suppose there are recommendations to seal duct air leakage, upgrade to LED lighting, and replace an old air conditioning system. Sealing severe duct leakage and upgrading lighting may reduce the cooling load enough that the air conditioning system capacity may be able to be reduced, which reduces total costs. Next, consider that the three improvements together will not only use less energy (kWh) but also reduce the demand (kW) charges if applicable. Savings from demand reductions may substantially reduce electric costs and may also be eligible for utility rebates.

A good auditor will be able to prioritize recommended EEMs, given you have provided them with your sustainability and facility goals as well as the preferred financial analysis criteria. However, choosing the best measures for your facility can be complicated when priorities are not known, or the amount of capital available for improvements is not determined. Another complicating factor is that large agencies, like state government, may have several facilities with different utilities and rates. Very low utility rates help keep energy costs down, but they also diminish economic returns from investment in EEMs or renewable energy.

In such cases, a primary goal of simply reducing energy costs would prioritize measures in the locations with the highest utility rates.

CHOOSING THE BEST MEASURES

Prioritizing energy efficient measures is more difficult if facility goals and priorities haven't been determined and the amount for capital improvement is not known.

In Appendix C, an exercise is used to demonstrate an EEM and on-site solar PV energy improvement selection process using two different scenarios.

7. Measure Efficiency Improvements

In the pursuit of reducing energy use, it may seem that the job is done after improvements have been made. However, this is just part of an on-going process towards more sustainable energy use. How do you know how well your efforts are doing if you do not continue to measure them? Minimally, the utility bill energy use should be continuously monitored for anticipated energy reductions as well as unexpected increases. Unrealized savings or unexpected increased energy use are signals that something is wrong and should be investigated. For example, lighting improvements with daylight and occupancy sensors must be commissioned after installation to verify the controls work as intended. Too often occupancy sensors are installed incorrectly or possibly damaged during transport or installation. Also, conservation controls may stop working overtime.

Energy Benchmarking

An energy benchmark is an established starting point of how much annual energy a site uses. The auditor will determine a benchmark as a fundamental part of the energy audit. The process of comparing tracking energy use to a benchmark is known as benchmarking. Benchmarking is particularly useful in tracking energy reduction after making improvements. Benchmarking may also indicate unexpected increases in energy use that should prompt investigations into the cause. The benchmarking process is graphically summarized in **Figure 8**.

> **BENCHMARKING**
>
> Benchmarking is a process that tracks EUI over time to help verify savings and catch unexpected increases in energy.

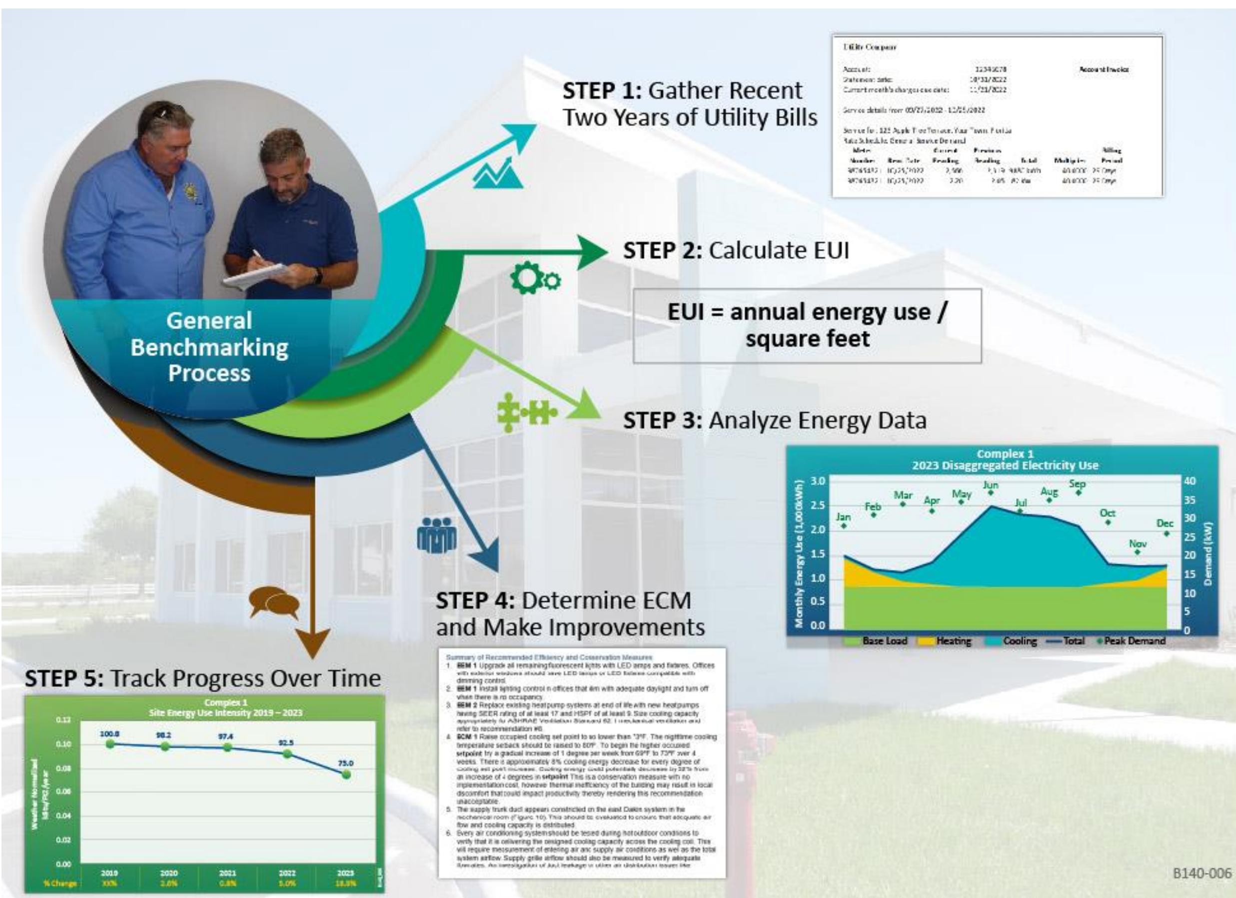

Figure 8: The Benchmarking Process. Measure and continue to monitor impact on facility sustainability goals.

Benchmarks are determined by calculating the facility's energy use index (EUI). EUIs establish the relative efficiency of a site and can be used to compare your building to other building types. EUIs can also be used to track energy reduction progress. The EUI is calculated by adding the total amount of a facility's annual energy use divided by the gross floor area. Gas and electric energy units are converted to thousands of British thermal units (kBtu) and then combined for the facility. The reported site EUI unit is usually kBtu/ft2/yr in IP units or kWh/m2/yr in SI units.

An energy auditor will establish a benchmark of total annual energy use, seasonal trends, and monthly energy use and peak demand trends. The annual energy use will be normalized by area. Business use type and schedule are considered in establishing the site EUI. The EUI for your building can be compared to the EUI of other similar building types on databases such as EPA ENERGY STAR® Portfolio Manager or the EUI of buildings built to new building codes to determine relative efficiency. Benchmarking is also useful in prioritizing which facilities to improve first when several are considered.

Some facilities may have multiple electric or gas meters and several buildings. For example, a facility may have separate meters for different functions or meters may have been added for facility additions. Each metered account should be independently benchmarked to improve the accuracy of estimating financial savings and as an important part of determining the feasibility of on-site renewable energy. The facility staff should be prepared to help determine what buildings and systems are on each metered account or otherwise make a full set of building plans available to the auditor.

ENERGY STAR PORTFOLIO MANAGER

The ENERGY STAR Portfolio Manager is a no-cost, interactive energy management tool that allows you to securely track and assess energy and water consumption across your building portfolio.

As part of the benchmarking process, continue to collect electric and gas bills. Delivery of fuel such as fuel oil should also be included. Fuel used for transportation should be considered separately from site operations use. If you have staff to input utility bill data, the online ENERGY STAR Portfolio Manager tool can help you track your progress for free. An intern could take on this activity with little oversight. See the Resources Section on Benchmarking for links to more information.

Measurement and Verification

You may consider installing energy monitors, at least temporarily, on specific equipment to accurately verify savings at an end-use level. Energy improvements representing smaller fractions of the total building use may be harder to observe on a monthly bill. A more accurate account of the energy use may be required following a large expenditure such as a chiller plant upgrade, for example. Energy savings performance contracts (ESPC) at Federal facilities, and other grants or conservation programs, require a formal process to measure and verify the intended outcome from large expenditures from improvement. This formal process is also known as Measurement and Verification (M&V). M&V energy monitoring will need to track energy use before and after a retrofit. If M&V is required, seek program guidance to assure the pre- and post-retrofit monitoring period is sufficient. M&V should also involve annual verification that the equipment is properly maintained and continuing to deliver the expected savings. Annual equipment maintenance checks are usually performed by an energy service contract company (ESCO).

Measurement and Verification energy monitoring will need to track energy use before and after a retrofit. *Photo: Getty Images*

8. Determine On-Site Renewable Feasibility

The feasibility of on-site renewable energy centers around how much energy must be produced, whether the site can accommodate the required equipment, and if the financial considerations are acceptable. The required renewable energy production goal may be to produce as much energy as a facility uses in a year, called a Zero Energy Building (ZEB). However, perhaps a site will not accommodate enough equipment to meet all the energy use. The site assessment will still be able to determine how much on-site production is possible and how to prioritize renewable feasibility among different sites.

ZERO ENERGY BUILDING (ZEB)

Phase in energy conservation measures slowly to allow occupants to adjust to changes.

The most common sources of renewable energy are solar, wind, biomass, and hydropower. Of these, solar energy is the only practical on-site renewable energy application for ZEB goals. The primary purpose of including this section is to provide agencies with a better understanding of the main considerations in determining solar feasibility at a site. Not only are site characteristics such as roof area, roof slope, orientation and shading considered, but the specific site energy use and energy rate, as well as utility policies must also be considered by the assessor. In a ZEB, ideally, the PV array is sized to provide just as much power as a building requires over a year. In practice, there will be some months of over production balanced by some months of underproduction to consider.

Solar Feasibility and Potential Impact Overview

The amount of energy generated by a solar array greatly depends on its size and is influenced by orientation and shading from nearby trees and structures. A rooftop array will also be limited by the available roof space. The potential for solar power production can be estimated using PV Watts, a software tool developed by the U.S. Department of Energy and available free online from the National Renewable Energy Laboratory at https://pvwatts.nrel.gov/. The tool uses 30 years of historical weather data to estimate the amount of solar radiation available at a particular site during every hour of the year. Weather data are pulled from a site's nearest weather station. The results from a PV Watts calculation can be included as part of a facility EEM and solar assessment or as a standalone assessment if completed independently from an energy audit. The solar feasibility report resulting from the assessment should include the system's capacity (expressed in terms of kilowatt-hours direct current – kWdc), production (kWh), value (cost per kWh produced based on actual electric rates). Aerial images of the building showing the approximate footprint required for the PV installation should also be included in the report. The solar feasibility assessment and an estimated system cost can be used to conduct an economic analysis, including lifetime savings, simple payback, and the return on investment that can be expected from installation of the solar system. An example of a PV Watts solar feasibility assessment and report are shown in Appendix B, Level 2 Energy Audit.

PVWATTS CALCULATOR

A free online solar assessment tool developed by NREL for the US Department of Energy.

Annual Balance of Produced and Purchased Power

With an established net metering agreement between you and your utility provider, the facility's solar production can be fed into the utility grid for credit, offsetting at least a portion of facility's annual energy use and reducing or eliminating the amount of power purchased from the electric utility.

Any excess power generation is carried forward as a credit in subsequent months for the 12-month billing cycle. If an excess credit remains, the solar customer is paid for the remaining kWh production at a wholesale electric rate. For economic reasons, it is not recommended to size systems beyond the average annual electrical use because a utility may pay very little or nothing in future years for excess on-site renewable energy sent out to the grid. The greatest value is in avoided utility cost of consumed energy. It is recommended to install the amount of PV needed to offset predicted annual energy use after EEMs are adopted, and to minimize any overproduction.

Installed Output Capacity Considerations

Your electric utility has requirements that must be considered for on-site generation of any type. There may be maximum limitations to excess production. There may also be requirements for insurance or proof of self-insurance for different capacities of generation. The Figure 9, below, indicates one utility's insurance requirements according to the size the solar array:

Level	System Size	Insurance
Tier 1	<= 10 kW generation	Not required
Tier 2	> 10 kW to <= 100 kW	Insurance of at least $1 million; may self-insure
Tier 3	>100 kW to < 2 megawatts	Insurance of $2 million; may self-insure

Figure 9: Insurance requirements vary according to PV system size and tier.

Check with your electric utility for their policy towards grid-tied on-site power generation before committing to a specific amount of PV equipment.

Estimated Installed Cost and Simple Payback

The cost of photovoltaic systems has historically declined. The current installed cost of a commercially installed photovoltaic system is about $1.58 per watt[3]. Factors that influence actual cost include system location, mounting method, as well as PV panel and inverter selection.

PV Life Expectancy, Ongoing Maintenance Cost

The average life expectancy of a photovoltaic panel is 25 to 30 years. Typical industry warranties run for 25 years, with the expectation that performance will degrade less than ½ percent per year. The panels are relatively maintenance free, especially in Florida where the climate is not as harsh as other regions, and our rainfall tends to keep the panels clean. The balance of PV system components also come with manufacturer warranties that are honored by the installing contractor and manufacturers.

It's recommended that plant or maintenance personnel be trained by the equipment providers on routine maintenance and troubleshooting. *Photo: Getty Images*

Performance Monitoring

Most PV systems on the market today come with monitoring capabilities that allow customers to check system performance. For large commercial installations with multiple sites, the installation contractor should provide a period of service and maintenance. Many solar companies routinely offer this service.

[3] $ / watt dc. Source: Solar Energy Industries Association https://www.seia.org/research-resources/solar-market-insight-report-2023-year-review

General Recommendations for Solar System Installations

Orientation and Panel Location

The preferable orientation for solar panels is facing the southern sky; however, east- and west-facing panels can be effective as well. For buildings with limited roof space, a canopy over parking or other ground-mounted system offers alternative locations.

SOLAR ORIENTATION

A solar system is most productive in a southern, unobstructive, cloud-free sky.

Attachment and Roof Loading

When panels are going to be attached to existing structures, it is paramount to engage a structural engineer to evaluate the roof support system as part of preliminary design work. The specific PV panel and structural mounting will need to be chosen so that the exact system weight can be determined. For the system attachment, it is common for the PV installer to work directly with the roofing contractor to coordinate regarding any roof penetration to assure any roof warrantee is not voided.

Ballasted mounting is an option on flat roofs; however, the weight of a ballast can add significant weight to the overall system, ranging from four to six pounds per square foot of collector area. The benefit of the ballasted system is that it avoids roof penetrations since they rely on weight to resist live loads – such as uplift. The Florida building code allows use of ballasted systems on roof with less than 1 in 12 pitch. However, unless the existing roof structure can accommodate the additional weight, ballasted mounting may be impractical. The ballasted system can also be expected to cost more than a roof penetration system.

Photo: Getty Images

Appendix A: Energy Audit Preparation Checklist

	Energy Audit Preparation Checklist
PRIOR TO ENERGY AUDIT	
☐	**List the name and address of all facilities to be evaluated.**
☐	**Indicate level of energy audit requested and sustainability goals if known.**
☐	**Indicate preferred economic metric if known (simple payback, IRR, NPV, etc.)**
☐	**Collect the most recent 2 years of electric and gas energy bills for each facility.**
For each billing account note:	
☐	which facilities are on each account.
☐	the primary type of facility use. *Examples: office, general public assembly, storage, retail, library, laboratory, garage, fire station, police station*.
☐	total floor area of the noted facility; *include all buildings if more than one building on the same utility account.*
Significant changes that may have impacted energy use over past 2 years	
☐	building envelope renovation. *Examples: windows, walls, doors, roof, or other.*
☐	lighting renovations or controls added or removed.
☐	HVAC- major repairs, replacements or controls added/removed. *Examples: air conditioner, heat pump, chiller, boiler, ventilation repair.*
☐	changes in facility use. *Examples: longer or shorter hours of use, higher or lower occupancy, type of use.*
☐	DHW replacement.
☐	the age of roof for each facility and future plans on replacements.
☐	any roofs to be considered for solar PV.
☐	any grounds to be considered for ground mount or floating solar PV.
DURING ENERGY AUDIT	
Be prepared to assist the energy auditor to gain access to equipment or information to determine:	
☐	an inventory of all heating and cooling systems to note location, age, capacity, efficiency, and types of controls.
☐	HVAC maintenance practice; *change filters and belts regularly or as needed? O&M program?*
☐	an inventory of current types and number of lamps and fixtures, as well as types of light controls.
☐	a count of personal computers and other significant plug loads such as personal space heaters, fans, or refrigerators.
☐	special lab or facility equipment unique to the facility operations.
☐	particular areas of excessive comfort complaints or poor thermal and moisture control.

Appendix B: Example of a Level 1 and Level 2 Energy Audit Reports

Level 1 Energy Audit Report Example

CITY OF SMALLTOWN
CITY HALL
123 FLORIDA BLVD.
SMALLTOWN, FL 32900

Business Energy Assessment By Utility Company

Service Rep
Generic Utility Company
9/25/2023

CITY HALL, CITY OF SMALLTOWN Report Date 9/25/2023

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CITY HALL, CITY OF SMALLTOWN Report Date 9/25/2023

September 25, 2023
CITY OF SMALLTOWN
123 FLORIDA BLVD.
SMALLTOWN, FL 32000

Dear Customer,

Thank you for allowing us to conduct a comprehensive Business Energy Evaluation at your facility. Our analysis of energy usage has provided valuable information to help control energy costs. We aim to form a partnership with you to further lower your energy bills.

In this report, you will find a usage breakdown, comparison charts highlighting your business's energy consumption, inventory of equipment used, and general business operations and behavioral recommendations that could help reduce costs. We have also included potential ways to save that you could take advantage of if you choose to implement some or all the proposed recommendations.

Our top three recommendations for your business are:

- Cooling - A/C - Always clean or replace filters regularly and be sure to use proper filter size
- Lighting - We recommend using lower wattage LED lamps
- Replace existing 12-year-old heat pump with newer more efficient heat pump
- Office Equipment - When possible, ensure computers are powered off during non-business hours

Energy Manager Portal
Discover valuable insights about your business energy usage with our online Energy Manager Portal. Analyze the variables affecting your bill and optimize your energy usage to save money.

We appreciate the opportunity to assist you, and if you have any questions about this report or need further assistance, please do not hesitate to contact me.

Best regards,

Service Rep
Service.Rep@Utility.com

EQUIPMENT INVENTORY OF EXISTING EQUIPMENT

Lighting consists of T8 32-watt fluorescent lamps with electronic ballasts in four-foot ceiling fixtures with prism lenses.

LIGHTING

Type and Model	Qnty	Kwh/Mo.	Peak kW	Est. Cost/Mo.	% of Bill
Fluorescent	9	174	1	$26	19%
Fluorescent	3	131	0	$12	8%
Fluorescent	1	18	0	$3	2%

COOLING

Type and Model	Qnty	Kwh/Mo.	Peak kW	Est. Cost/Mo.	% of Bill
Central split unit	1	648	1	$64	45%
Window AC	1	80	1	$16	11%

HEATING

Type and Model	Qnty	Kwh/Mo.	Peak kW	Est. Cost/Mo.	% of Bill
Central split unit heat pump	1	103	1	$21	15%

CITY HALL, CITY OF SMALLTOWN Report Date 9/25/2023

EQUIPMENT INVENTORY OF RECOMMENDED IMPROVEMENTS

LIGHTING

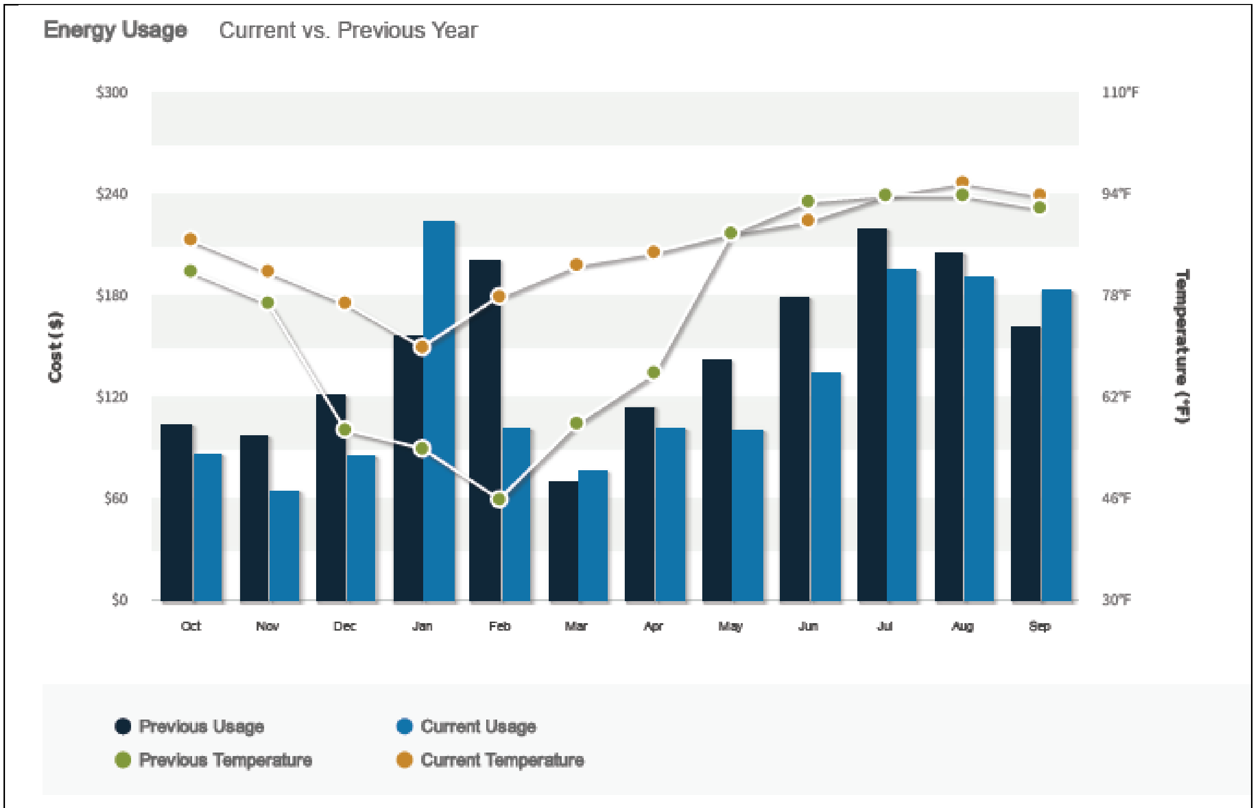
Type and Model	Existing Qnty	Recommended Equip. Type	Recommended Equip. Qnty	Savings/Yr	Recommended Equip. Cost	Payback
Fluorescent	9	LED	9	$159	$157	1 year
Fluorescent	3	LED	3	$26	$26	1 year
Fluorescent	1	LED	1	$37	$70	2 years

HEATING AND COOLING

Type and Model	Existing Qnty	Recommended Equip. Type	Recommended Equip. Qnty	Savings/Yr	Recommended Equip. Cost	Payback
Central split heat pump	1	New heat pump	1	$950	$8,500	9 years

CITY HALL, CITY OF SMALLTOWN Report Date 9/25/2023

ENERGY USAGE



ENERGY BREAKDOWN

ENERGY BILL

$183.40

DIFFERENCE VS. PREVIOUS MONTH

▼ -$8.11

Category	% of Total	Cost	kWh Used
Cooling	47.4%	$87.01	585
Miscellaneous	19.7%	$36.09	243
Lighting	19.3%	$35.39	238
Office Equipment	13.6%	$24.91	168

Billing Cycle Aug 9, 2023 – Sep 10, 2023

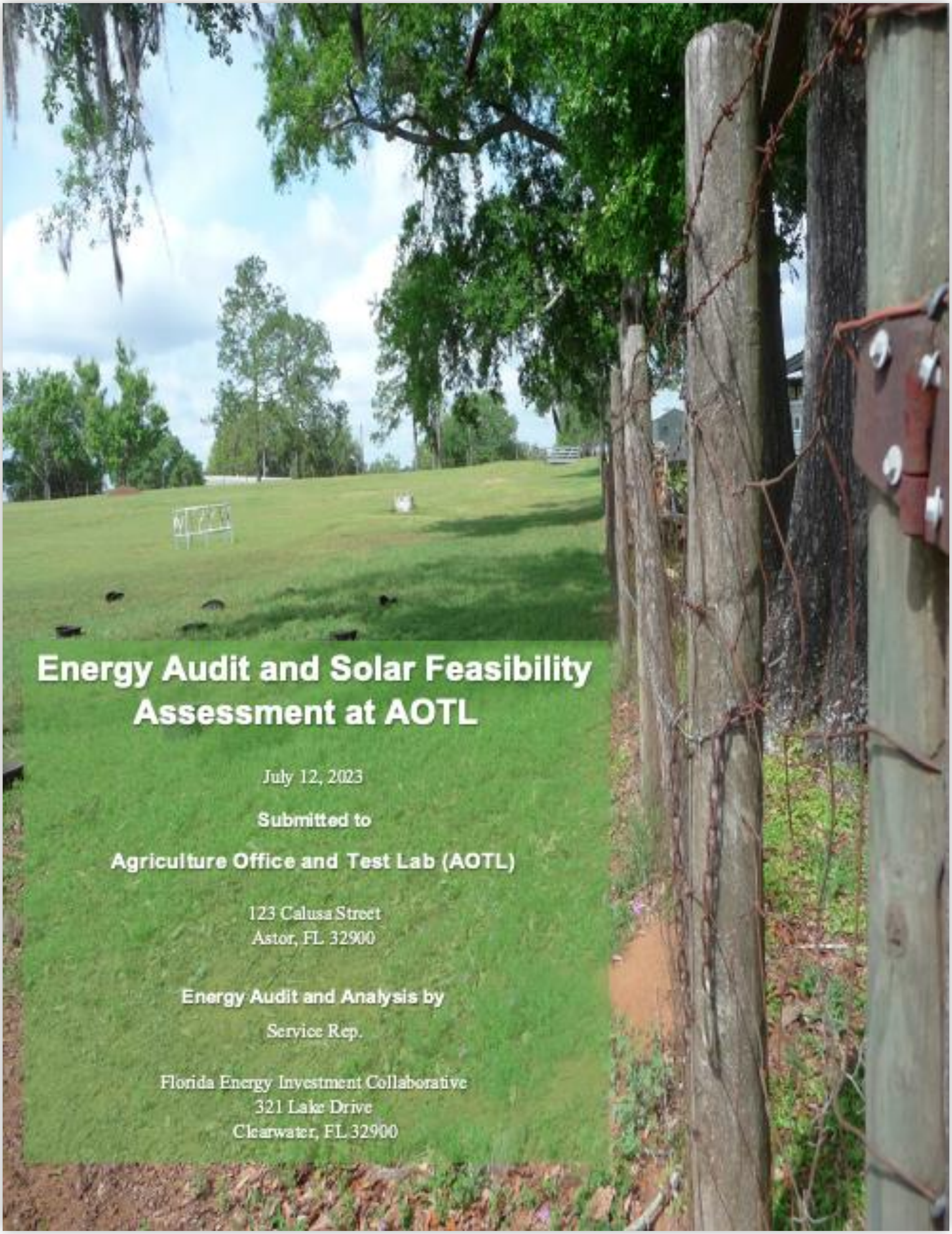
CITY HALL, CITY OF SMALLTOWN Report Date 9/25/2023

RECOMMENDATIONS

RECOMMENDATIONS
Cooling- A/C
• Always clean or replace filters regularly and be sure to use proper filter size
• Remember to service your A/C system on a regular annual basis
• When A/C needs to be replaced, consider replacing unit with a high efficiency (SEER) model
Cooling- Building
Add to attain R38 ceiling insulation in attic
Lighting
Use lower wattage LED lamps to replace existing old fluorescent lamps
Consider installing motion sensors, timers or photo cells to control lighting
Office Equipment
Turn off computers during non-business hours when possible

END OF LEVEL 1 ENERGY AUDIT REPORT EXAMPLE

Level 2 Energy Audit and Solar Feasibility Report Example



Energy Audit and Solar Feasibility Assessment at AOTL

July 12, 2023

Submitted to

Agriculture Office and Test Lab (AOTL)

123 Calusa Street
Astor, FL 32900

Energy Audit and Analysis by

Service Rep.

Florida Energy Investment Collaborative
321 Lake Drive
Clearwater, FL 32900

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Agriculture Office and Test Lab (AOTL) Executive Summary

The following report is based on an on-site visit, energy billing analysis and solar PV assessment. Investigations were carried out to determine the most cost-effective method to consider operations at Zero Energy or near Zero Energy.

Southwest side of west office building.

Southwest and south east side of east lab building.

Figure 1. Exterior views AOTL facility offices and lab.

This site was visited March 8, 2023 from about 10am through 12:20pm. The building, shown in Figure 1, functions as offices and labs. The primary business function is to inspect and study various types of agricultural plants. The lab serves to start buds to study different variants of plants. Greenhouses on the grounds use electric fan energy to cool and gas heating only as weather conditions dictate need for the plants. Given the infrequent and specialized use of greenhouse energy, no recommendations are made for greenhouses and no other considerations are offered for them within this assessment.

The AOTL facility is a 1950s era original masonry block wall structure having had major energy-impacting improvements over several years. Daily operations at the facility occur from 8am-5pm five days a week. It is comprised of two building sections connected by an enclosed unconditioned corridor. The total building area is 8,651 ft^2. The east building houses the plant lab, a conference space, and two small rooms. The west building serves as office spaces. The occupancy varies through the day as inspectors leave offices to go out to perform site visits.

The building was maintained well. It was comfortable clean and dry, adequately illuminated, with regular scheduled air filter replacement of the HVAC systems. Some southwest offices with daylighting appeared to be over-illuminated during mid-day. Several notable improvements have been made to the building over the past 16 years.

The AOTL prior energy efficiency measure (EEM) improvements to the building such as the new roof, windows, wall repair, and installation of LED lighting in most of the east side of building are already making significant reductions at this facility that has resulted in a site use Energy Use Index (EUI) of 52.2 kBtu/ft2/yr. If this building was solely considered an office it is slightly better than the median of other existing offices in the U.S. Given that there are lab operations, which are more energy-intensive than offices, the EUI is substantially more efficient than other existing lab buildings in the southeast U.S. Generally, getting your building EUI target down to about 31 through efficiency measures would be the goal before planning on-site solar, however, the relatively low cost of energy for this specific site limits cost-effective EEM options. Therefore, the first 3 EEM in the Summary of Recommended EEM are the highest priority suggested measures that are estimated to reduce EUI down to 43.0 kBtu/ft2/yr. Adding the suggested solar on-site after priority EEM is estimated to nearly produce the same annual total electric energy use. The recommended EEM package with 74 kW of solar may result in a site use EUI of about 1.4 kBtu/ft2/yr.

The first three recommendations are the highest priority EEM. The indication of EEM 1 EEM 2 and ECM 1 are noted here as well as in summary tables later in this report. Other recommendations may also provide reductions in energy or help improve dependable healthy operations.

Summary of Recommended Efficiency and Conservation Measures

1. **EEM 1** Upgrade all remaining fluorescent lights with LED lamps and fixtures. Offices with exterior windows should have LED lamps or LED fixtures compatible with dimming control.
2. **EEM 1** Install lighting control in offices that dim with adequate daylight and turn off when there is no occupancy.
3. **EEM 2** Replace existing heat pump systems at end of life with new heat pumps having SEER rating of at least 17 and HSPF of at least 9. Size cooling capacity appropriately for ASHRAE Ventilation Standard 62.1 mechanical ventilation and refer to recommendation #8.
4. **ECM 1** Raise occupied cooling set point to no lower than 73ºF. The nighttime cooling temperature setback should be raised to 80ºF. To begin the higher occupied setpoint, try a gradual increase of 1 degree per week from 69ºF to 73ºF over 4 weeks. There is approximately 8% cooling energy decrease for every degree of cooling set point increase. Cooling energy could potentially decrease by 32% from an increase of 4 degrees in setpoint. This is a conservation measure with no implementation cost, however thermal inefficiency of the building may result in local discomfort that could impact productivity thereby rendering this recommendation unacceptable.
5. The supply trunk duct appears constricted on the east Daikin system in the mechanical room (Figure 10). This should be evaluated to ensure that adequate air flow and cooling capacity is distributed.
6. Every air conditioning system should be tested during hot outdoor conditions to verify that it is delivering the designed cooling capacity across the cooling coil. This will require measurement of entering air and supply air conditions as well as the total system airflow. Supply grille airflow should also be measured to verify adequate flowrates. An investigation of duct leakage or other air distribution issues like

constricted or undersized flex ducts should be completed if zonal comfort issues remain. Every duct connection should be sealed by duct mastic, not tape.
7. Any leakage in the exterior louvered doors of the east mechanical room should be sealed to improve building airtightness since there is a large continuous open pathway from inside the top of the east mechanical room into the area above the east building ceiling.
8. A mechanical engineer should evaluate if there is adequate mechanical ventilation for the east and west buildings if this has not been done since the new windows and exterior wall renovations.
9. New HVAC equipment sizing should account for future mechanical ventilation loads.
10. Given the daily variable occupancy, demand-based control ventilation should be considered.
11. Replace the original old main electric service panel in the east building with new box and breakers. Confirm breakers are still appropriate amperage for current end uses.

Site Energy Billing Data Analysis and EUI

Three different energy utility bill accounts were provided for this site assessment covering the period from January 2021 through December 2022. Since electric billing provided a comparison to the previous year, we were also able to look at 2020 data. One electric metered account was solely for outdoor street lamps. The second electric account covered the AOTL buildings. A gas utility account only applied to greenhouse heating and emergency back-up generation.

Gas was not used for conditioned space or domestic hot water heating. Gas was only used as needed to warm greenhouse plants or run emergency generators during loss of grid power. Given the unpredictable and minimal use of gas, gas energy use will not be considered in site analysis. No recommendations are offered here for reducing gas use due to the limited use for emergencies.

Energy Anomalies and Analytical Adjustments

A total of three years (2020-2022) of electric billing data were analyzed. There was no significant long-term change in occupancy or operations reported related to the COVID pandemic during 2021-2022. Energy and demand use was drastically higher from October 2021 through February 2022 compared to the same period in 2020. It was discovered that major building renovations had occurred that included replacing all exterior windows and the utility meter. During this same unusual use period, the meter reading on the bills were noted as “estimated”. The billing estimates occurred just after the new meter was changed out and during the renovation period. Most of the interior lighting in the east building section had also undergone an upgrade from fluorescent to LED about the same anomaly period. Monthly energy data among the three years was compared, but major construction disruption and estimated billing periods of earlier years made it not very useful in looking for trends across years. The biggest value in the billing data was to establish the current EUI, and disaggregated energy baselines.

Normally the most recent year after retrofits would be used for establishing a current baseline for further efficiency considerations. Full use of the 2022 year could not be used since retrofits had not been completed until around the end of February 2022, and the disruption of removing and replacing windows one at a time had a noticeable winter peak power increase of 70% (from 30 kW to 51 kW) compared to 2020 during these months. Furthermore, the utility “estimated” bills made January and February 2022 more unreliable. Therefore, the first two months of 2022 were replaced with the first two months of 2020 since it would not have had any operational interference occurring then.

The adjusted 2022 total annual energy use was 132,276 kWh. Normalizing the site energy use by conditioned area established an energy use index (EUI) which can be compared to other buildings of similar use and size. The EUI is 52.2 kBtu/ft^2/yr. The summary of site energy use, EUI, and utility cost is shown in Table 1. Utility cost of energy (kWh) includes non-fuel, fuel, and any other cost that is associated with kWh consumption.

Table 1. 2022 Adjusted Energy Use Summary

Floor Area (ft^2)	Annual kWh	Annual Peak kW (max / avg)	**EUI kBtu/ft^2/yr**	$/kWh	$/peak kW
8,651	132,276	(37 / 34)*	**52.2**	$0.04992	$16.53

* 37 kW based on estimate disregarding winter 2022 anomaly of 51kW

This site is comprised of about 90% office space and approximately 10% laboratory space with relatively low exhaust and ventilation requirements compared to whole buildings classified as laboratories. The electric baseload energy use is about 10%-15% higher than most office buildings which is believed to be due to the lab appliances. Since much of the AOTL building offices support work beyond the lab, we suggest comparing this site EUI of 52.2 to a hybrid weighted EUI consisting of 90% office and 10% lab.

Table 2 shows different published sources of historical existing EUI data as well as EUI target goal of net zero energy (NZE) for office and also for lab spaces. Net zero energy is where building energy efficiency and conservation are used along with renewable energy such that the net annual energy consumption is near zero. The NZE target goal EUI reflects the utility energy use without renewable energy accounted for. For fairer comparison, the weighted hybrid EUI comparison was derived once for existing buildings and also for the NZE target.

Lawrence Berkeley National Lab (LBNL) considers a lab EUI less than the 10th percentile of peer group using the LBNL Laboratory Benchmark Tool (LBT) to be operating at “Best practice”. The LBNL LBT peer group consists of 92 different Bio/Chem labs located in hot humid climate zones 1A, 2A, and 3A (southeast United States). The 10th percentile EUI of this group is 169 kBtu/ft^2/y.

The AOTL Building EUI of 52.2. is less than the derived existing building hybrid of 64.5, which indicates that it is more efficient than existing buildings similar in use. With further energy efficiency improvement, the EUI could be reduced closer to the NZE weighted target EUI of 31.

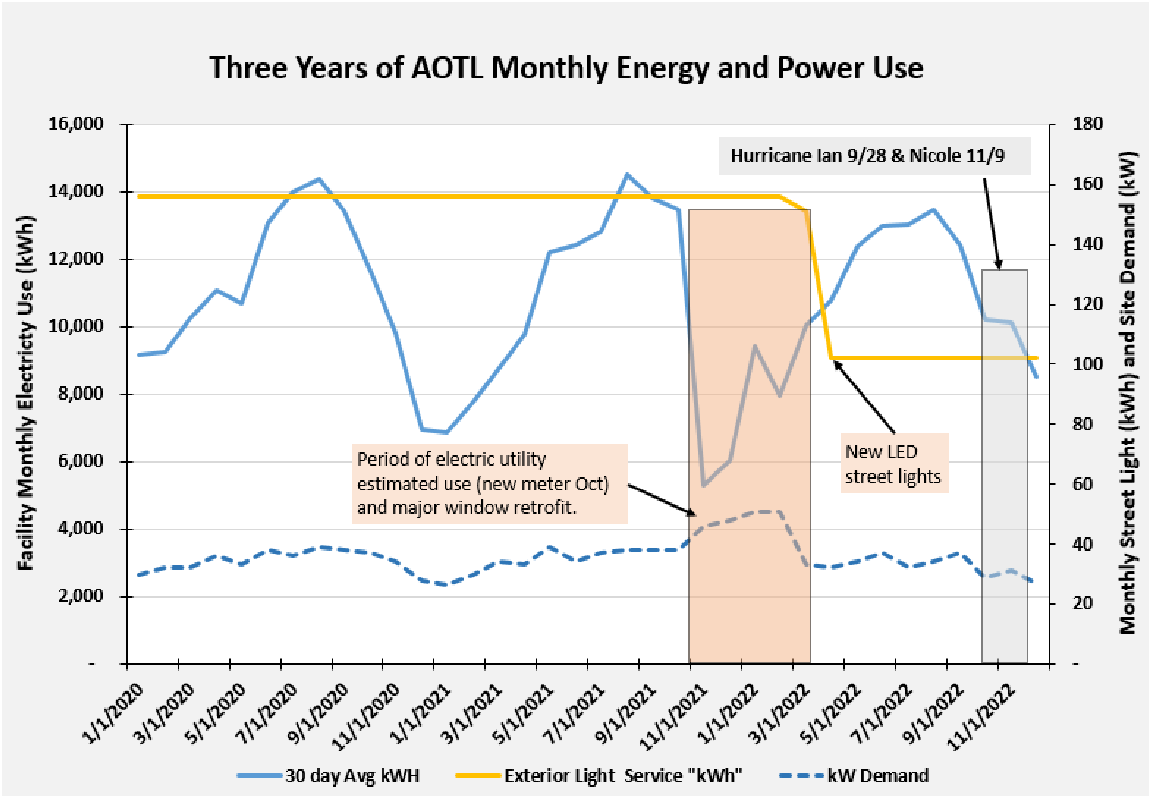
Table 2. EUI Comparison to Office, Lab, and Weighted Hybrid Spaces for Existing and NZE Target Goals

EUI of Existing Buildings of Various Age (kBtu/ft^2/yr)			**EUI of NZE Target Goal (kBtu/ft^2/yr)**		
Office CBECS Data (peer)	Lab LBL/LBT S.E. U.S. 10th percentile (peer)	Weighted EUI 90% Office CBECS & 10% 10th prcnt. Lab	Office NZE (FL)	Lab NZE	**Weighted EUI 90% Office 10% Lab**
52.9	169	64.5	23	<100	**31**

A linear regression analysis was conducted with data from the monthly utility bills which were provided for the AOTL, to estimate the amount of heating, cooling, and baseload energy used at the site monthly and annually.

The model predicts an annual baseload energy use that is about 79,507 kWh/y (60% of total), cooling energy of about 48,758 kWh/y (37%) and heating of about 3,866 kWh/y (3%). These results are presented graphically in Figure 2, with baseload shaded in green, heating in red, cooling in blue, and total energy use indicated with a purple line. The reported monthly demand is also presented, as an orange diamond.

The baseload is mostly lighting, lab operations as well as other plug loads. The cooling energy is the single largest use during the summer months. Indicated heating energy use is modest as is normal for central Florida offices. The existing electric heat pumps heating the space are much more efficient than electric strip heat and are already helping to keep heating costs lower.



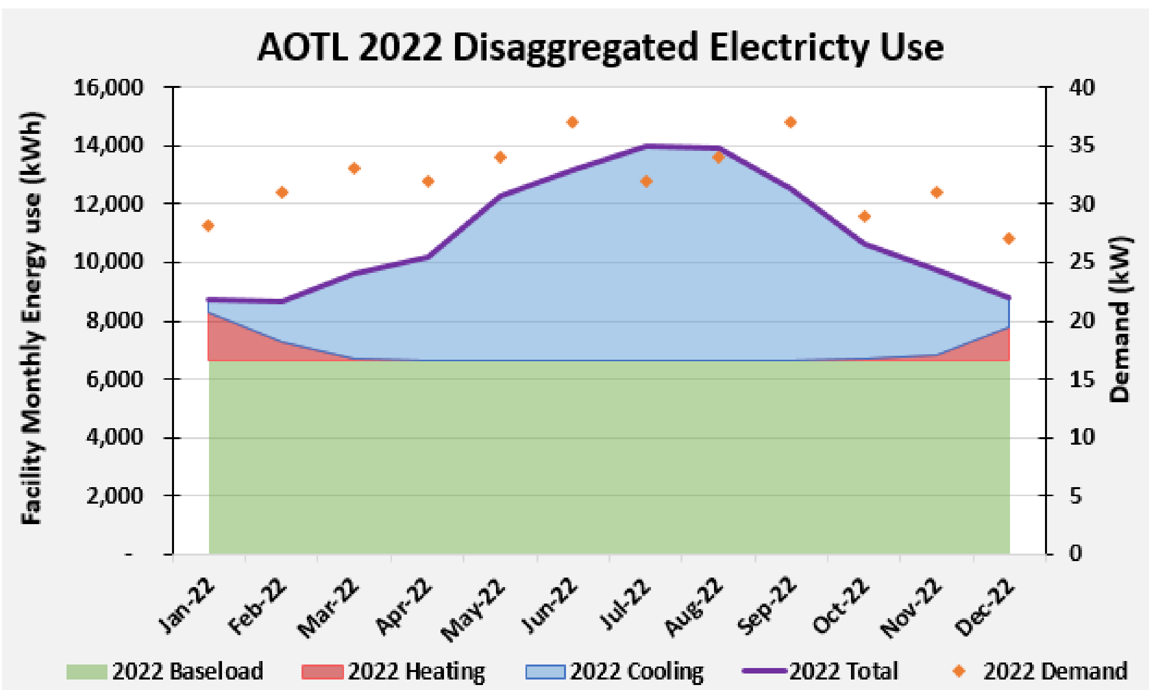


Figure 2. AOTL thre- year trend of monthly energy and power use (top) and 2022 monthly disaggregated energy use, normalized to 2022 calendar months, and monthly demand (bottom).

The most recent utility peak and energy charges were used based on the most recent utility billing data from the electric service provider. The peak power charge of $16.53 / kW and energy charge of only $0.04992 / kWh were used in analysis. Standard service charges and fees not associated with energy use were not included in energy costs analysis. The very low energy costs for this site diminish rates of return and prolonged simple payback. No assumptions or adjustments were made to predict future cost of energy in the analysis. As real energy costs increase, real savings would be greater than estimates in this report.

Relevant Findings

Street Lights
There were only two fixtures noted on this account. These fixtures were identified on site as the two lampposts on the entry road. It appeared that the street lighting bill is really a fixed service fee. The energy use was exactly 156 kWh every billing period regardless of the number of days in the billing cycle until April 2022. It appears that a street lighting retrofit may have occurred late March 2022 with the later 2022 billing history indicating a 34.6% drop in energy use (to 102 kWh), however the customer monthly charge remained around $36. The energy use rate was changed to reach the pre-retrofit amount. No recommendations are made for the street lamp account.

AOTL Building
This building consists of CMU exterior walls, slab on grade, and new insulated low-e glass windows. The original roof is lightweight concrete on top of fluted metal roof deck. A new sloped metal roof was constructed over the existing roof about 15 years ago. Plans indicate R19 insulation located at the metal roof deck. There are several offices with exterior windows. Lighting is provided by T832W fluorescent lamps as well as newer LED lamps. Space heat and cooling is provided by electric heat pump central ducted split DX systems that are estimated to be at least 9 years old. The west building had two identical Goodman 5-ton systems serving two different zones. The east building had one ducted 10-ton Daikin with two-stage cooling system connected to two identical Daikin 5 ton heat pumps. All systems appeared to be maintained well and delivered cooling near set-point with exception to the lab. Cooling set-points were reported to be maintained between 68ºF-70ºF and heating at 70ºF-72ºF. Each system was controlled by a single thermostat zone accessible on interior walls. The observed thermostat temperature during visit was 69ºF.

Major Renovations Noted on AOTL Building
Original construction of the building was about 50 years ago, but there have been some major renovations within the last 16 years. In 2007 a new trussed metal roof was built over the existing flat built-up roof with R19 insulation added to the metal roof deck noted on plans. HVAC ductwork was replaced with R6 insulated ducts in 2010. Beginning in 2021, three different major renovations occurred to windows, walls and lighting. The renovations spanned from approximately fall 2021 through spring 2022. The electric utility meter was replaced during the same period as the window renovation making energy analysis more challenging. There were four months (Nov. 2021-Feb. 2022)

where the electric utility indicated billing use was estimated and does not match prior year profile. The renovations and estimated billing made this period of measured energy unreliable to predict a normal baseline and disaggregate energy use. Therefore, previous and past use profiles, normalized to weather, were used to create estimated monthly use for Nov. 2021-Feb. 2022.

Recent renovations that occurred during two-year billing analysis period:

- Original single-pane clear jalousie windows replaced with double-pane low-e tinted insulated glass units, thermal blinds added
- Interior block walls had moisture retarder added to control moisture issues, ~R3 wall insulation added and covered by painted drywall
- East building fluorescent T8 lamp and fixture lighting changed to LED lamps and fixtures. The site manager indicated that lighting retrofits to LED are also planned in the future.
- Occupancy lighting control installed in east conference and east and west bathrooms

Indoor Environment- Temperature, Humidity and Illumination
Overall indoor conditions were clean, dry and illuminated well. HVAC systems were in cooling mode during the visit and temperatures were very cool in most locations. Hand-held sample measurements of indoor temperature, RH and illumination levels found readings mostly within generally acceptable levels of comfort during the site walk-through, although some temperatures were low due to low cooling setpoint. Temperatures ranged from as low as 68.7ºF in east building auditorium (no windows and vacant) up to 78.8ºF in the Plant Lab. Outdoor conditions during measurements were sunny and about 81ºF between 11am-12pm. This lab space had a significant amount of electric powered equipment that generated internal heat as well as a high exterior wall ratio resulting in higher cooling load than other spaces of the buildings. Relative humidity was under reasonable control throughout the east and west buildings. Most measurements were between 45%-50% RH, however the humidity in the east conference room was slightly elevated at 63% RH.

96ft^2 office with daylighting and a 4-lamp T8 fixture

87 fc during daytime with lights on is more illumination than necessary for a small office.

Same office above with lights off

41 fc illumination with lights off during daylight and thermal blind down ¾ is adequate lighting.

Figure 3. Top row: Office light on and blind nearly ¾ down; desktop illumination 87 fc. Bottom row: Office light off and blind nearly ¾ down; desktop illumination 41 fc.

Indoor illumination was more than adequate with electric lights on. IESNA recommended lighting for offices is at 30-50 footcandles (fc), however less task lighting is needed when working at a computer monitor and reduced lighting can minimize glare issues. Figure 3 shows a group of photos of illumination levels in a day lit office having a 4-lamp fixture. The illumination at desktop level was 87fc with lights on and 41 fc with lights off. This demonstrates an opportunity to de-lamp down to two to three LED lamps and add occupancy and light level control in day lit offices with three or more lamps per fixture. Overall, offices with available daylight had desktop illumination, with lights off, at levels generally between 17-41 footcandles (fc). Most thermal blinds were found drawn down over about nearly ¾ of the upper window area. Day lit offices had illumination with lights on at levels 27-87 fc. The office with lowest illumination (17 fc with light off and 27 fc when light on) appeared to have a preference for lower illumination as only 1 lamp of 4 was lit within the one overhead fixture.

Illumination at desktop level was also measured in the east building conference room under the new LED troffer fixtures. Illumination varied from 46 to 71 fc and had occupancy control. This is a good demonstration that 2'x4' LED panel lighting was effective in replacing pre-existing T8 32 watt linear fluorescent lamp-based troffer lighting. The new lighting was very efficient and effective, however this space was over cooled while unoccupied. There is only one central ducted system serving the entire east building. Installing a variable damper control to the conference room may be a consideration to better distribute cold air where it is needed given that the lab section was warmer than setpoint. Figure 4 shows a partial view of the conference room and a sample of desktop illumination and temperature measurements.

Figure 4. Left: Partial view into the east conference room with new LED lights and occupancy controls. Right: Desktop illumination in east conference room varied from 46 fc to 71 fc, however the space was overcooled to about 69° F while unoccupied.

Recommendations

There are still opportunities for cost-effective energy efficiency measures (EEM) to indoor electric lighting and HVAC. Electric lighting in the west side building is mostly 2'x4' troffer fixtures with T832W lamps and electronic ballasts. These should be replaced with LED equivalents similar to efforts already completed in the east side of building. It is also recommended that offices with natural daylight have occupancy-based control with integrated electric light output control (daylighting control). Occupant instruction may be needed to help learn how to maximize natural illumination as much as individual visual and thermal comfort needs will permit.

The interior cooling setpoint is very low. Cooling setpoints maintained continuously below 74ºF have a higher risk of condensation on cold air exterior ductwork or any building surface able to cool to the very low setpoint during warm moist summer conditions. It is assumed this may be needed to maintain comfort in some zones such as exterior offices or the Plant Lab in the east building, which has a significant amount of lab appliances. The Lab had the warmest indoor temperatures during the site visit. One comfort and energy conservation solution for the east building could be to add a ductless mini-split heat pump with the indoor unit attached to an upper portion of accessible wall. This would allow better zone cooling of the lab space without overcooling other east building zone spaces. Although another heat pump would be added, total operational cooling energy costs could decrease substantially. This is because the ductless system would be about 2-3 times more efficient than the central ducted system, and would enable a higher cooling setpoint of the central ducted system. Further detail on savings from higher cooling setpoint is provided below in Recommendation #4.

If a low cooling temperature is what it takes for comfort in the west building office spaces, that is an indication of remaining thermal envelope and/or cooling air distribution inefficiencies that should be addressed. A professional assessment should be made to determine if: the cooling system is delivering expected cooling capacity, there is inadequate airflow to each space, there is duct leakage, or if there is any duct restriction limiting space cooling.

The following recommendations are made, with the first four being the highest priority with the best-known financial returns. The remaining recommendations should be considered in efforts to enable cooling setpoints above 70ºF and maintain acceptable comfort in the future. Lastly, mechanical ventilation is discussed since ducted outdoor mechanical ventilation was not evident during the site visit and recent renovations likely decreased natural ventilation. Estimated EEM costs, savings and returns are summarized in Tables 3 and 4.

Summary of Recommended Efficiency and Conservation Measures

1. **EEM 1** Upgrade all remaining fluorescent lights with LED lamps and fixtures. Offices with exterior windows should have LED lamps or LED fixtures compatible with dimming control.
2. **EEM 1** Install lighting control in offices that dim with adequate daylight and turn off when there is no occupancy.
3. **EEM 2** Replace existing heat pump systems at end of life with new heat pumps having SEER rating of at least 17 and HSPF of at least 9. Size cooling capacity appropriately for ASHRAE Ventilation Standard 62.1 mechanical ventilation and refer to recommendation #8.
4. **ECM 1** Raise occupied cooling set point to no lower than 73ºF. The nighttime cooling temperature setback should be raised to 80ºF. To begin the higher occupied setpoint, try a gradual increase of 1 degree per week from 69ºF to 73ºF over 4 weeks. There is approximately 8% cooling energy decrease for every degree of cooling set point increase. Cooling energy could potentially decrease by 32% from an increase of 4 degrees in setpoint. This is a conservation measure with no implementation cost, however thermal inefficiency of the building may result in local discomfort that could impact productivity thereby rendering this recommendation unacceptable.
5. The supply trunk duct appears constricted on the east Daikin system in the mechanical room (Figure 5). This should be evaluated to ensure that adequate air flow and cooling capacity is distributed.
6. Every air conditioning system should be tested during hot outdoor conditions to verify that it is delivering the designed cooling capacity across the cooling coil. This will require measurement of entering air and supply air conditions as well as the total system airflow. Supply grille airflow should also be measured to verify adequate flowrates. An investigation of duct leakage or other air distribution issues like

constricted or undersized flex ducts should be completed if zonal comfort issues remain. Every duct connection should be sealed by duct mastic, not tape.

7. Any leakage in the exterior louvered doors of the east mechanical room should be sealed to improve building airtightness since there is a large continuous open pathway from inside the top of the east mechanical room into the area above the east building ceiling.
8. A mechanical engineer should evaluate if there is adequate mechanical ventilation for the east and west buildings if this has not been done since the new windows and exterior wall renovations.
9. New HVAC equipment sizing should account for future mechanical ventilation loads.
10. Given the daily variable occupancy, demand-based control ventilation should be considered.
11. Replace the original old main electric service panel in the east building with new box and breakers. Confirm breakers are still appropriate amperage for current end uses.

Figure 5. The main supply duct trunk serving the east building is severely constricted.

Table 3. AOTL EEM and ECM Recommendation Cost Savings and Payback

		Annual Energy and Cost Savings				Simple Payback	
Measure ID	EEM description	Peak (kW)	Electric (kWh)	Gas (therms)	Total Cost Savings	Measure Cost	Simple Payback (years)
EEM1	Replace T832W Fluorescnt. With LED Lamps; install 8 office occ./daylight controls	2.17	6,098	0	$736	-$4,633	6.3
EEM2	Replace both Goodman 5 ton and Daikin 10 ton heat pumps with new SEER 17 & HSPF 9 heat pumps	5.54	17,138	0	$1,954	-$14,000	7.2
Total Impact of All EEM		7.71 22.4%*	23,236 17.6%*	0	$2,690	-$18,633	6.9
Conservation measure below does not have any cost to implement							
ECM1	Raise thermostat cool setpoint from 69ºF to 73ºF	0	15,669	0	$3,671	$0	0.1

* % of annual average peak of 34.4 kW (2020) and annual total energy of 132,276 kWh (2022 blend disag.).

Table 4. AOTL EEM Recommendation IRR and Lifecycle Benefits

Measure ID	EEM Financial Benefits							
	Lifecycle Gross Savings	Avoided Costs	Potential TECO Utility Incentives	Net EEM Cost	IRR EEM Lifetime	NPV	Simple Payback (years)	EEM Assumed Lifetime (years)
EEM1	$14,713	$2,802	$359	-$4,275	16%	$5,503	5.8	20
EEM2	$23,450	$0	$0	-$14,000	9%	$4,173	7.2	12
Total Impact of All EEM	$38,163	$2,802	$359	-$18,275	11%	$9,676	6.8	12-20

On-site Solar Renewable Energy Generation Potential

The goal pursued for this site was to find suitable options for on-site solar energy panels to be used that could offset the annual electric energy consumption. The building metal roof is suitable for installation for solar PV panels, however portions have inadequate area and some obstructions that are not considered suitable. Panels are considered for south and east facing roof slopes at 3 to 12 pitch. This alone was not suitable to meet the annual energy usage, therefore two separate ground mount options were also considered in addition to the roof mount PV.

The potential for solar power production was calculated using PVWatts®, a software tool developed by the U.S. Department of Energy and available free online from the National Renewable Energy Laboratory (NREL) at https://pvwatts.nrel.gov/. The analysis uses 30 years of actual weather data to estimate the amount of solar radiation available for a particular site during every hour of the year. Weather data is pulled from the weather station closest to the latitude and longitude of each site.

The specific characteristics of the buildings and grounds around the building were considered for installing solar photovoltaic (PV) renewable electric power to offset energy consumption. The power and energy use of the electric utility meter associated with this site was used to establish a current baseline from which to size the PV system.

Economic summaries of a 74 kW PV installation are provided in Tables 5, 6, and 7. The relatively low cost of electric utility energy for this site is resulting in longer payback than usual and a negative NPV. Given the long lifespan of solar PV and higher utility costs, positive NPV would be expected. The estimate provided is based upon assumed site locations, rated panel output, PV system efficiency, PV panel orientations, and long-term historical weather data for this site location. Real PV performance will vary from this estimate depending upon how different installed equipment varies from assumptions. Best efforts were made to include typical published industry efficiency as well as consider potential shading impacts from growth of nearby trees. The assumed assumptions and estimated outputs are provided at the end of this subsection in the PVWatts® output summary reports. The potential variability of annual energy output is also provided in the output summaries.

The PVWatts® Calculator provides a monthly and annual total energy production. **The goal was to use the most suitable locations for PV panels that could provide substantial output for the investment. The PV system target size was based on the recommended EEM1 and EEM2 being fully implemented. The efficiency measures are the most economical and should be the first priority. This helps reduced the amount of PV needed to be purchased.**

The southeast orientations on rooftop are recommended for the installation. The northwest orientations on the roof were not recommended due to more limited output and the very low cost of utility energy rate. Instead, two separate ground mount locations are also recommended in an effort to increase total power production to offset about 80% of the annual energy used on the site. A 36 kW PV array canopy is suggested to be placed over the north side parking area. This will also provide shaded parking for employees. The second ground mount is proposed just to the southeast of the buildings using a 10 kW array of panels. The illustration in Figure 6 shows the approximate location of the proposed roof and ground mount PV panel arrays. Given the business mission, no trees are suggested to be removed and the PV output accounts for an estimate of modest seasonal shading of existing trees on the south side after several years of growth. The standing seam metal roof is good for PV panel mounts as this is a common type of roof system that handles mechanical and structural loads of PV well. The mounting racks can utilize the standing seam of the roof without the need for roof penetrations.

Estimates were made on the installed PV cost and cost savings from reduced electric utility consumption offset by on-site generation. An assumed cost of $2.00 per installed PV Watt was assumed. This is almost 9% higher compared to the current national estimate of $1.84 / W used by NREL for estimation purposes (Ramasamy et al 2022). A higher value was used since some estimates covering the Florida region cite costs between $2-$3 / W. The NREL value is based on more substantial research and considered more reliable. It should be noted that total installed costs have been dropping over the last several years instead of steadily rising like other products.

The utility peak and energy charges were used based on the most recent utility billing data from the service provider. The peak power charge of $16.53 / kW and energy charge of $0.04992 / kWh were used in analysis. Standard service charges and fees not associated with energy use were not included in energy costs analysis. This resulted in a very low energy cost for this site that diminishes rates of return and prolongs payback. Predicting solar PV impact on reducing the peak use charge is very uncertain, therefore a very conservative (minimal) benefit was assumed.

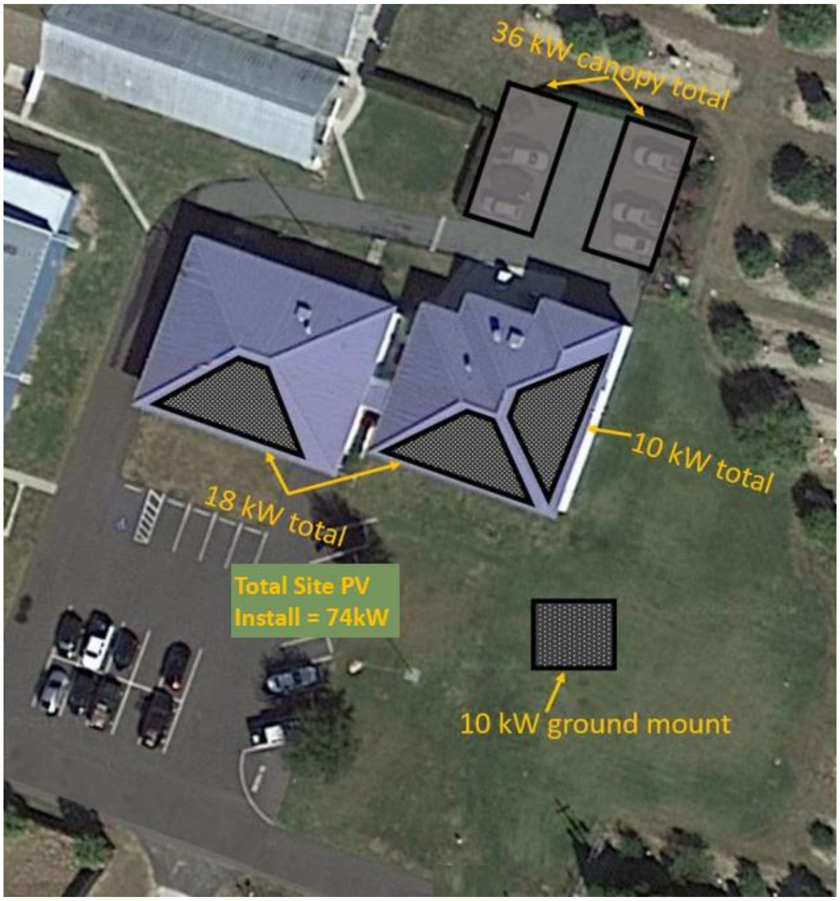


Figure 6. Arial view of potential PV panel arrays. Approximate locations are indicated and are not shown to scale.

Table 5. AOTL EEM Package and Solar Cost Savings and Payback

		Annual Energy and Cost Savings				Simple Payback	
Measure ID	EEM description	Peak (kW)	Electric (kWh)	Gas (therms)	Total Cost Savings	Measure Cost	Simple Payback (years)
EEM1 & EEM2	Total EEM1 & EEM2 Package	7.71 22.4%*	23,236 17.6%*	0	$2,690	-$18,633	6.9
Solar PV	Rooftop & Ground Mount Total 74 kW	1.85 5.4%**	105,556 79.8%*	0	$5,636	-$148,000	26.3
EEM Pkg & PV	Total EEM Package & 74 kW Solar	9.56 27.8%**	128,792 97.4%*	0	$8,326	-$166,633	20.0

* % of annual average peak of 34.4 kW and annual total energy of 132,276 kWh.
** Peak savings of solar PV is conservative estimate of only 2.5% kW annual average reduction (2.5% of 74 kW installed PV) (*SOURCE: NREL/FS-6A20-69016 • September 2017*)

Table 6. AOTL EEM Package and Solar IRR and Lifecycle Benefits

Measure ID	EEM Financial Benefits							
	Lifecycle Gross Savings	Avoided Costs	Potential Utility Incentives	Net Cost	IRR Lifetime	NPV	Simple Payback (years)	EEM Assumed Lifetime (years)
Total EEM Package	$38,163	$2,802	$359	-$18,275	11%	$9,676	6.8	12-20
Solar PV	$169,090	$0	$0	-$148,000	1%	-$48,593	26.3	30
EEM&PV	$207,252	$20,802	$359	-$166,275	1.6%	-$38,917	20.0	12-30

Table 7. Reduction of Site Utility Energy Use With EEM Package and Solar PV

	Annual Utility (kWh)	EUI (kBtu/ft^2/yr)
Existing	132,276	52.2
EEM Pkg	109,040	43.0
EEM Pkg & Solar PV	3,484	1.4

PVWatts® Output Summary Reports

Note that the information and disclaimer below applies to all PVWatts® Results posted herein this report.

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at //sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

Disclaimer: The PVWatts® Model ("Model") is provided by the National Renewable Energy Laboratory ("NREL"), which is operated by the Alliance for Sustainable Energy, LLC ("Alliance") for the U.S. Department Of Energy ("DOE") and may be used for any purpose whatsoever. The names DOE/NREL/ALLIANCE shall not be used in any representation, advertising, publicity or other manner whatsoever to endorse or promote any entity that adopts or uses the Model. DOE/NREL/ALLIANCE shall not provide any support, consulting, training or assistance of any kind with regard to the use of the Model or any updates, revisions or new versions of the Model.

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The energy output range is based on analysis of 30 years of historical weather data, and is intended to provide an indication of the possible interannual variability in generation for a Fixed (openrack) PV system at this location.

RESULTS

25,064 kWh/Year*

System output may range from 23,996 to 26,147 kWh per year near this location.

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)
January	3.55	1,560
February	4.15	1,621
March	5.22	2,225
April	6.78	2,689
May	6.69	2,726
June	6.19	2,413
July	5.73	2,310
August	5.70	2,306
September	5.46	2,175
October	4.61	1,958
November	3.93	1,634
December	3.34	1,446
Annual	5.11	25,063

Location and Station Identification

Requested Location	3027 Lake Alfred Road Winter Haven, FL 33881
Weather Data Source	Lat, Lng: 28.05, -81.74 0.5 mi
Latitude	28.05° N
Longitude	81.74° W

PV System Specifications

DC System Size	18 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	14°
Array Azimuth	225°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
15%	13%	11%	0%	0%	0%	0%	0%	0%	11%	13%	15%

Performance Metrics

DC Capacity Factor	15.9%

Roof mount 18 kW array on SW roofs

RESULTS

14,282 kWh/Year*

System output may range from 13,674 to 14,899 kWh per year near this location.

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)
January	3.54	866
February	4.18	906
March	5.26	1,248
April	6.84	1,509
May	6.78	1,541
June	6.45	1,402
July	6.05	1,362
August	6.07	1,372
September	5.53	1,227
October	4.66	1,107
November	4.01	928
December	3.39	814
Annual	5.23	14,282

Location and Station Identification

Requested Location	3027 Lake Alfred Road Winter Haven, FL 33881
Weather Data Source	Lat, Lng: 28.05, -81.74 0.5 mi
Latitude	28.05° N
Longitude	81.74° W

PV System Specifications

DC System Size	10 kW
Module Type	Standard
Array Type	Fixed (roof mount)
System Losses	14.08%
Array Tilt	14°
Array Azimuth	135°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
15%	13%	11%	0%	0%	0%	0%	0%	0%	11%	13%	15%

Performance Metrics

DC Capacity Factor	16.3%

Roof mount 10 kW array on SE roof

RESULTS

51,366 kWh/Year*

System output may range from 49,178 to 53,686 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	3.58	3,131
February	4.29	3,337
March	5.55	4,739
April	6.68	5,360
May	6.83	5,617
June	6.49	5,111
July	6.01	4,895
August	5.85	4,785
September	5.28	4,242
October	4.73	4,028
November	3.94	3,262
December	3.34	2,858
Annual	5.21	51,365

Location and Station Identification

Requested Location	3027 Lake Alfred Road Winter Haven, FL 33881
Weather Data Source	Lat, Lng: 28.05, -81.74 0.5 mi
Latitude	28.05° N
Longitude	81.74° W

PV System Specifications

DC System Size	35.9 kW
Module Type	Standard
Array Type	Fixed (open rack)
System Losses	14.08%
Array Tilt	0°
Array Azimuth	270°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4%
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Performance Metrics

DC Capacity Factor	16.3%

Ground mount 36 kW parking canopy array

RESULTS

14,846 kWh/Year*

System output may range from 14,214 to 15,487 kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.49	1,109
February	4.87	1,067
March	5.56	1,330
April	6.63	1,482
May	6.18	1,417
June	5.67	1,248
July	5.33	1,214
August	5.60	1,280
September	5.56	1,248
October	5.21	1,246
November	4.88	1,142
December	4.36	1,063
Annual	5.36	14,846

Location and Station Identification

Requested Location	3027 lake alfred road winter haven, FL
Weather Data Source	Lat, Lng: 28.05, -81.74 0.5 mi
Latitude	28.05° N
Longitude	81.74° W

PV System Specifications

DC System Size	10 kW
Module Type	Standard
Array Type	Fixed (open rack)
System Losses	14.08%
Array Tilt	28°
Array Azimuth	180°
DC to AC Size Ratio	1.2
Inverter Efficiency	96%
Ground Coverage Ratio	0.4
Albedo	*From weather file*
Bifacial	No (0)

Monthly Irradiance Loss

Jan	Feb	Mar	Apr	May	June
10%	10%	10%	0%	0%	0%

July	Aug	Sept	Oct	Nov	Dec
0%	0%	0%	10%	10%	10%

Performance Metrics

DC Capacity Factor	15.9%

Ground mount 10 kW array on south side of east building

(*The original report had supplemental appendices with references and source information on the basis for cost and savings estimates, analytical methodology, and further detail on considerations used for solar assessment. These would add several more pages to this report and are not shown appended here as they are redundant to information already provided within this guidebook.*)

END OF LEVEL 2 ENERGY AUDIT REPORT EXAMPLE

Appendix C – Example Selection Process of EEMs and Solar PV Improvement Options

This exercise is offered to demonstrate an example of two different selection processes using two different priority scenarios. The first scenario has a known spending limit and energy savings will be expected to pay back the expense within five years. The second scenario has a more impactful sustainability goal of identifying potential zero energy buildings with an IRR of at least 5%. In this exercise there are different utility rates at different facilities that demonstrate a range that small or local governments would not have.

To begin this exercise, suppose you had several energy audits and solar PV feasibility analyses completed at five different facilities and each of those with different buildings and utility accounts. Next, suppose the summary of recommendations was split into two considerations: 1) EEMs without solar PV and 2) EEM packages with solar PV found in Tables 1 and 2, respectively. Then consider the two following scenarios. In this example, EEM packages indicate where more than one type of EEM may be recommended. LED indicates replacing fluorescent lights with LED, HVAC indicates replacing specific heating and cooling units, and RCx HVAC is retro-commissioning HVAC. Further EEM details would be provided within a larger report (not shown here).

Selection Scenario One- Choose all sites with EEMs having estimated payback within 5 years that will not exceed estimated total cost of $100,000.

Referencing Table 1, we see that only the Administration Building with recommended LED lighting upgrade has a simple payback within 5 years and an estimated cost under $100,000. But, if the simple payback restriction is increased to about 6 years, then the Smith Conference Center and the Administration Maintenance Office buildings could also be considered; or the Large Warehouse could take the place of the conference center and maintenance office if that was considered a higher priority.

Selection Scenario Two- Choose all sites with EEMs combined with on-site solar PV having estimated IRR no less than 5%.

Looking at Table 2, at the IRR column there are three buildings at the Administration Complex and one building at the Farmers Market Complex that have IRR of 5% or more. The utility rates are also noted on Table 2 that show the sites with low cost of energy ($/kWh) have lower IRR since savings are tied directly to the cost of energy.

Table 1: Packaged EEM Recommendations Example.

EEM Locations and Description	Lifecycle Gross Savings	Avoided Costs	Net EEM Cost	IRR Lifetime	NPV	Simple Payback (years)
Agricultural Office and Test Lab						
AOTL Buildings; LED and HVAC	$38,163	$2,802	-$18,275	11%	$9,676	6.8
Forestry Office and Community Complex						
Conference Center; LED and RCx HVAC	$35,276	$9,359	-$14,000	11%	$7,291	6.1
Forestry Office; LED retrofit and HVAC	$29,242	$9,195	-$19,125	9%	$5,601	10.1
Ext. Office & Ag. Center; LED and HVAC	$114,666	$29,666	-$81,636	6%	$9,055	10.5
Administration Complex						
Admin. Building; LED	$399,860	$68,923	-$73,943	27%	$190,162	3.7

EEM Locations and Description	Lifecycle Gross Savings	Avoided Costs	Net EEM Cost	IRR Lifetime	NPV	Simple Payback (years)
Maintenance Office; LED and HVAC	$9,864	$1,088	-$3,473	16%	$3,445	5.7
Large Warehouse; LED and HVAC	$56,540	$12,132	-$22,337	17%	$24,488	6.3
Laboratories 1-4; LED	$149,583	$32,245	-$48,300	14%	$51,292	6.5
Lab Building. 5-6; LED	$89,293	$17,498	-$29,373	14%	$30,099	6.6
Farmers Market Complex						
FMC Blg.6 Lab Newer Building	**No recommendations**; has LED lights and controls; EUI of 92 kBtu/ft²/y qualifies for "best practice" at 10th percentile of other labs.					
FMC Blg.7 Office Newer Building.	**No recommendations**, Building meets current code with LED lights and controls. Low priority since tenant space use remains unknown.					

Table 2 shows a prioritized table based on the most cost-effective package of EEM combined with on-site solar PV. The Low cost of utility energy as well as unsuitable site locations were the primary causes of poor solar financial benefits. Some sites have suitable location for solar, but perhaps very low energy costs. Such sites could still be considered for demonstration of long-term sustainability efforts.

Table 2: EEM With Solar PV Economic Analysis Estimates Example.

Measure Locations and Description	Lifecycle Gross Savings	Avoided Costs	Net EEM Cost	IRR Lifetime	NPV	Simple Payback (years)
Agricultural Office and Test Lab						
Poor PV economics due to low utility cost of energy $0.049/kWh and less than ideal available PV orientation.						
AOTL Buildings EEM & PV	$207,252	$20,802	-$166,275	1.6%	-$38,917	20.0
Forestry Office and Community Complex						
Low utility cost of energy results in poor PV financial benefit. ($0.029/kWh & $9.30/kW)						
Conference Center EEM+PV	$121,724	$9,359	-$142,000	-1.4%	-$67,873	27.4
Forestry Office EEM+PV	$67,064	$9,195	-$75,125	-0.5%	-$27,284	23.9
Ext. Office & Ag. Center EEM & PV	Lighting retrofit already underway; Site not ideal for solar PV					
Administration Complex						
Different utility rates on site; GSD $0.062/kWh & $15.50/kW; GSND $0.101/kWh)						
Admin. Building EEM & PV	$668,215	$68,923	-$273,943	9%	$146,585	9.5
Admin. Maintenance Office EEM & PV ($0.101/kWh)	$39,457	$1,088	-$19,473	6.1%	$4,462	12.2

Large Warehouse EEM & PV	$174,628	$12,132	-$108,337	4.7%	$7,243	14.5
Labs 1-4 (Pods 1&2) EEM & ground PV	$449,255	$32,245	-$266,300	4.3%	$7,765	15.2
Farmers Market Complex						
Utility rate is $0.120/kWh						
FMC Blg.6 Lab Newer Building	Solar PV not feasible due to inadequate space.					
FMC Blg.7 Office Newer Building Solar PV	$180,185	$0	-$72,000	7.3%	$30,634	12.0

Table 2: EEM With Solar PV Economic Analysis Estimates Example.

Resources and References Organized by Topic

Benchmarking Assistance

"Benchmark Your Building With Portfolio Manager" U.S. Environmental Protection Agency.
https://www.energystar.gov/buildings/benchmark

"Zero Energy Commercial Building Targets" Carbonnier, Kevin. New Buildings Institute. Sept. 2019. Table 3 pg.8 https://newbuildings.org/wp-content/uploads/2019/09/ZeroEnergyPerformanceTargetsVariousBuildingTypesClimateZonesTable.pdfhttps://newbuildings.org/ZeroEnergyTargetsTable.pdf .

Building Emissions Calculator

"ENERGY STAR Portfolio Manager Building Emissions Calculator" online at
https://www.energystar.gov/buildings/resources-topic/energy-star-portfolio-manager-building-emissions-calculator

Energy Audit Procedure and Guidance

*"*Procedures for Commercial Building Energy Audits Second Edition*"* American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA. 2011.
Purchase copy at: https://www.ashrae.org/technical-resources/bookstore/procedures-for-commercial-building-energy-audits

ASHRAE Standard 211
https://www.techstreet.com/standards/ashrae-211-2018?product_id=2016437
Standard for energy audits provides a more tightly defined scope and consistent reporting requirements for energy audits. Standard 211 is used by cities around the U.S., and agencies procuring services, to set the scope for energy audits

Supplemental energy audit forms and templates geared for the energy auditor but offers checklists that can help prepare site manager for types of information or questions the auditor may need. Available at www.ashrae.org/PCBEA.

"A Guide to Energy Audits by PNNL US DOE". By M. Baechler and C. Strecker and J. Shafer. PNNL-20956 Pacific Northwest National Laboratory, Richland, Washington. Prepared for U.S. Department of Energy. Sept. 25, 2011.
https://pnnl.gov/main/publications/PNNL-20956.pdf
Or at
https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwj91JLGqoWCAxUsEFkFHR6oArMQFnoECDQQAQ&url=https%3A%2F%2Fwww.pnnl.gov%2Fmain%2Fpublications%2Fexternal%2Ftechnical_reports%2FPNNL-20956.pdf&usg=AOvVaw1iOzkgvh7z9tefTJigyrwA&opi=89978449

"Energy Savings Toolbox –An Energy Audit Manual and Tool"
By Natural Resources Canada, Ottawa, Canada. 277p. Catalogue number M144-101/2008E-PDF.
https://publications.gc.ca/site/eng/9.856168/publication.html *This is a comprehensive document and links to excel sheets covering energy audit process intro, prepare, step by step, types of systems, survey checklists, instruments to use to measure several things (light, power, airflow, T&RH, leak detect, tachometer).*

Kelsey, J. 2021. “Your Guide to Level 1, 2, & 3 Commercial Energy Audits: Differences Between Cost & Content”. KW Engineering June 18, 2021 online post. https://kw-engineering.com/guide-energy-audit-level-1-2-3-commercial-building-differences-cost-content/

Energy Management Program Guidance

“Guidelines for Energy Management” U.S. Environmental Protection Agency. Sept. 2021. 43 p. https://www.energystar.gov/buildings/tools-and-resources/energy-star-guidelines-energy-management

Finding an Energy Auditor or ESCO

“How to hire a commercial building energy auditor?” By Peter Polland. Sept. 7, 2018. Online post kW Engineering, Inc.
https://kw-engineering.com/hire-energy-audit-auditor/

U.S. Department of Energy Qualified List of Energy Service Companies. Online page date March 26, 2024. https://www.energy.gov/femp/energy-service-companies.

Funding Opportunities for State & Local Government Entities

USDA Rural Development, Energy Programs:
https://www.rd.usda.gov/programs-services/energy-programs

USDA Rural Development, Electric Infrastructure Loan & Loan Guarantee Program:
https://www.rd.usda.gov/programs-services/electric-programs/electric-infrastructure-loan-loan-guarantee-program

U.S. Department of Energy, Clean Energy Infrastructure Funding Opportunity Exchange
https://infrastructure-exchange.energy.gov/Default.aspx#FoaId7397f57a-df4f-4974-875a-bd7f3b0de785
Search terms "local government"

Measurement and Verification (M&V)

“Advanced Energy Retrofit Guide, Practical Ways to Improve Energy Performance, Office Buildings” buildings PNNL-20761 by PNNL September 2011 Prepared for U.S. Dept. of Energy, Energy Efficiency & Renewable Energy. 199 p. See chapter 6 (p87-97)
Link for Office, as well as retail, grocery, k-12, and healthcare guides at:
https://www.energy.gov/eere/buildings/advanced-energy-retrofit-guides

“Improving Energy Efficiency through Commissioning: Getting Started with Commissioning, Monitoring, and Maintaining Performance”. Parrish, K., J. Granderson, A. Mercado, and P. Mathew. LBNL-6495E. Lawrence Berkeley National Laboratory. Oct 2013 https://eta.lbl.gov/publications/improving-energy-efficiency-through.

Reducing Energy in Commercial Buildings

“Advanced Energy Retrofit Guide, Practical Ways to Improve Energy Performance, Office Buildings” buildings PNNL-20761 by PNNL September 2011 Prepared for U.S. Dept. of Energy, Energy Efficiency & Renewable Energy. 199 p.
Link for Office, as well as retail, grocery, k-12, and healthcare guides at:

https://www.energy.gov/eere/buildings/advanced-energy-retrofit-guides

ASHRAE Advanced Energy Design Guides Office buildings 50% energy savings compared to base code ASHRAE 90.1-2004. Applies to office buildings up to 100,000 ft2.
"Advanced Energy Design Guide for Small to Medium Office Buildings, Achieving 50% Energy Savings Toward a Net Zero Energy Building." Developed by American Society of Heating, Refrigerating, and Air-Conditioning Engineers, The American Institute of Architects, Illuminating Engineering Society of North America, U.S. Green Building Council, U.S. Department of Energy. ASHRAE Atlanta, GA. 2014. 236 p.
(Note: Climate specific recommendations: CZ1 p82-83; CZ2 p 85-86. (LPD would be lower than 0.75 now and SEER higher than 15.0 (<65kbtu), heat 9.0 HSPF)).
Free from ASHRAE available through links at:
https://www.energy.gov/eere/buildings/advanced-energy-design-guides
https://www.ashrae.org/technical-resources/aedgs/50-percent-aedg-free-download

ENERGY STAR® Websites to help consumers select energy efficient products.
https://www.energystar.gov/productfinder/?s=mega
Selecting LED bulbs: https://www.energystar.gov/products/choose_a_light .
Selecting data center equipment https://www.energystar.gov/products/data_center_equipment .