CSCU

CONNECTICUT STATE COLLEGES & UNIVERSITIES
ENERGY MASTER PLAN

AUGUST 2017

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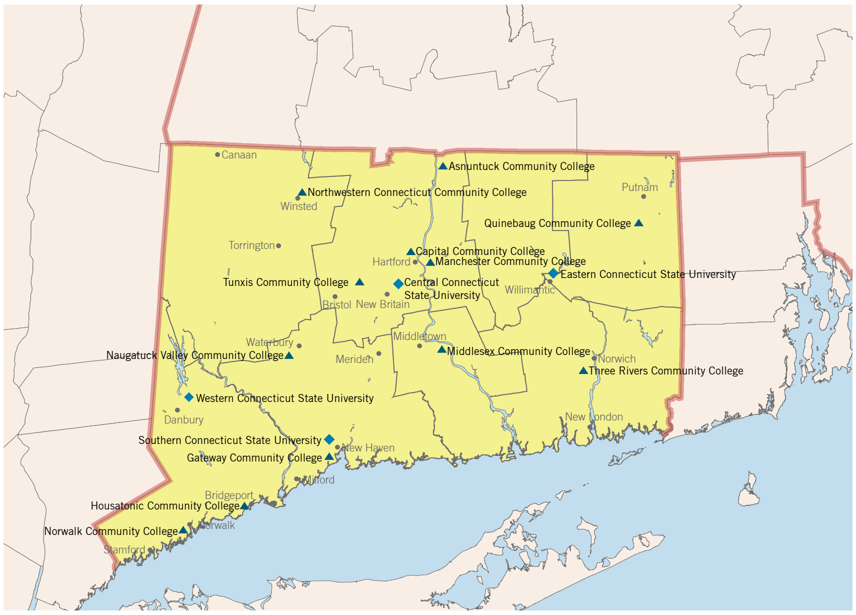

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CONNECTICUT STATE COLLEGES & UNIVERSITIES
ENERGY MASTER PLAN

AUGUST 2017

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

1.1 INTRODUCTION

As part of a larger, system-wide Master Plan updates, Connecticut State Colleges & Universities (CSCU) embarked on this Energy Master Plan (plan) to create a strategic framework for the CSCU System's (System) energy management and energy reduction efforts. The plan documents existing energy use, energy management practices, and energy reduction initiatives and provides a comprehensive path forward for the System and CSCU campuses to take advantage of identified energy reduction opportunities and best management practices. The plan includes recommendations from a system-wide perspective in Chapters 1-5, as well as specific energy efficiency measure (EEM) recommendations in each campus chapter (Chapters 6.1 - 6.16).

CSCU GOALS AND OBJECTIVES

PURPOSE

The purpose of the Energy Master Plan was to conduct an assessment of CSCU's energy practices and develop an energy management strategy to reduce energy use and efficiently manage energy in the short and long-term. The largest priority for the campuses was cost savings, followed by promoting sustainability and climate change mitigation through projects that would reduce or curb greenhouse gas.

The Energy Master Plan approach was based on five proactive principles:

1. Collaborate with campus stakeholders
2. Understand and optimize energy spending.
3. Develop sustainable energy conservation programs and principals to reduce greenhouse gas emissions.
4. Continuously develop operational improvements and building management practices
5. Integrate and disseminate information regarding energy cost and energy consumption as tools to drive a managed energy program.

METHODOLOGY

Perkins + Will and Woodard & Curran initiated the project in November 2015. The team provided a preliminary energy survey and data request to representatives from each of the 16 participating campuses, which comprised the Energy Master Plan Steering Committee. All of the CSCU campuses, with the exception of Charter Oak State College, were involved in this Energy Master Plan. The survey and request intended to gather information about current energy management practices, and goals prior to the kickoff meeting.

In order to gain an understanding of each campus energy program, the team engaged with the campus stakeholders via data requests, steering committee meetings, and two to three in-person visits, depending on campus size. The first campus visits occurred between December and February 2016 and consisted of gathering a baseline knowledge of campus energy management, current practices and existing conditions. After reviewing data, the teams returned for a second site visit between April and May 2016 with a focus on reviewing energy benchmarking, locating possible renewable energy/ solar photovoltaic opportunities, and exploring other building-level/architecture-based EEMs.

Energy consumption data (FY14 and FY 15) and information from interviews was processed and benchmarked. The understanding gained led to specific focus areas that were explored and allowed strategic recommendations to be developed. Each focus area formed the basis of the overall System recommendations. The focus areas are outlined below.

- Energy Use Intensity Benchmarking- Energy use data was compiled in order to benchmark the campuses using Energy Use Intensity (EUI), a measure of annual energy use per gross square foot. Benchmarking campuses and buildings helped to identify opportunities for improvement and associated energy savings.

- Renewable Energy – Solar photovoltaic (solar panels) opportunities were the primary focus of identifying feasible renewable energy projects. The assessment consisted of examining roof size, ground space and shading for rooftop solar, solar on parking garages or canopies and ground-mount. Other potential opportunities such as wind energy depending on wind speed at each site were investigated. Renewable energy provides benefits of local generation, decreased emissions and cost savings. In particular, power purchase agreement (PPA) contracts, can be an attractive arrangement. A typical structure of a PPA is one in which a third party owns, operates and installs the renewable energy equipment, and sells the electricity at a lower price to the entity hosting the panels over a certain term. This can be attractive to CSCU as it provides long term price assurance without having to maintain the equipment.
- Cogeneration – Cogeneration, also known as Combined Heat & Power (CHP) or in some cases tri-generation, is a means of using a fuel source, often natural gas, to create electricity and hot water or steam simultaneously (Figure ES-1). This enables a more efficient use of fuel rather than separate generation by a boiler and power plant, for instance. For this focus area, cogeneration opportunities were explored by identifying campuses with centralized heating systems, high energy costs and a need for thermal energy across the year. Cogeneration is most suitable when there is a year round need for electricity and heat production such as for space heating or domestic hot water.

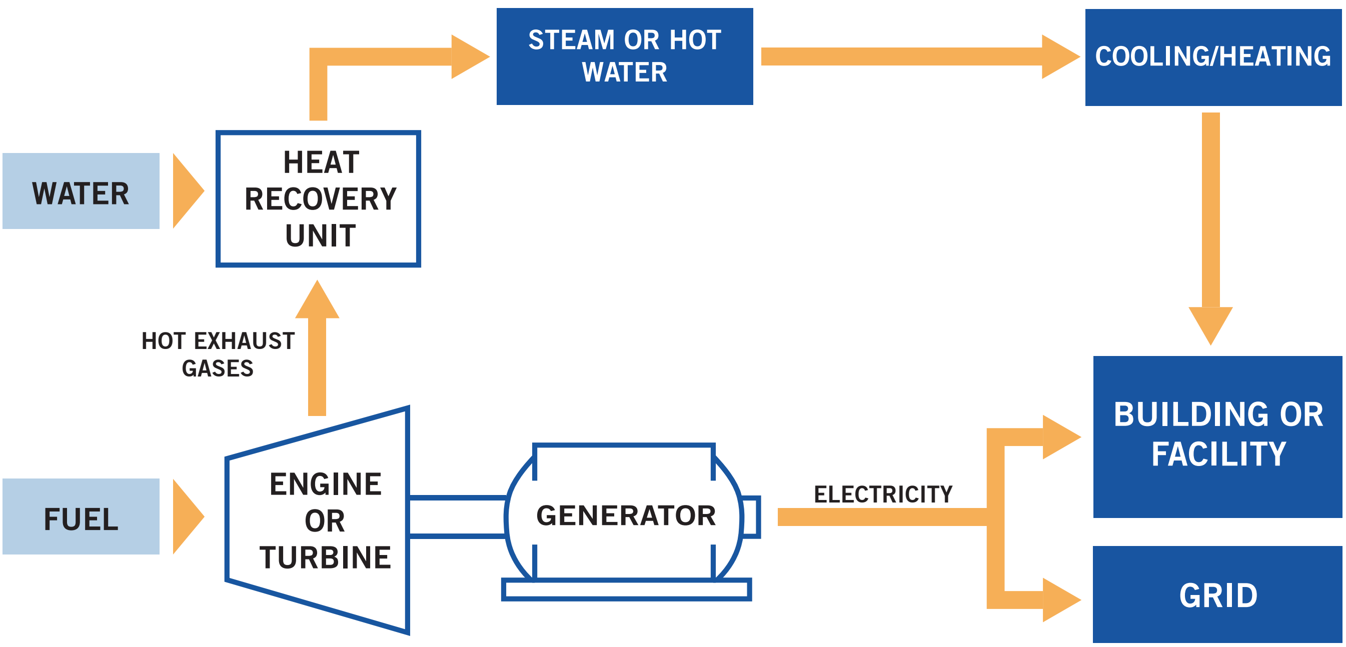


FIGURE ES-1: Cogeneration Schematic (Source: U.S. EPA – Combined Heat and Power Partnership

- Design Standards and Operating Policies – Reviewed existing policies, standards and operations & maintenance practices and existing commissioning practices for programmatic improvements. Building commissioning is an intensive quality assurance process that ensures the building operates as intended and building staff are sufficiently prepared to operate and maintain its systems and equipment. Existing Building Commissioning (EBCx) can either be retro-commissioning, where the building has never been commissioned in the first place, or re-commissioned, where the existing building has been previously commissioned. Commissioning leads to effective maintenance and continued use of equipment for its designated purpose.
- Energy Procurement- Examined campus total energy expenditures, energy suppliers and contracts including contract deadlines and contract structure. The review was conducted to identify potential saving opportunities by negotiating different contract types. Energy Funding and Financing - Identified funding/ financing mechanisms and programs available for future use to implement EEMs.The Steering Committee participated in a total of seven different teleconferences to discuss updates, recommendations and to provide input. Monthly meetings were also held with a smaller group including the CSCU System Office, Perkins +Will and Woodard & Curran.

Conference calls were held with each campus for a facilitated review of key findings. A closing Steering Committee meeting was held on November 11, 2016 to review the final findings and future direction.

KICK-OFF

TARGETED ENERGY AUDITS (SITE VISITS)

BENCHMARKING

SECOND SITE VISIT

ESTABLISHED STRATEGIC RECOMMENDATIONS

FACILITATED REVIEW OF KEY FINDINGS WITH CAMPUS REPRESENTATIVES

DRAFT ENERGY MASTER PLAN

FINAL ENERGY MASTER PLAN

1.2 ENERGY USE

To compare and measure energy for the campuses, EUI was used. EUI is a benchmarking metric based on energy use in kBtu per building area in gross square foot.

$$EUI = \frac{\text{Energy Use (kBtu)}}{\text{Gross Area (ft}^2\text{)}}$$

EUI allows a comparison of total energy use based on square footage and shows the energy efficiency of a particular space. Depending on building function, energy use intensity tends to vary; for instance, cafeterias and laboratory functions tend to be more energy intensive. Therefore, EUI is not meant as a direct comparison across campuses. EUI was reviewed on a campus level based on FY 14 and FY15, as well as at the building level, when data was available to allow for building level analysis. The EUI was compared to the EUI of the Northeast College/University type using the Department of Energy's (DOE) Building Performance Database. The Northeast College/ University median site EUI is 104.

Figure ES-2 summarizes the FY14 site and source EUIs for the CSCU campuses. Site EUI refers to energy consumed by building systems, not taking into consideration the additional energy needed to transmit and transport the energy commodities to the actual site. Source EUI takes into consideration transmission of energy through powerlines for electricity or piping losses for natural gas. Buildings/campuses supplied with local energy generation, such as with cogeneration or solar photovoltaic power, may have lower source EUIs, as there are less losses in comparison to being supplied by a utility. Electricity from utilities in the northeast for example requires approximately 3 units of energy for every one unit finally delivered to the customer.

Site EUIs range from as low as 64 kBtu/sf to 180 kBtu/sf, with half of the campuses with a lower EUI than the Northeast median site EUI. Source EUIs ranged from 129 kBtu/sf to 270 kBtu/sf. Energy use is further examined in individual campus chapter plans.

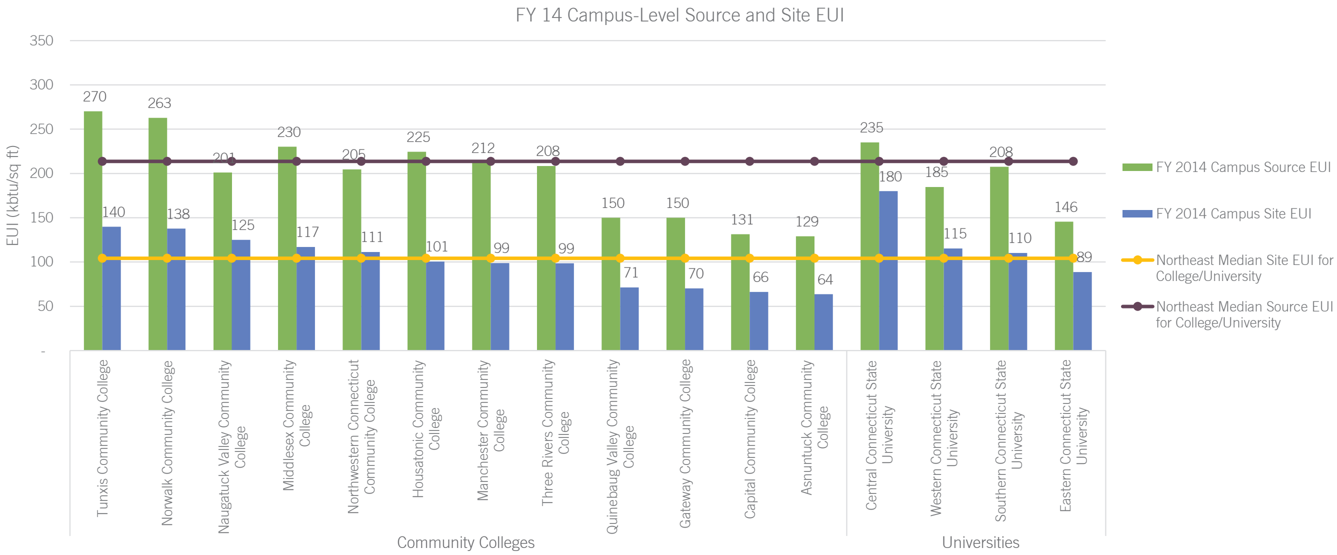


FIGURE ES-2: FY 14 Campus-Level Source and Site EUI

Note: Central largely relies on natural gas for cogeneration, its fuel cell as well as its central boilers. The use of natural gas contributed to a higher EUI in FY 14, but the campus benefits from a proportionally lower source EUI, as a portion of the campus' electricity/heat is generated onsite.

In the campus specific chapters, benchmarking at building levels helps to identify outliers and subsequent energy reduction recommendations.

Targeted recommendations depended on understanding the amount spent on total campus energy on an annual basis. In FY 2014, the CSCU campuses collectively paid roughly $27 million in energy commodities (Figure ES-3). Approximately 65% of the spending, at around $17.5 million, is attributed to electricity spending followed by natural gas. Energy spending for power purchase agreements for fuel cells, a CSCU initiative to create local electricity and thermal generation, is approximately $1.5 million annually. Fuel cells, another form of cogeneration, are located at Eastern Connecticut State University, Central Connecticut State University and Western Connecticut State University. In FY 2014 the fuel cells produced over 17,000 MWh in electricity, as well as the added benefit of savings from heat generation.

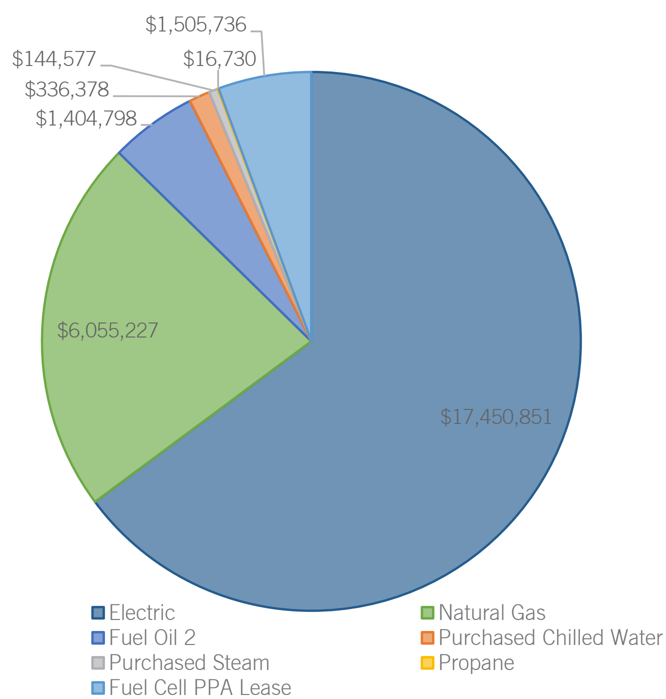


FIGURE ES-3: FY 2014 Total CSCU Campuses Energy Commodity Costs

1.3 RECOMMENDATIONS

A system-wide energy strategy was developed from the data gathered and an understanding of the current CSCU energy program. Figure ES-5 displays a recommended energy management approach and aspirational goals to reduce energy in the short and long term. The initial five-year goals involve reducing each campus' energy intensity that is above the Northeast median EUI to at least 104 kBtu/sf. These goals are not intended to be absolute or required

The aspirational Energy Master Plan goals provide targets to strive for which the planning team believes are attainable through the implementation of the EEMs recommended in each individual chapters. [1]

CSCU will gain value in formalizing an energy management structure. First priority projects include activities which set the framework for energy management in the future, such as robust System Office management strategies.

Longer term goals relate to implementing projects. The prioritization approach will leverage modest investment for high priority projects that produce significant savings on an annual basis. Savings from this approach will exceed investment in the long-term and establish a sustainable funding source for implementing and championing projects. Table ES-1 provides additional details on the programmatic recommendations represented in Figure ES-4 including further prioritization (priority 1, 2 or 3) of initiatives and projects to complete. The table includes an overview of the recommendation, the main action as well as the intended result.

SUMMARY	TODAY		5-YEAR GOAL
AVERAGE ENERGY USE INTENSITY (ANNUAL)			
UNIVERSITIES	**125** kBtu/SF	→	**104** kBtu/SF
COMMUNITY COLLEGES	**100** kBtu/SF	→	**90** kBtu/SF

PRIORITY 1

- DEVELOP PROCUREMENT APPROACHES
- CREATION OF FUNDING STRUCTURE
- ENERGY MANAGER / SUPPORT FOR DATA MANAGEMENT
- DATA MANAGEMENT AND MONITORING
- CREATION OF STEERING COMMITTEE
- • POLICIES
  • POWER PURCHASE AGREEMENTS
  • EEM PROJECTS WITH 1 YEAR ROI
- IMPLEMENTATION OF REVOLVING FUND

PRIORITY 2

- COGENERATION
- ENERGY PROJECT DATABASE
- TEMPERATURE GUIDE
- PROJECTS WITH PAYBACK GREATER THAN 1 YEAR

PRIORITY 3

- METERING

CSCU ACTION CAMPUS ACTION CSCU + CAMPUS ACTION

FIGURE ES-4: CSCU ENERGY MASTER PLAN ROADMAP

[1] Given the EMP energy reduction goals, it is estimated there is opportunity to achieve cost avoidance of approximately $4.5 million in the 5-year timespan. Assumed strategies for achieving cost savings include: EUI savings resulting from campuses implementing recommended EEM projects, solar PV PPA savings, electricity and natural gas procurement savings, capturing on-going incentives like Renewable Energy Credits (RECs) and capacity management savings. Actual energy cost savings must be considered with other capital expenses, budgets and operational priorities.

Recommendation Type	Main Action	Intended Result	Priority
Energy Procurement	After current procurement contract, explore layered fixed pricing or shorter term contracts. Rather than choosing a bulk purchase at a fixed price over a set time period as CSCU has done in the past, layered fixed pricing allows the customer to purchase percentages or layers of energy at varying times.	Contract diversity for greater savings. Buying smaller percentages of energy can provide more flexibility enabling the customer to enter the market at different times to take advantage of possible lower prices.	1
Clarify Funding and Financing Pathway	Create formal project funding plan for energy conservation projects implemented at the campuses, identify partnerships and continuously monitor opportunities.	Streamline project implementation and match funding with project type.	1
Green Revolving Fund	Establish revolving fund structure for energy conservation projects. This concept would use the cost savings achieved from completing energy conservation projects to fund future conservation projects.	Reinvests savings to fund additional energy projects and help campuses fund energy conservation projects they might not be able to fund in their own budgets. This will help alleviate some of the lack of resources at the campus level.	1
Energy Manager Role	Develop an energy manager role responsible for system-wide energy tracking, energy procurement oversight and involvement in capital projects, and additional responsibilities.	Centralize energy management and continuously identify and implement opportunities for energy conservation and cost savings.	1
Data Tracking and Benchmarking	Create one data tracking spreadsheet/ platform for campuses to report. Monitor energy use including EUI and $/GSF	More efficient tracking and continuous understanding of energy use and costs.	1
Energy Committee	Form an Energy Committee including a representative from each campus familiar with energy endeavors.	Facilitate information sharing to promote best practices.	1
Collaboration Across Campus Departments	Establish regular meetings or include energy into regularly scheduled business conversations.	Promotes energy reduction priorities in campus culture.	1
Leverage Lighting Upgrades	Re-evaluate lighting opportunities every five years and pursue opportunities with a less than 5-year payback with utility incentives.	Electricity savings, and decreases payback for other projects in utility programs, when paired with projects in that tend to have a longer payback.	1
Commissioning Policy or Standards, Energy Design Standards and Revision of Existing Standards	Create a policy including training in preventative maintenance for staff, recommissioning of existing buildings at minimum every 5 years and other guidelines.	Ensures proper close out of projects and saves time and capital compared to projects that are not properly commissioned the first time.	1
Solar Photovoltaic Opportunities	System Office to continue to arbitrate RFP solar process and pursue solar PV opportunities.	Cost savings, localized generation of power, and greenhouse gas reductions.	1
Lifecycle Cost Assessment for Energy Projects	Conduct lifecycle analysis for capital projects and conduct feasibility studies for costly projects.	Clarifies realistic return on investment for energy projects to better inform project feasibility.	1
Occupancy Standards	Provide guidelines of use of existing space.	Saves energy through class consolidation and reduction of energy from building systems in unoccupied spaces	1
Energy Audits	Creation of guideline for energy audits at all buildings older than 2005.	Prioritizes energy and cost saving opportunities.	2
Cogeneration	Periodic reassessment of combined heat and power opportunities.	Cost savings, and localized generation of heat and power.	2
Energy Project Database	Creation of a uniform project tracking platform to track projects, timelines, payback and information on exceptional vendors.	Creates awareness of project opportunities and promotes best practices.	2
Temperature Guide	Outline temperature setpoints by space type, with occupant comfort and energy efficiency in mind.	Energy savings.	2
Metering	Energy submetering at all buildings, where possible.	Easier identification of energy problems and prioritization of capital investments.	3

TABLE ES-1: System-wide Recommendations

CAMPUS SPECIFIC RECOMMENDATIONS

While the System can provide overall direction for the campuses, many of the actionable energy reduction measures must happen on the campus level. There were several common opportunities for each of the campuses. The sections below describe each of the common recommendations, and benefits to the campuses. Each chapter further specifies the categories and recommendation types as applicable to the specific campuses.

HVAC AIR SIDE

HVAC air side is a term summarizing air distribution from building systems for heating or cooling. Figure ES-5 lists example HVAC air side recommendations and the number of opportunities represented at the campuses. For example, installation of demand control ventilation (DCV), a means to monitor carbon dioxide and reduce air exchange in spaces, was a common recommendation. The action helps to save fan, cooling and heating energy year round. Fume hood recommendations followed as the most frequent HVAC air side recommendation, since the lab equipment can often exhaust conditioned air unnecessarily. By implementing training programs to close unused hoods or installing variable frequency drives (VFDs), the campuses with fume hoods can reduce air flow and associated costs.

DCV - Demand Control Ventilation: A programmed system connected to ventilation fans used to reduce unnecessary airflow saving electrical energy for the fan motor, and preventing valuable heat or cool air from escaping.

DDC - Direct Digital Control: Electronic/digital controls that are more efficient than HVAC systems controlled pneumatically (with air pressure).

EBCx - Existing Building Commissioning: A tune up requiring monitoring of the building system to provide energy saving adjustments. Includes optimization of existing equipment or building functions, through improved quality assurance or operation and maintenance measures.

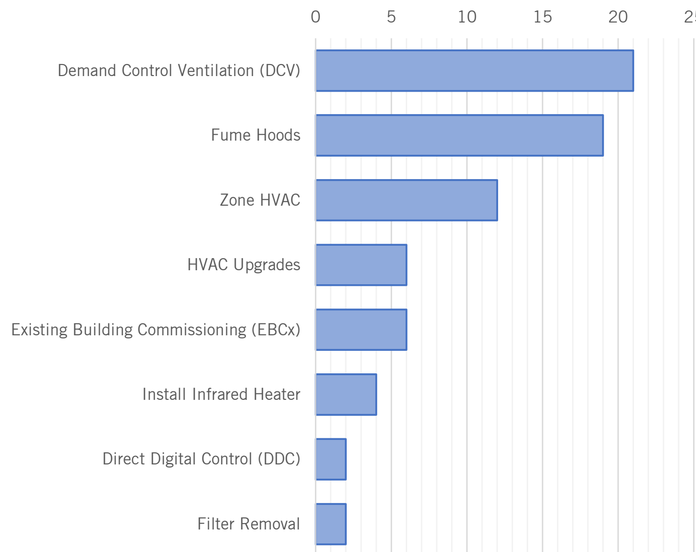


FIGURE ES-5: HVAC Air-Side System-Wide Opportunities

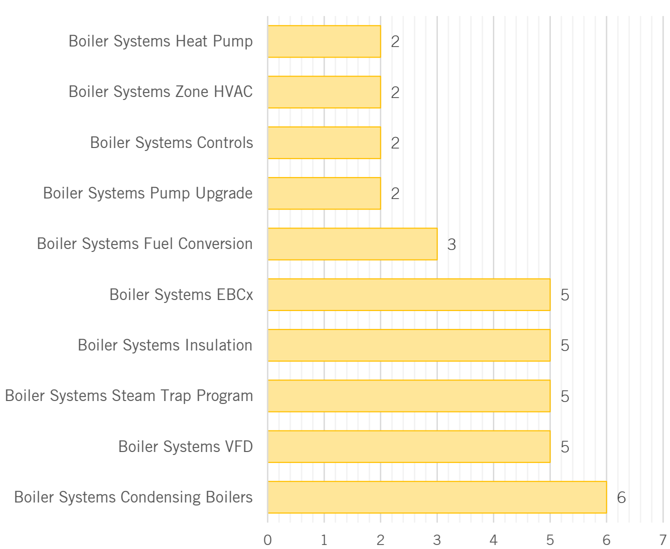


FIGURE ES-6: Boiler System System-Wide Recommendations

BOILER SYSTEM

Another frequent EEM category related to boiler system upgrades to improve efficiency and reduce fuel costs. Figure ES-6 lists recommendations and the number of opportunities across the campuses.

VFD - Variable Frequency Drive: Electronic means to slow motors down to save energy instead of running the motor at one speed only.

EBCx - Existing Building Commissioning: A tune up requiring monitoring of the building system to provide energy saving adjustments. Includes optimization of existing equipment or building functions, through improved quality assurance or operation and maintenance measures.

LIGHTING

The type of lighting across the campuses varied; many campuses have been proactively upgrading existing lighting indoors as well as on building exteriors and parking lots. Lighting upgrade opportunities generally have quick payback with utility incentives. Figure ES-7 provides the recommendations categories, with the majority related to replacing existing lighting with LEDs.

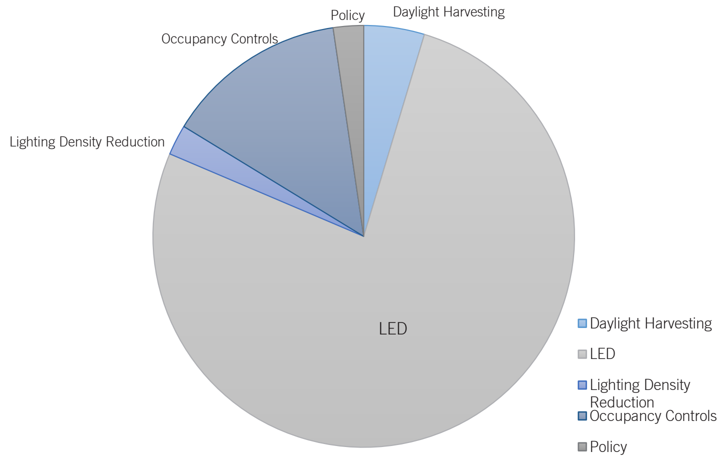


FIGURE ES-7: Lighting System-Wide Recommendations Categories

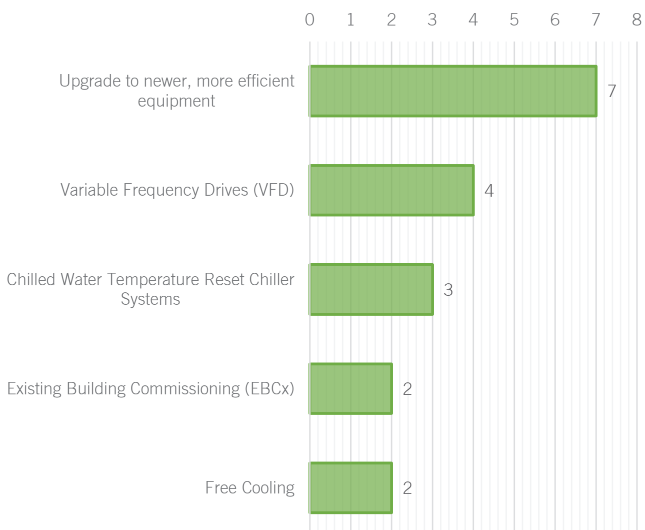


FIGURE ES-8: System-Wide Chiller Recommendations

CHILLER SYSTEMS: There were opportunities on campuses to optimize chiller system use with the addition of variable frequency drives, upgrading existing chillers, and adjusting temperature set points for savings.

Figure ES-8 displays chiller recommendation types and frequencies.

Free Cooling- Free Cooling takes the major energy mover (compressors) out of the loop when the outdoor wet bulb temperature (often less than ambient) is cooler than the indoor temperature and there is a cooling demand in the building. Most cooling systems use energy in the form of electricity (for compressors) to move energy from one place to another.

EBCx- Existing Building Commissioning: A tune up requiring monitoring of the building system to provide energy saving adjustments. Includes optimization of existing equipment or building functions, through improved quality assurance or operation and maintenance measures.

Building Envelope: Campus age and building types varied, some with more modern buildings and others with many older buildings dating back to the early 1900s. Depending on building age and structure, there were common opportunities for increased insulation, air sealing, and some window replacements to help reduce heating costs and energy loss.

Building Management System (BMS)/Building Automation System (BAS): Broadly, each campus has opportunities for building management system utilization and upgrades to better manage data and building systems. Continued education and training on the functionalities of BMSs is important.

Chiller Systems: There were opportunities on campuses to optimize chiller system use with the addition of variable frequency drives, upgrading existing chillers, and adjusting temperature set points for savings.

Renewable Energy: Solar PV provides the opportunity for local generation at a fixed electricity cost through a PPA, making it a common EEM, given available space on campus. Additional strategies include exploring offsite renewable energy, virtual net metering and available incentives programs like the state's Zero Emission Renewable Energy Credits (ZRECs).

Cogeneration: Opportunities for cogeneration were established mainly for the Universities as they tended to have the most use for thermal energy in the summer due to residence halls and other year round activities. In addition, strategies were developed to optimize existing cogeneration by running the units more when feasible. Financial incentives were also taken into consideration such as by monetizing Renewable Energy Credits, and using cogeneration as an instrument to reduce demand charges.

Figure ES-10 summarizes the recommended EEMs at each campus by the various categories.

NAME	BAS/BMS	BOILER SYSTEM	BUILDING ENVELOPE	CHILLER SYSTEM	COGENERATION	HVAC AIR SIDE	LIGHTING	RENEWABLE ENERGY
COMMUNITY COLLEGES								
ASNUNTUCK	Low	Medium	Low	Low		Low	Low	
CAPITAL	Low	Low				Medium	Low	
GATEWAY	Medium	Medium		Low		High		Low
HOUSATONIC	Low	Low				Medium	Medium	Low
MANCHESTER	Low	Medium	Low	Medium		High	Low	Low
MIDDLESEX	Low	Low	Low			Low	Medium	Medium
NAUGATUCK VALLEY	Low	Medium	Low	Low		Medium	Medium	
NORTHWESTERN CONN.	Low	Medium	Medium	Low		Low	Low	
NORWALK	Medium	Low		Medium			Low	Low
QUINEBAUG VALLEY	Medium	Low				Low	Low	Low
THREE RIVERS	Medium	Low				Low	Low	
TUNXIS	Low	Medium	Low	Medium		Low	Low	
UNIVERSITIES								
CENTRAL	Medium	Low		Low	Low	High	High	Low
EASTERN		Medium	High	Low	Low	Medium	Medium	Low
SOUTHERN	Low	Medium	Low	Medium	Low	Medium	Medium	Low
WESTERN	Medium	Medium			Low		Low	Medium

Legend:	Low	Low frequency, 1 to 2 Recommendations	Medium	Medium frequency, 3-6 Recommendations	High	High frequency, 7 or more Recommendations

TABLE ES-2: Summary of Campus-Specific Recommendation Types

SUMMARY

The CSCU campuses are diverse in program offerings, student enrollment and resulting energy needs. While each is unique, the campuses have made concerted efforts to creatively manage existing energy programs through efficient use of operating budgets and other funding opportunities. Many campuses have been active in implementing energy efficiency measures, such as HVAC upgrades, conversion of existing lighting to LED and building envelope upgrades. Much of this work has been done in conjunction with building or enhancing a culture of sustainability. From a system-level, CSCU has promoted energy reductions and local generation through fuel cell initiatives, bundled procurement and solar PPAs.

The Energy Master Plan outlines strategies to realize increased reduction in energy use among the campuses, through a system-wide energy management program. Working together as a system to focus resources through the recommendations will help to optimize efforts and achieve greater benefit, for instance:

- Creating a Green Revolving Fund (GRF) will help expand funding opportunities and reallocate initial payback savings into future energy reduction projects
- Working collaboratively with utility companies and other energy partners will increase potential for alternative funding sources
- Working towards a centralized energy management role will provide added capabilities for the campuses to access, through system level support.
- Creating and updating of standards and guides like commissioning policies and lifecycle cost assessments will provide tools to streamline energy project procedural issues.
- Completing energy savings/reduction projects with short paybacks and focusing longer term on more complicated efforts with longer paybacks.

Through collaborative efforts, information sharing and innovative programs, CSCU can strengthen and transform its existing energy program to elevate savings and sustainability.

1

INTRODUCTION

INTRODUCTION

Connecticut State Colleges & Universities (CSCU) led the development of this Energy Master Plan as a collaborative, system-wide effort to focus on its energy management program and energy decision-making. Perkins + Will and Woodard & Curran were hired to complete the Energy Master Plan. CSCU is comprised of 12 community colleges, four universities, and Connecticut's only public online college, Charter Oak State College. All of the CSCU campuses, with the exception of Charter Oak State College, were involved in this Energy Master Plan.

1.1 GOALS & OBJECTIVES

The overall objective of the Energy Master Plan was to conduct a comprehensive evaluation of CSCU's energy program components and develop an integrated energy management strategy that will guide energy management decisions in the short and long-term. The approach to achieve this goal was based on five proactive principles:

- Collaboration with campus stakeholders to help guide, support, and prioritize energy management opportunities that are consistent with the campus goals and objectives.
- Understanding building energy performance and optimizing energy spending
  - Understanding energy spending and building energy performance allows for prioritization of future efforts helping to target opportunities for savings and leveraging existing budgets.
- Development of sustainable energy conservation programs and principals to reduce greenhouse gas emissions.
- Continuous development of operational improvements and building management practices to ensure the efficiency of energy related mechanical systems.
- Integration and dissemination of information regarding energy cost, consumption and carbon output that can be used to create and drive a managed energy program.

Based on campus feedback, the largest priority for the outcome of the Energy Master Plan was to reduce costs for more budget flexibility. This was closely followed by a motivation to reduce energy use for climate change and sustainability purposes.

1.2 PLANNING PROCESS

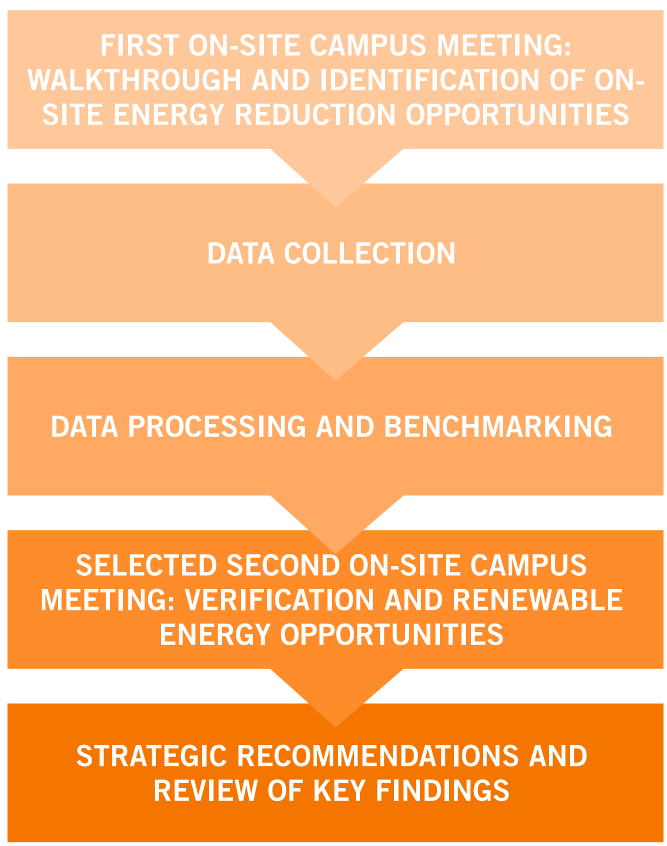
ENERGY MASTER PLAN STEERING COMMITTEE

The Energy Master Plan was guided by significant input from CSCU stakeholders, listed in the acknowledgements section of the report.

The Energy Master Plan Steering Committee included one main representative from each campus, two from the CSCU and invited Electric Utility stakeholders. The Energy Master Plan Steering Committee met on a monthly basis to provide input to the plan and review key findings. The Energy Master Plan Steering Committee members were responsible for coordinating activities for its campus, providing input into the planning process, supplying data regarding existing conditions and insights into the desired future direction of energy management. The Energy Master Plan Steering Committee was supported by multiple stakeholders across all of the CSCU campuses which provided data and participated in interviews.

ENERGY MASTER PLAN PROCESS

The steps comprising the planning process are summarized below followed by planning methodology.



INTERVIEWS AND ENERGY ASSESSMENTS

The planning process began with a project meeting summit to officially assemble the Energy Master Plan Steering Committee, solicit campus feedback on expectations and to provide high-level strategic direction for the Energy Master Plan. Data essential to the planning effort was gathered via a data request and direct engagement on the campus.

All campuses were visited once with targeted follow up completed via email and conference call or in some cases via a second campus visit. The campus visits consisted of the following:

- First Campus Visit: Meeting with Energy Master Plan Steering Committee member and/or key Facility Department or building representatives for information on the unique energy-related characteristics of the campus. The site visit included targeted walkthroughs of campus buildings.
- Second Campus Visit: The visits were conducted to verify data and energy use/management understanding. Site visits included further assessing renewable energy potential with a specific focus on solar energy, discussing cogeneration and fuel cells, if applicable, and visiting additional key campus buildings. Seven campuses received these second campus visits: Central, Eastern, Gateway, Manchester, Naugatuck, Southern, and Tunxis.

DATA PROCESSING AND BENCHMARKING

Data review and assessment occurred in concert with site visits, and consisted of reviewing FY14 and FY15 campus energy consumption data, where available, utility bills, procurement information, operating protocols and design standards. Specifically, the following energy management components were assessed:

- **Energy Use Intensity –** Compiled data in order to benchmark the campuses using Energy Use Intensity (EUI), a measure of energy per gross square feet.
- **Solar Photovoltaic (PV) Opportunities –** Examined roof size, ground space and shading for renewable energy potential.
- **Cogeneration –** Explored opportunities for cogeneration by identifying campuses with centralized heating systems, high summer thermal load and high energy costs.
- **Design Standards and Operating Policies –** Reviewed existing policies, standards, operations & maintenance practices for potential programmatic changes.
- **Energy Procurement –** Identified campus total energy spend, energy suppliers and contract types, including existing power purchase agreements for energy saving opportunities.
- **Energy Funding and Financing –** Documented funding/ financing mechanisms and programs available for future use to implement Energy Efficiency Measures (EEMs).

STRATEGIC RECOMMENDATIONS AND REVIEW OF KEY FINDINGS

Strategic recommendations were formed at a system and campus level. EEMs and projects were recommended based on review of best siting locations, business case, and other factors the universities and colleges deemed important. The last individual meeting with the campuses involved review of the campus-specific key findings. The Energy Master Plan Steering Committee was also involved in review and discussion of system-wide findings.

1.3 CSCU INTRODUCTION

Each of CSCU's institutions vary widely in its campus environment and courses of study, offering over 1,300 programs for incoming students. The Board of Regents of Higher Education governs CSCU. CSCU's strategic plan, Transform 2020, provides a roadmap for bringing together the 17 colleges and universities into one interrelated system with an overall objective of providing students an accessible and affordable education, unmatched by any other system.

The campuses are already united in the established commitment to energy conservation and sustainability. Six of the campuses have made a commitment to carbon neutrality through participation in the Second Nature Climate Leadership Commitment (formerly the American College & University Presidents' Climate Commitment) and development of climate action plans. In 2015, the commitment was expanded to include a pledge for climate resilience planning and implementation. Campuses continue to exemplify energy reduction responsibilities through a variety of campus initiatives. Existing energy conservation and renewable efforts include:

- Leadership in Energy and Environmental Design (LEED) Building Construction
- "Green" Electricity Procurement
- Energy Efficiency: LED Lighting, Re-ballasting, Increased Building Insulation, Equipment Upgrades
- Updates and construction of central heating plants
- Solar Thermal
- Solar Photovoltaic (PV)
- Fuel Cells
- Geothermal Installation

Table 1.1 provides a summary of each campus' FY 14 total floor area and student enrollment which were factored in the energy analysis.

Colleges	Existing Floor Area (GSF)	Enrollment (FTE, Fall 2013)
Asnuntuck Community College	166,636	989
Capital Community College	304,000	2,210
Gateway Community College	532,500	4,708
Housatonic Community College	355,186	2,994
Manchester Community College	473,662	4,259
Middlesex Community College	122,237	1,801
Naugatuck Valley Community College	598,276	4,194
Northwestern Connecticut Community College	184,042	817
Norwalk Community College	350,765	3,795
Quinebaug Valley Community College	143,282	1,074
Three Rivers Community College	295,644	2,628
Tunxis Community College	258,099	2,419
Universities	Existing Floor Area (GSF)	Enrollment (FTE, Fall 2013)
Central Connecticut State University	2,195,884	9,483
Eastern Connecticut State University	1,808,915	4,672
Southern Connecticut State University	2,152,440	8,684
Western Connecticut State University	1,811,803	4,896

Note: GSF does include leased spaces or parking garages, or any of the exceptions listed in Section 2.1. FY15 enrollment information is available as indicated in the text, however, the energy analysis factored energy use from FY14 and associated FY14 metrics.

TABLE 1.1: Campus Size and Enrollment

COMMUNITY COLLEGES

1.3.1 ASNUNTUCK COMMUNITY COLLEGE

Asnuntuck Community College (Asnuntuck) is a public, two-year community college that was established in 1969. The college is located just off I-91 in north-central Connecticut. Asnuntuck is one of the smallest CSCU community colleges, with student enrollment of 1,571 (as of fall 2015). Asnuntuck's campus will expand by 27,000 gross square feet (GSF) with a new Advanced Manufacturing Center.

1.3.2 CAPITAL COMMUNITY COLLEGE

Capital Community College (Capital) is a two-year, open admittance institution. Capital is Hartford's only public undergraduate institution.

In 2002, Capital relocated to Hartford's Main Street – a significant step in helping the redevelopment of the City's downtown. The campus is located in a historic 11-story former department store. As of fall 2015, enrollment was 3,517 students served by 264 faculty members, 64 of which were full-time.

1.3.3 GATEWAY COMMUNITY COLLEGE

Gateway Community College (Gateway) is a two-year public community college established in 1992. Gateway's LEED Gold, state-of-the-art main campus is located near downtown New Haven. The college also includes a second satellite campus in North Haven.

Gateway serves a student population of 14,000 and employs 387 full- and part-time faculty members. The college offers over 100 academic programs or program options that lead to either an associate degree or a certificate.

1.3.4 HOUSATONIC COMMUNITY COLLEGE

Housatonic Community College (Housatonic) is a two-year public community college located in Bridgeport, Connecticut, and is situated at the confluence of three major highways: Interstate 95 and Connecticut Routes 8 and 25. Housatonic offers 40 associates degrees in arts and sciences and 24 certificates. The college employs 198 full-time staff and faculty to serve a fall 2015 population of 5,369 students.

The campus has a 4,000 piece art collection, valued over $13M, that is free and open to the public The museum has one of the largest collections of any community college in the nation.

To meet additional space needs, a 50,000 GSF addition to Lafayette Hall is currently being constructed.

1.3.5 MANCHESTER COMMUNITY COLLEGE

Manchester Community College (Manchester) is located 15 minutes east of downtown Hartford, and is in close proximity to I-384. Fall 2015 student enrollment exceeded 6,800 students. Students have the option of pursuing an Associate Degree in art or an Associate Degree in science in over 40 disciplines, as well as completing certificates and continuing education courses.

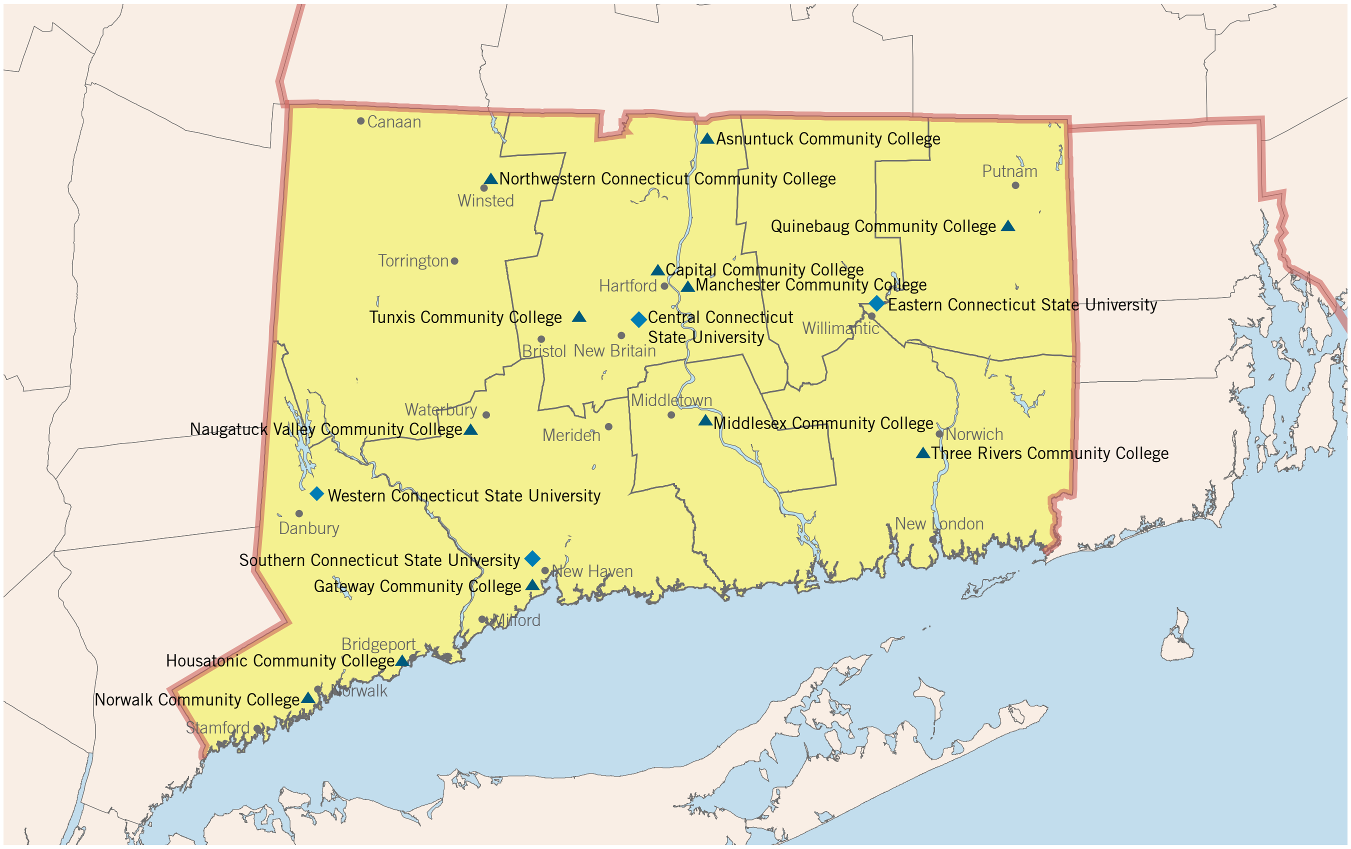


FIGURE 1.1: CSCU Colleges and Universities Locations

Manchester has received national accreditation for eight of its programs of study. Additionally, the college's middle college high school, Great Path Academy, provides education for 280 students in grades 10-12.

Manchester's campus will continue to expand in the coming years. The campus has sought bonding for a 50,000 GSF academic building to house Allied Health labs, a Child Development Center, and a Hospitality and Culinary Center.

1.3.6 MIDDLESEX COMMUNITY COLLEGE

Middlesex Community College (Middlesex) is an open admission public community college established in 1966. Middlesex has campus buildings in two locations that are about 14 miles apart in the towns of Middletown and Meriden. The college has a total enrollment of 13,267 student., and employs 125 full-time faculty members.

Middlesex offers students over 25 programs to complete their two-year associate degrees in art and science. There are plans for minor additions and renovations to Middlesex's campus to address space needs cited in Middlesex's 2014 Master Plan.

1.3.7 NAUGATUCK VALLEY COMMUNITY COLLEGE

Naugatuck Valley Community College (Naugatuck) is a public two-year college located in Waterbury. The college's fall 2015 enrollment is approximately 7,001 students who are served by 543 full and part-time faculty members. The college offers over 100 accredited programs resulting in a professional certification or associate degree, and more than 120 continuing education courses.

Students can also pursue credit programs, workforce development classes, and lifelong learning course in Naugatuck's off-site campus, the Danbury Center. Naugatuck is in the construction phase for the renovation of the oldest building on campus, Founders Hall. The 97,000 square foot building, will house Naugatuck's Allied Health and Nursing program and attain LEED Silver Accreditation.

This building was not included in the energy Master Plan as it is not currently open and is awaiting commissioning. The addition of an occupied Founders Hall and the planned replacement of their Physical Plant's heating and cooling systems is likely to change Naugatuck's current energy use pattern.

1.3.8 NORTHWESTERN CONNECTICUT COMMUNITY COLLEGE

Northwestern Connecticut Community College (Northwestern) is a two-year college founded in 1965. The college is located in Winsted and serves a primarily rural section of the state.

As of Fiscal Year (FY) 2015 Northwestern's full-time equivalent student (FTE) enrollment is the smallest of the twelve CSCU community colleges.

Northwestern is currently updating its Master Plan, which is expected to be adopted in 2017. Near-term construction projects include renovations to the exterior of Green Woods Hall and development of a new 24,000 square foot Veterinary Technology Facility to replace the Elizabeth H. Joyner Learning Center. Other potential projects include the renovation of White Building.

1.3.9 NORWALK COMMUNITY COLLEGE

Norwalk Community College (Norwalk) is a two-year college founded in 1961. Norwalk is the second largest college of the twelve Connecticut Community Colleges with a student body of 7,000 (full and part-time), served by approximately 100 full-time faculty and 260 part-time instructors.

In addition, about 5,000 students partake in Norwalk's non-credit programs annually. The college offers 45 associate degree and 26 certificate programs, including degrees such as an Associate in Arts, Associate in Science, and Associate in Applied Science Norwalk.

Norwalk is in its final phase of its Master Plan. A timeline for expansion of the West Campus has not been announced.

1.3.10 QUINEBAUG VALLEY COMMUNITY COLLEGE

Quinebaug Valley Community College, a public two-year institution with its main campus in Danielson and a satellite campus (or center) in Willimantic, serves the residents of Windham County in the northeast corner of Connecticut. Since its founding in 1971, QVCC has enabled thousands of students to earn an associate's degree or a certificate in such disciplines as accounting, business administration, computer science, early childhood education, engineering science, general studies, liberal arts and sciences, manufacturing, medical assisting, technology studies, and visual arts.

Quinebaug's campus will be altered with the addition of a new 11,000 square foot Advanced Manufacturing Technology Center. The new building's HVAC system will utilize geothermal technology.

1.3.11 THREE RIVERS COMMUNITY COLLEGE

Three Rivers Community College (Three Rivers) is a two-year community college located in Norwich. The college employs 200 full and part-time faculty, and enrolls approximately 4,500 students each semester.

Students have a choice of a wide array of course offerings including liberal arts, science, and technical courses for a total of 45 associate degree programs and 42 certificate programs.

The college also offers Nursing, Business, and Technology programs, which have special accreditations and licensing requirements.

Three Rivers underwent a major multi-phased campus expansion project, completed in 2009. The expansion has provided sufficient space needs for the campus eliminating a current need for further expansion in the coming years.

1.3.12 TUNXIS COMMUNITY COLLEGE

Tunxis Community College (Tunxis) is a two-year public college established in 1969 located in Hartford County. The college serves approximately 6,000 full and part-time students enrolled in credit and continuing education classes. Its online courses have the largest enrollment in the CSCU system. Tunxis is located in a former shopping mall and has featured several phased expansions, the most recent in 2013. Future campus changes will occur through space reorganization rather than renovations or expansions.

UNIVERSITIES

1.3.13 CENTRAL CONNECTICUT STATE UNIVERSITY

Central Connecticut State University (Central) is the largest of CSCU's four regional public universities, serving a fall 2015 student body of approximately 12,086 undergraduate and graduate students. Central is located about nine miles southwest of Hartford. Central's student body is served by 800 faculty members, half of which are full-time. The University offers an extensive range of undergraduate programs including 100 majors in more than 80 fields of study.

In the short-term, Central has plans for campus expansion through a new engineering building, and addition to its recreation center, and renovations to Willard Hall and Diloreto Hall, two of their academic and administrative buildings.

1.3.14 EASTERN CONNECTICUT STATE UNIVERSITY

Eastern Connecticut State University (Eastern) is one of four CSCU state universities and is located approximately 30 miles east of Hartford. Eastern is the state's only public liberal arts university. Eastern supported a student body of 5,261 in the fall of 2015, served by 225 faculty members.

Eastern's campus will continue to grow through renovations of existing buildings, and as a result, alter current energy use. For instance, its academic building Shafer Hall is being transitioned to a residence hall while renovations of the Communication Building is set to increase square footage to increase academic space.

1.3.15 SOUTHERN CONNECTICUT STATE UNIVERSITY

Southern Connecticut State University (Southern) is one of four CSCU state universities. The university's buildings and residence halls are located in three precincts (East, North, and West), on its main campus, located less than three miles from downtown New Haven. The university offers 45 graduate and 69 undergraduate degree programs. In 2015, Southern enrolled 10,473 graduate and undergraduate students, and employed 434 full-time faculty members.

Since 2015 there have been two major campus additions. Southern's new state-of-the art library and new Science Building have provided the campus with significant resource enhancements.

1.3.16 WESTERN CONNECTICUT STATE UNIVERSITY

Western Connecticut State University (Western) is one of CSCU's four state universities. The university is comprised of two campuses: Midtown, the main campus in Danbury, and Westside, a much larger campus located about four miles away. In the fall of 2015, Western served 5,826 students and employed 205 full-time faculty members. Western offers a total of 39 undergraduate and 17 graduate programs of study.

Western's campus will soon be home to a new LEED Silver Police building. Renovations to its Litchfield Hall residence building are also being constructed to LEED Silver standards, or equivalent and High Performance Building Standards.

1.4 PREVIOUS SYSTEM-WIDE ENERGY STUDIES AND PROJECTS

While many energy conservation and efficiency initiatives happen at the campus level, the CSCU has led targeted specific energy-saving and monitoring opportunities in the past. CSCU initiatives are highlighted in the list below:

- **Fuel Cells:** In 2012, CSCU commissioned a study to analyze the feasibility of fuel cells on each of the university campuses. As a result, fuel cells were installed at Eastern, Western and Central.
- **Procurement:** In 2013, the CSCU went out to bid for procurement of electricity and gas supply. The system purchased a three-year term of electric supply at a fixed rate. In fall of 2016, the CSCU will be conducting another reverse auction for both natural gas and electricity. This is described in more depth in the Section 2.2.
- **Capital Expenditures Benchmarking:** In 2013, the campuses underwent a benchmarking and capital planning process to assess their physical portfolio as well as their operational effectiveness. The study also looked at utility expenditures in comparison to campuses of similar size and geographic region.
- **Energy Benchmarking:** Eastern's campus is home to the Institute for Sustainable Energy (ISE), which provides energy benchmarking services to its clients. During 2016, ISE performed energy benchmarking for all 12 community college campuses, entering the data into EPA's Energy Star Portfolio Manager tool. ISE has generated reports that summarize energy and water use trends over the past few years for each of the community colleges. (Please see: http://www.easternct.edu/sustainenergy/ise-publications/).
- **Auditing:** The CSCU has been proactive in seeking energy saving opportunities through audits. In 2012, the CSCU requested funding from DCS to administer energy audits at nine community colleges. The initiative was in keeping with Connecticut's Lead By Example (LBE) Goals to reduce energy use by state agencies
- **Master Planning:** Each of the campuses are in a phased process to update their facility master plans. These plans include information on existing energy infrastructure and necessary improvements.

2 SYSTEM LEVEL EXISTING CONDITIONS

SYSTEM LEVEL EXISTING CONDITIONS

To recommend an improved energy path forward for CSCU, a thorough understanding of how the current system operates had to be established. Review of existing conditions included analysis of each campuses energy data, procurement methods and energy management practices, all included herein. Observations were also made about existing alternative energy projects, the project implementation process, and existing funding and financing methods.

2.1 FACILITY ENERGY BENCHMARKING

Energy management and identification of energy improvement opportunities starts with understanding current energy use. Energy use data and costs were reviewed for outliers and energy trends to help inform energy recommendations. A system-wide energy understanding was formed based on analyzing energy use, cost, enrollment and campus size parameters. For the CSCU campuses, the energy consumption and cost values were compiled from a variety of sources:

- Utility Bills
- Records maintained by campus staff, and
- Online utility tracking programs including Eversource's Customer Engagement Platform (CEP) and SchoolDude's Utility Direct

ENERGY CONSUMPTION TYPES

Energy consumed at the campuses include electricity, natural gas, propane, fuel oil #2 and diesel. Capital is the only campus supplied by district chilled water, and district steam. The demonstrated energy consumption types includes only energy generated offsite and not onsite generation like fuel cells and solar PV. Based on energy consumption in kBtu natural gas is the most used commodity, followed by electricity (See Figure 2.1).

BENCHMARKING WITH EUI

Energy Use Intensity (EUI), a common benchmarking metric, was used to assess energy consumption at the campus and building level. This analysis makes it possible to compare buildings and campuses of varying sizes under a common framework. EUI is calculated by dividing the total energy consumed in a one-year period by the gross square footage of the building(s) under consideration:

$$EUI = \frac{\textit{Energy Use (kBtu)}}{\textit{Gross Area (ft}^2\textit{)}}$$

EUIs can be calculated using either site energy or source energy, as shown in Figure 2.2

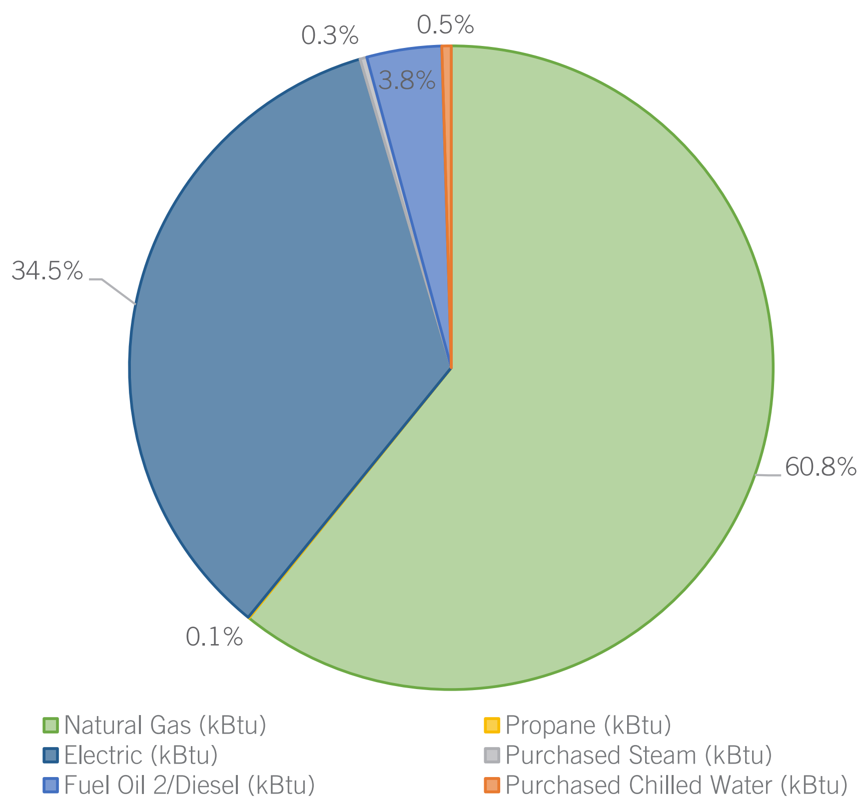


FIGURE 2.1: FY 2014 Consumption by Energy Type

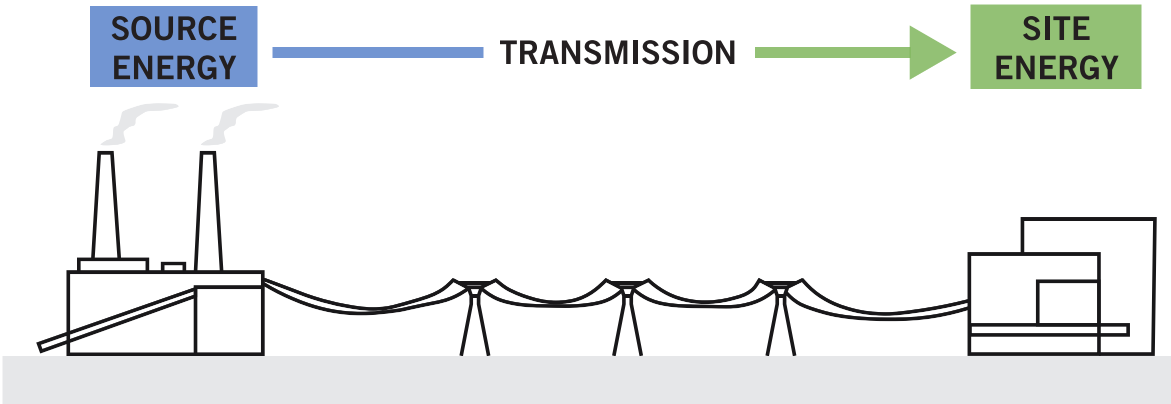


FIGURE 2.2: Site vs Source Energy

SITE ENERGY: Includes the amount of electricity and fuel (and/or steam, chilled water) consumed by a building as recorded by the building meters and utility bills independent of where the energy originates. In this instance, there is no differentiation between electricity purchased from the grid and electricity produced in onsite generation.

SOURCE ENERGY: Accounts for these differences in energy purchased off site by applying a correction factor, which incorporates transmission, delivery, and production losses, to the site consumption values.

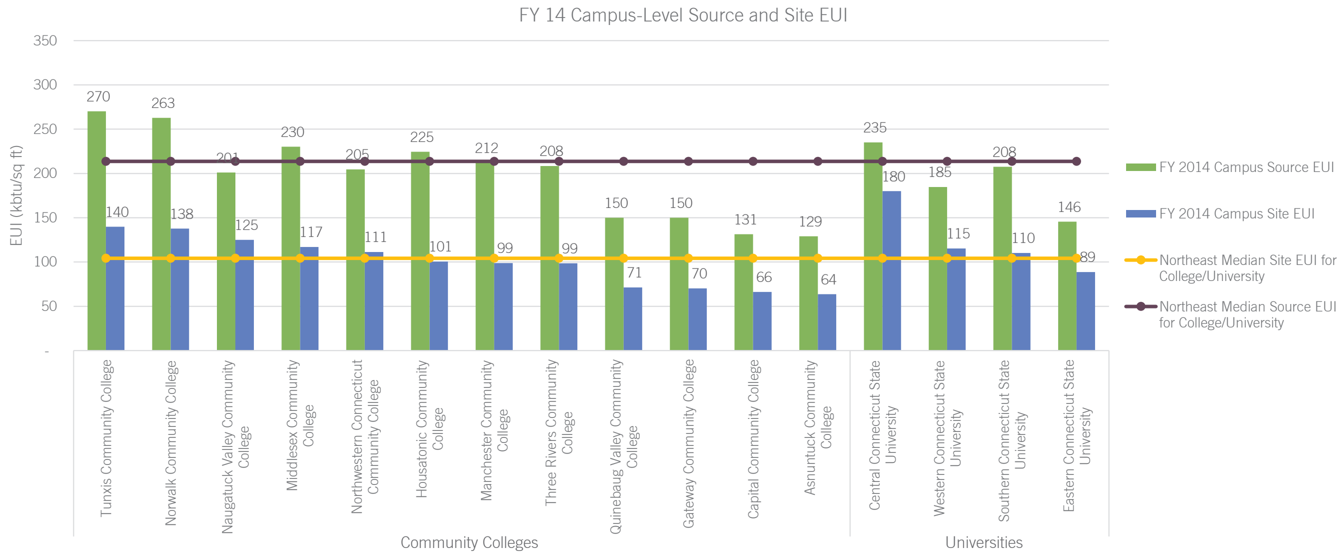
For EUI, only certain campus buildings were included in the calculation. The methodology for building exclusions are:

- Buildings constructed after July 2015 since they did not have a full year of data in any of the fiscal years under consideration (FY13-15) and therefore could not be consistently compared.
- Parking garages, surface parking lots, pavilions, utility tunnels, and athletic fields because they add significant area to the total campus with little to no energy use.
- Demolished buildings, even if they existed in FY13-15
- Radio towers, cell towers, and clock towers since they are small energy users
- Buildings leased to CSCU since they are not part of the owned campus footprint

CAMPUS SITE AND SOURCE EUI

Figure 2.3 displays both the Site and Source EUI values at the campus level for fiscal year 2014 for comparison of CSCU campuses. The campuses were also compared against other College/ University Building types in the Northeast. Half of the campuses had a larger EUI than the Northeast median site EUI of 104. It is important to note however, that this is not a direct comparison, since each campus has different building programs with varying energy use profiles. Variations will be present for campuses with high energy intensity programs, such as laboratories, which have higher EUIs.

Central, Tunxis and Norwalk all presented the largest site EUIs suggesting more energy intensive campuses. Their use is further examined in their individual chapter plans.



Note: Northeast States Median Site and Source EUI for College/University category, per U.S. Department of Energy Building Performance Database http://energy.gov/eere/buildings/building-performance-database

FIGURE 2.3: FY 14 Campus-Level Source and Site EUI

Site EUI is also visualized in comparison to total energy use and total gross square feet in Figure 2.4. The size of the circle demonstrates the campus' total building square footage (with the exception of parameters listed in the EUI methodology). From the chart, an obvious outlier is Central, which has a higher total energy use and EUI than the other Universities. Central's high natural gas use contributes to its substantially larger EUI described further in the Central chapter.

The campus has a 1400 kW fuel cell, and cogeneration system, which use about the same amount of natural gas as other campus energy centers. However, in FY 15 Central's EUI decreased, which is demonstrated in its chapter plan. The Universities are clustered together ranging from an EUI of 89 to 115, but the community colleges are spread out on the energy scale with EUIs ranging between 64 and 138. Energy use assessments across the campuses can be found in the individual campus plans.

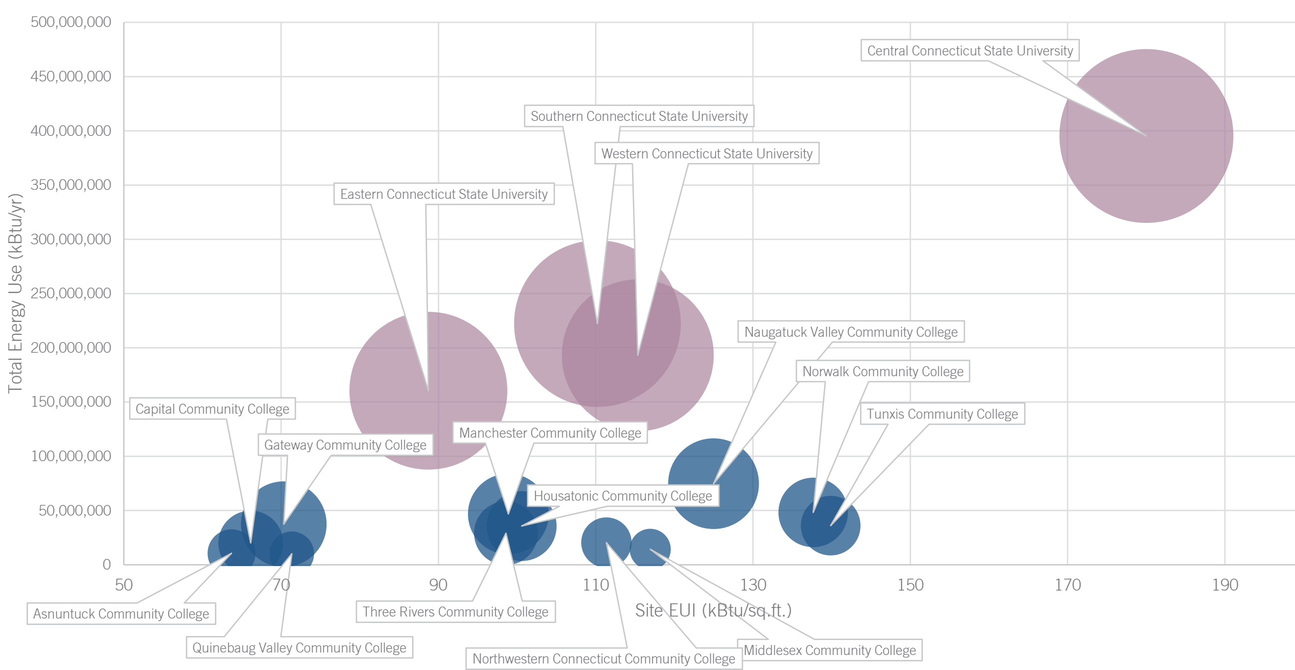


FIGURE 2.4: CSCU Site EUI, Total Energy and GSF

ENERGY/FTE STUDENT

Greater disparity between campus student enrollment is visible through analysis of energy per FTE student (Figure 2.5). The Universities have a larger energy use per FTE student, most likely attributed to energy intensive buildings such as laboratories and residence halls, which some of the community colleges do not have. Northwestern shows double the energy use per FTE student than most of the community colleges. Northwestern has the smallest FTE enrollment of all the campuses at 816 FTE in Fall 2013, but has a higher energy use than campuses with a lower FTE.

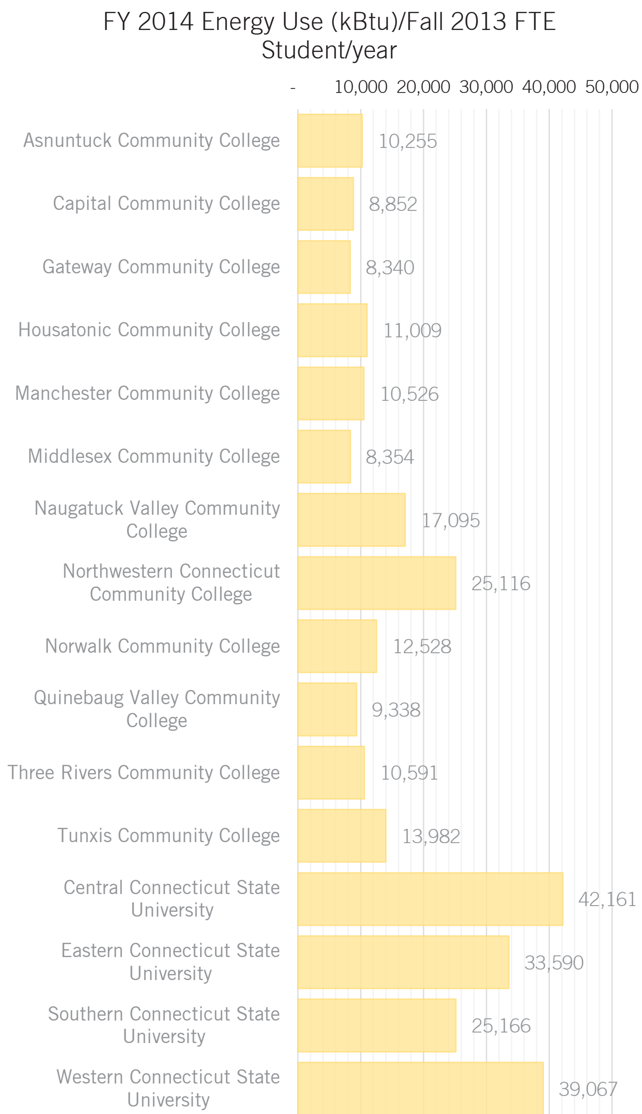


FIGURE 2.5: FY 2014 Energy Use (kBtu)/Fall 2013 FTE Student/Year

CAMPUS ENERGY SPEND BENCHMARKING

Another way to visualize the energy use is through energy spend.

The FY 14 total energy spend per GSF across the CSCU campuses ranges from $1.68/GSF/yr to $3.65/GSF/yr (see Figure 2.6). Middlesex has the highest cost per gross square feet. Middlesex uses oil rather than natural gas for its central plant, which contributes to the higher cost on a building area basis. Asnuntuck has the lowest cost per gross square foot most likely due to only having to provide energy for one campus building.

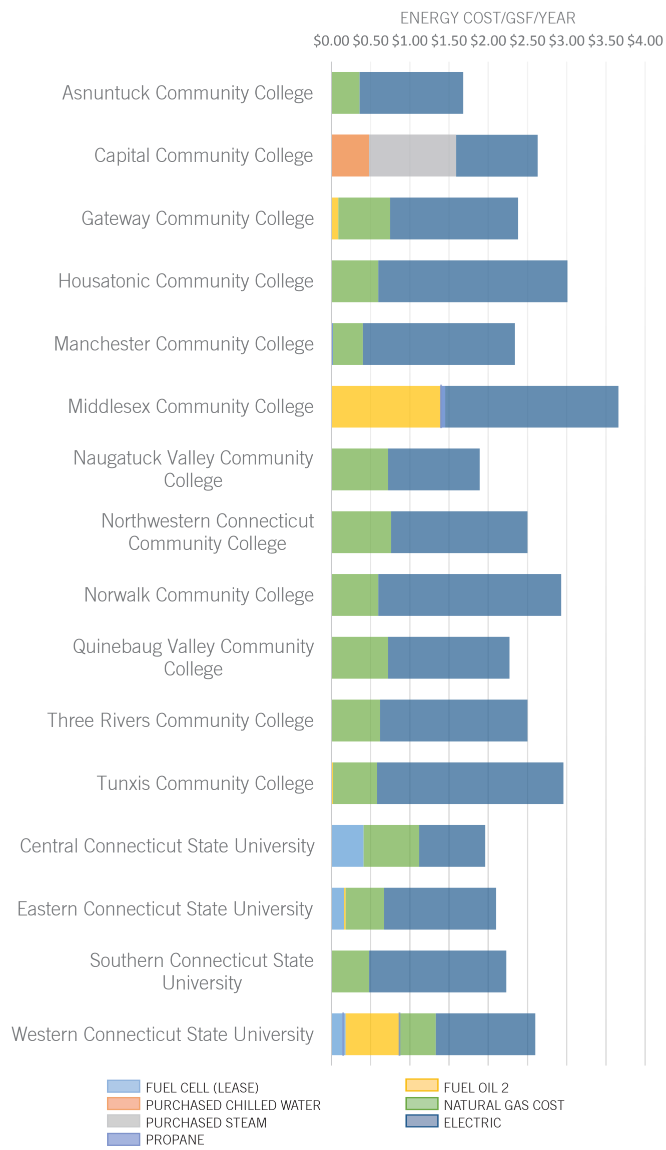


FIGURE 2.6: FY 2014 Energy Cost/GSF/Year

KBtu and energy cost per GSF are the primary means of benchmarking campuses, while kbtu and energy cost per FTE is an interesting discussion which takes into account campus utilization and density.

Figure 2.7 demonstrates each campus' FY 2014 energy cost per Fall 2013 FTE student. Western and Eastern have the largest energy spend per student on campus out of the Universities. Northwestern has the smallest FTE enrollment, with larger energy use resulting in its larger ratio of cost to FTE.

Campuses with numerous smaller buildings often have a higher energy use while campuses with a single building can help to lower their overall energy use and cost. This is evident in comparing Asnuntuck's single building campus with Northwestern's many buildings on an energy cost per FTE basis.

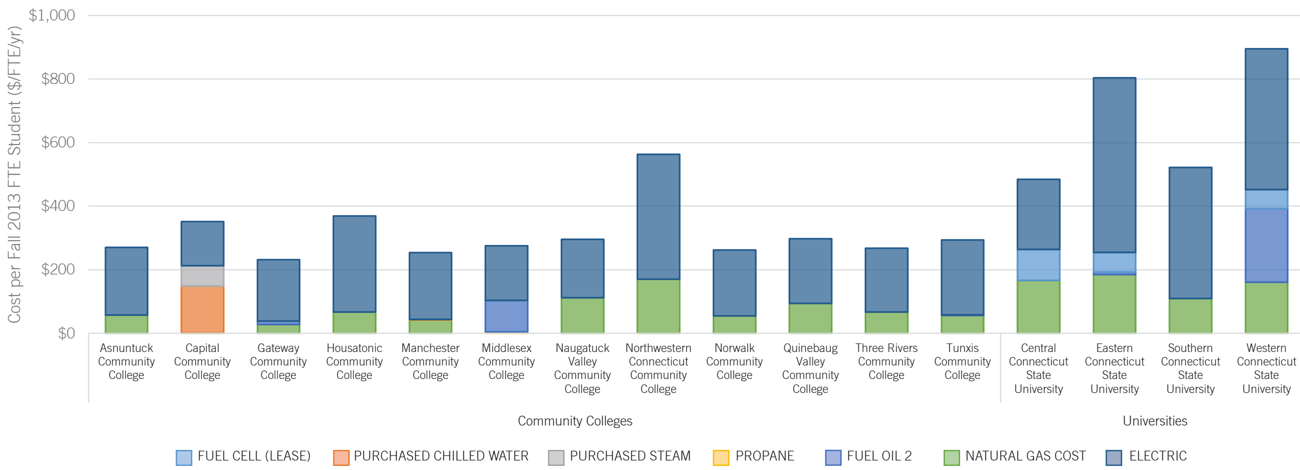


FIGURE 2.7: FY 14 Energy Cost per Full-Time Equivalent Student/Year

2.2 ENERGY PROCUREMENT

Purchasing energy can be an effective method for mitigating risk and controlling cost. With its 17 campuses, CSCU can take advantage of its purchasing position by joining together, where feasible. In FY 2014, the CSCU campuses collectively paid roughly $27 million in energy commodities. The majority of this cost, at around $17.5 million, is attributed to electricity spending.

While there are the standard delivery charges for fuel and electric that cannot be avoided, energy supply prices frequently fluctuate, providing an opportunity to procure energy in a way to control costs. The right procurement fit can afford CSCU flexibility and ultimately savings. For more information on types of controllable energy charges and the different procurement strategies, see Appendix A.

2.2.1 CURRENT CSCU PROCUREMENT STRATEGY

CSCU has utilized different procurement methodologies to source energy. CSCU has procured both electric and gas supply through a bundled contract and procured energy commodities independently. Energy contracting is important for realizing the best commodity prices and can drive how a campus makes operating decisions. It has been noted from various campus visits that utility costs vary greatly between campuses.

For example, Central used a third-party supplier and local distribution company for different accounts and had a low natural gas unit price of $5.19 /MMBTU in comparison to the average CSCU university price of $7.32/MMBTU. By switching completely to the local distribution company in FY15, the campus saw even more savings on supply costs. Third-party suppliers do not always offer the best rates, and favorable procurement contracts often depend on timing of energy purchases. Other campuses take advantage of bulk purchasing. Multiple campuses such as Middlesex, Gateway and Manchester use a Department of Administrative Services (DAS) fuel oil contract which offers discounts off of the market price, varied by location.

COMPETITIVE ELECTRIC SUPPLY

In 2013, CSCU went out to bid for competitive electric supplier pricing for the system. Fifteen of the CSCU campuses participated in the aggregated bid. Hess Corporation was chosen as the commodity supplier over a 36-Month term. The contract is now under Direct Energy, which acquired Hess Corporation's Hess Energy Marketing business in the beginning of purchase term. The contract is for a total price of $21,112,532 from 11/1/2013 to 10/31/2016. The electric procurement results yielded both advantageous pricing for the campuses as well as inclusion of low emission electricity generation. Between 2013 and 2016, Connecticut's Renewable Portfolio Standard required utilities to provide 17-21% of electricity from renewable energy. CSCU's procurement contract included 5% more than the state mandate. CSCU is planning to execute another reverse auction for both natural gas and electricity in the Winter/Spring 2017. Recommendations for future energy procurement strategies are outlined in the Section 4.1.

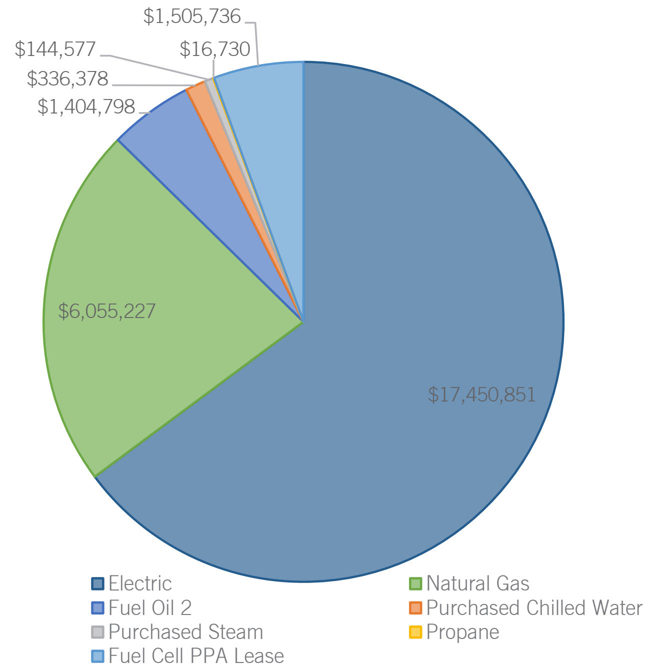


FIGURE 2.8: FY 2014 Total CSCU Campuses Energy Commodity Costs

COMPETITIVE GAS SUPPLY

A few years prior, in 2010, Connecticut Department of Administrative Services (DAS) procured a firm supply of natural gas for a term of 24 months. The procurement RFP included 12 accounts, of which 10 belonged to the four CSCU Universities. The accounts chosen included each campus' boiler house or respective energy center. Hess Corporation was chosen for the 2011 to 2013 contract, providing a basis cost of $1.55/dekatherm at an estimated price $1,318,626. While the basis price provided is fixed, the commodity price fluctuates based on the New York Mercantile Exchange (NYMEX) market. On a monthly basis, Hess reported the total price of supply, shown in Table 2.1 as an example.

At the end of the contract, CSCU conducted another reverse auction in May 2013 for natural gas.

The results were not favorable in comparison to the Local Distribution Company (LDC) prices, and the campuses reversed back to the LDC utility as the supplier. Since June of 2013, CSCU has been on LDC supply. It is recommended that other competitive supply options are reviewed annually.

Table 2.2 summarizes the non-competitive suppliers or local distribution companies and the separate suppliers from FY 2013-Current, if existing, for each of the campuses.

10PSX0167 - February 2013					
SUPPLIER	DIRECT ENERGY		HESS (DUAL FUEL)		
Service Area	SCG	CNG	Yankee	SCG	CNG
Basis ($/Dth Meter)	$ 1.8192	$ 1.8192	$ 1.5500	$ 1.5500	$ 1.5500
Natural Gas ($/Dth Meter)	$ 3.2944	$ 3.2612	$ 3.2619	$ 3.2959	$ 3.2616
Total Price ($/Dth Meter)	$ 5.1136	$ 5.0804	$ 4.8119	$ 4.8459	$ 4.8116
Total with GRT ($/Dth Meter)	$ 5.3827	$ 5.3478	$ 5.0650	$ 5.1010	$ 5.0650

10PSX0167 - March 2013					
SUPPLIER	DIRECT ENERGY		HESS (DUAL FUEL)		
Service Area	SCG	CNG	Yankee	SCG	CNG
Basis ($/Dth Meter)	$ 1.8192	$ 1.8192	$ 1.5500	$ 1.5500	$ 1.5500
Natural Gas ($/Dth Meter)	$ 3.4997	$ 3.4644	$ 3.4651	$ 3.5012	$ 3.4648
Total Price ($/Dth Meter)	$ 5.3189	$ 5.2836	$ 5.0151	$ 5.0512	$ 5.0148
Total with GRT ($/Dth Meter)	$ 5.5988	$ 5.5616	$ 5.2789	$ 5.3170	$ 5.2790

TABLE 2.1: Monthly Natural Gas Charges Provided by Suppliers

Campus	Distribution Company	FY 13- Current Electric Supplier	Natural Gas Local Distribution Company	Natural Gas Supplier	Current Natural Gas Supplier	Other Fuel Supplier	Energy Cost ($)/GSF
Asnuntuck Community College	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	NA	$ 1.68
Capital Community College	Eversource	Hess Corporation, Hartford Downtown Revival	UIL (formerly Connecticut Natural Gas Corporation)	Santa Energy, Hartford Steam Co	UIL (formerly Connecticut Natural Gas Corporation)	NA	$ 2.62
Central Connecticut State University	Eversource	Direct Energy (formerly Hess Energy)	UIL (formerly Connecticut Natural Gas Corporation)	Direct Energy and UIL	UIL (formerly Connecticut Natural Gas Corporation)	Oil	$ 1.97
Eastern Connecticut State University	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	Fuel Oil (No.2): Santa Energy-Buckley Energy Group; Ardent Corp	$ 2.10
Gateway Community College	United Illuminating	Direct Energy (formerly Hess Energy)	UIL (formerly Southern Connecticut Gas)	UIL (formerly Southern Connecticut Gas)	UIL (formerly Southern Connecticut Gas)	Fuel Oil (No.2): East River Energy	$ 1.95
Housatonic Community College	United Illuminating	Direct Energy (formerly Hess Energy)	UIL (formerly Southern Connecticut Gas)	Direct Energy	UIL (formerly Southern Connecticut Gas)	NA	$ 3.00
Manchester Community College	Eversource	Direct Energy (formerly Hess Energy)	UIL (formerly Connecticut Natural Gas Corporation)	Direct Energy	UIL (formerly Connecticut Natural Gas Corporation)	Propane: AmeriGas, Diesel: Dime Oil Company	$ 2.35
Middlesex Community College	Eversource	Direct Energy (formerly Hess Energy)	NA	NA	NA	Propane: AmeriGas, Fuel Oil (No.4), Fuel Oil (No.2): Dime Oil	$ 3.65
Naugatuck Valley Community College	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	NA	Eversource (formerly Yankee Gas)	NA	$ 1.89
Northwestern Connecticut Community College	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	NA	Eversource (formerly Yankee Gas)	NA	$ 2.49
Norwalk Community College	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	NA	Eversource (formerly Yankee Gas)	NA	$ 2.93
Quinebaug Valley Community College	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	NA	Eversource (formerly Yankee Gas)	NA	$ 1.85
Southern Connecticut State University	United Illuminating	United Illuminating	UIL (formerly Southern Connecticut Gas)	Direct Energy	UIL (formerly Southern Connecticut Gas)	NA	$ 2.23
Three Rivers Community College	Norwich Public Utility	Norwich Public Utility	Norwich Public Utility	Norwich Public Utility	Norwich Public Utility	NA	$ 2.50
Tunxis Community College	Eversource	Direct Energy (formerly Hess Energy)	UIL (formerly Connecticut Natural Gas Corporation)	Direct Energy, Santa Energy	UIL (formerly Connecticut Natural Gas Corporation)	Fuel Oil: Dime Oil	$ 2.95
Western Connecticut State University	Eversource	Direct Energy (formerly Hess Energy)	Eversource (formerly Yankee Gas)	Direct Energy	Eversource (formerly Yankee Gas)	Propane: Leahy Fuels	$ 2.60

TABLE 2.2: CSCU Utility Distribution Companies and Suppliers

2.2.2 POWER PURCHASE AGREEMENTS

Another form of energy procurement, in particular for distributed generation projects that have tax incentives or other attributes that are not routinely monetized, is the power purchase agreement (PPA). Entities that desire on-site generation without significant capital costs and associated maintenance, often enter into PPAs. With this type of financial structure, the developer is responsible for obtaining the capital for project development, while the entity hosting the renewable energy site enters into a long-term agreement with lower electric rates. The developer also capitalizes on obtaining tax credits & other financial incentives that are traditionally not available to the public sector. The benefits of PPAs are further outlined in the Section 4. Below is example of how a PPA structure can work.

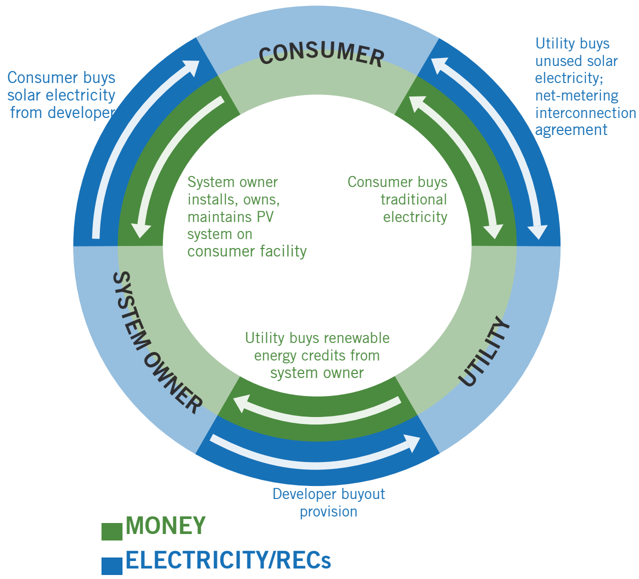


FIGURE 2.9: PPA Terms and Financial Structure

Central, **Eastern** and **Western** each have PPAs for fuel cells on their campuses. The following sections provide a summary of the current PPA terms followed by recommendations for structuring a PPA in the future.

CENTRAL

In 2011, Central entered into a PPA contract with FuelCell Energy for its 1.4 MW fuel Cell, located by East Hall. The following table summarizes the terms and prices under the PPA. Central's chapter plan provides more details on the language in the contract.

FIGURE 2.10: Central Fuel Cell

Seller: FuelCell Energy
Direct FuelCell 1500 Model
1400 kW

Time (Years):	10 years
Monthly Price:	Varies by Month
PPA Price over Term:	$9,097,200
Minimum Electricity Capacity promised over term (kW):	12,470
Approximate $/kWh Fuel Cell Cost over Term, Assuming 95% Uptime:	$0.087
$/kWh Fuel Cost over Term at $5/MMBtu:	$0.048
Normalized $/kWh Total Over Term:	$0.135
Environmental Attributes Owner:	FuelCell Energy

The approximate normalized cost for fuel cell operation at Central based on the terms of the PPA agreement is $0.14/kwh over the life of the contract. This is a conservative estimate which includes the maximum amount of natural gas which may be used in the fuel cell. According to the agreement, any environmental attributes, including Renewable Energy Credits (RECs) are assigned to the fuel cell owner, FuelCell Energy, and not the campus. As with many newer technologies, the campus does experience operational challenges with the fuel cell. However, with the contract, the fee gets reduced due to lack of performance. According to FY 14 data, Central is capturing some savings with the contract.

EASTERN

Eastern signed its PPA contract in 2011 and began operation in 2012. The table below summarizes important features of the contract between Eastern and Doosan Fuel Cell America (Doosan), formerly UTC Power.

FIGURE 2.11: Eastern Fuel Cell

Seller: Doosan Fuel Cell America, for UTC Power
PureCell Model 400
400 kW

Time (Years):	10 years
Fixed Payment per Month:	$24,834
PPA Price over Term:	$2,980,080
Guaranteed Minimum Output (MWh) Promised over Term:	31,073
Approximate $/kWh Fuel Cell Cost Over Term:	$0.096
$/kWh Fuel Cost over Term at $5/MMBtu:	$0.069
Normalized $/kWh Total over Term without RECs:	$0.158
Normalized $/kWh Total over Term with RECs:	$0.137

Environmental Attributes Owner: Eastern retains any and all RECs; Doosan is the seller and Doosan retains a 5% fee for gross sale price of attributes

As shown above the approximate normalized cost for operation of the fuel cell is $0.158/kWh without the capture of RECs. This price is inclusive of the fuel input required, using the guaranteed maximum fuel consumption of 425,790 MMBtu over the term. The PPA is structured so that any lack of generation is the responsibility of the campus unless it is explicitly caused by the system itself. Problems with broadband, electrical issues or any other kind are the responsibility of the campus. The campus has expressed concern with the fuel cells continuity of operation that results in not obtaining full benefit of the unit.

Based on FY 14 data, this appears to be the case given that REC's were not secured. When RECs are secured, the project is much closer to breakeven.

Eastern is able to take advantage of the Connecticut's Class III RECs. With the inclusion of RECs, assumed at $20/MWh, the normalized price drops approximately 2 cents, making it a more attractive option. The financial benefit of this unit appears cost neutral as originally projected. In order to achieve the RECs, the Fuel Cell must have an average operating efficiency of greater than 50% for the quarter. For this PPA it is important that the unit is operating as efficiently as possible and takes advantage of RECs in order to capture needed savings.

As of production of this report and in response to the sporadic operation of the fuel cell, Doosan is replacing the current system with a 440 kW fuel cell. Doosan is providing the capital for the premature replacement and a new contract is being issued. Similar to the original contract, the new contract will specify that Eastern will obtain the RECs.

WESTERN

In March 2012, Western entered into a PPA with Doosan Fuel Cell America (Doosan), formerly UTC Power, for its fuel cell located at the Science Center. A summary of the PPA is provided below.

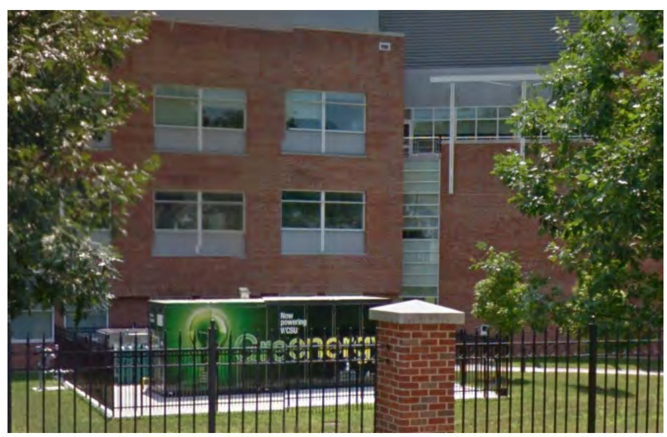


FIGURE 2.12: Western Fuel Cell

Seller: Doosan Fuel Cell America, for UTC Power
PureCell Model 400
400 kW

Time (Years):	10 years
Fixed Payment per Month:	$24,834
PPA Price over Term:	$2,980,080
Guaranteed Minimum Output (MWh) Promised over Term:	31,073

Approximate $/kWh Fuel Cell Cost over Term:	$0.096
$/kWh Fuel Cost over Term at $5/MMBtu:	$0.069
Normalized $/kWh Total over Term without RECs:	$0.158
Normalized $/kWh Total over Term with RECs:	$0.137

Environmental Attributes Owner: Western retains any and all RECs; Doosan is the seller and Doosan retains a 5% fee for gross sale price of attributes

Based from separate competitive bids, both Western & Eastern obtained similar contract agreements for their fuel cells and therefore the same normalized cost based on contract terms.

SOLAR PHOTOVOLTAIC PPA

Middlesex, Southern, Western and Quinebaug currently have solar photovoltaic Request for Proposal (RFPs) that are either recently awarded, recently bid or soon to be bid. The following is a high-level summary of the RFPs:

SOUTHERN
Size: Base Bid - Two sites for a total of 650 kW AC
Supplemental Bid - Approximately at 750 kW AC

RFP Close Date : May 6, 2016

MIDDLESEX / WESTERN
Size: Middlesex - 100 kW DC
Western - 60 kW DC

RFP Close Date : January 15, 2016

QUINEBAUG
Yet to be released

Success of PPA RFPs depend on multiple factors such as contract language, terms and siting arrangements of solar PV. For instance, Western's 60 kW site was bid three times without major interest partially due to the siting and small size of the array. As it was one of the original RFPs, the System has since acquired an understanding of what developers deem advantageous including appropriate site selection work and bundling of arrays or larger kW size to take advantage of economies of scale. Recommendations for additional solar sites are included in the campus master plans.

Note: Manchester is also pursuing up to two megawatts of solar on campus.

2.3 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

In general, facilities department and building operations staff at the campuses are involved in energy management in some form. However, the first and foremost responsibility of facilities staff is to ensure the smooth operation and maintenance of buildings and grounds on campus. Depending on the campus, facilities may also be in charge of capital planning from design to implementation. Staff availability and budgets can be a limiting factor on the amount of energy management possible at each campus. The following campuses have staff (either one person or multiple), according to the campus, which serve the role of an energy manager:

- Eastern
- Gateway
- Housatonic
- Naugatuck
- Norwalk
- Quinebaug
- Southern
- Western
- Central

Types of energy management occurring on the campuses include:

- Monitoring energy use at building and campus level
- Reviewing energy bills for discrepancies or outliers
- Capital planning targeted energy efficiency upgrades

2.3.1 ENERGY MONITORING

Energy monitoring can take different forms from sporadically assessing energy consumption, to daily tracking of changes in typical energy use. Most CSCU campuses will spot check their monthly bills, while some will compare year-to-year energy use. Most analytics, if any, used by smaller colleges are by hand. Universities with energy distribution systems may have BTU meters, but data tracking and logging on an hourly, monthly, and yearly basis was not found. The State of Connecticut's Office of Policy and Management (OPM) and now the Department of Energy and Environmental Protection (DEEP) has a role tracking the state's energy use and spending. No later than 30 days after the prior month, each campus files campus-level energy consumption as well as water and sewer.

The data only tracks campus total energy and spending per month and does not have granularity by account. To date, DEEP has not integrated this data for CSCU operating efficiency. The community colleges provide their files monthly to CSCU Finance Department. The Universities provide their information directly to DEEP. The CSCU Facilities Department does not have direct access to this data. Facilities should be integrated into the data sourcing.

An example of the monthly reporting form still used is below:

STATE OF CONNECTICUT
OFFICE OF POLICY AND MANAGEMENT
STRATEGIC MANAGEMENT DIVISION

MONTHLY ENERGY CONSUMPTION MONITORING REPORTING FORM

Agency No: 7705
Agency: Board of Trustees of Community - Technical Colleges
Facility: Housatonic Community - Technical College

Instructions
* Use GAAP (Generally Accepted Accounting Principals) to report all monthly CM data. Monthly bills should be reported based on the ending date of the billing cycle for each Utility and Fuel type. Do not split monthly bills between two months or fiscal years.
* The information reported on this form should relate only to the agency number indicated above.
* A monthly CM report should be submitted to OPM no later than 30 days from the end of each month.
* Complete a CM report for each month of the fiscal year and submit to - OPM STRATEGIC MANAGEMENT DIVISION ATTN: CONSUMPTION MONITORING PROGRAM
* Please do not alter this form. Make copies of this form for all monthly reporting.

REPORTING PERIOD: September (MONTH) 2013 (YEAR)

PLEASE "X" IF THIS IS A REVISED REPORT: ______ DATE REVISED ______
(Revised reports must be received by OPM no later than two months from the REPORTING PERIOD noted above)

AGENCY CONTACT: Teresa Oravetz (NAME) Director of Finance (TITLE) 203-332-5014 (TELEPHONE)

Identify each Electric and Natural Gas service provider and the annual percentage of total usage supplied.
ELECTRICAL SERVICE PROVIDED BY CL&P___% UI___% MUNICIPAL___%
NATURAL GAS SERVICE PROVIDED YANKEE____% CNG____% SCG____% MUNICIPAL____%

UTILITY and FUEL Types	QUANTITY (Round to whole units)	TOTAL COST (Round to whole dollars)
ELECTRICITY (KWH)	621	91,336
NATURAL GAS (CCF)	4,538	2,513
DISTRICT HEATING (MMBTU)	-	-
DISTRICT COOLING (DAYTONS)	-	-
No. 2 OIL (GALLONS)	-	-
No. 4 OIL (GALLONS)	-	-
No. 6 OIL (GALLONS)	-	-
PROPANE (GALLONS)	-	-
GENERATED ELECTRICITY (KWH)	-	

COMMENTS: Please note changes that impact facility energy requirements or costs (e.g. conversion of utility or fuel type(s), implemented energy savings projects, change in facility gross square footage, etc.)

FIGURE 2.13: The State of Connecticut's DEEP/OPM Monitoring

Detailed understanding of energy consumption starts with metering. The lack of building level utility meters or submeters installed on CSCU campuses was a challenge for the Energy Master Plan as it has prevented a detailed understanding of the energy consumption of specific buildings in many instances. In some instances, multiple buildings are grouped on single meters with no ability to separate out the energy consumption. The total number of buildings does not include leased spaces, garages or any buildings that were not included in the EUI calculations. In nearly all buildings detailed energy monitoring of different end use categories was not available.

In addition, the Institute for Sustainable Energy at Eastern has established Energy Star Portfolio Manager accounts for each of the community colleges. These accounts were recently updated and contain monthly energy and water (where available) data for 2013 – 2016 for each campus. The data in these accounts should be maintained to track changes in energy and water use over time compared to benchmarks and energy and cost saving targets.

Below shows a summary of the metering at the campuses.

Campus	Total Number of Buildings (As of FY 2014) [1]	Percent of Building Level Data of Buildings Using Electric	Percent of Building Level Data of Buildings using Gas/Central Steam/High Temperature Hot Water Heating
Asnuntuck Community College	1	100%	100%
Capital Community College	1	100%	100%
Gateway Community College	2	100%	100%
Housatonic Community College	2	100%	100%
Manchester Community College	12	33%	42%
Middlesex Community College	6	0% [2]	NA
Naugatuck Valley Community College	5	0% [3]	60%
Northwestern Connecticut Community College	10	80%	86%
Norwalk Community College	2	100%	50% [4]
Quinebaug Valley Community College	3	0%	0% [5]
Three Rivers Community College	2	100%	100%
Tunxis Community College	7	57%	0%
Central Connecticut State University	46	85%	85%
Eastern Connecticut State University	48	100%	45%
Southern Connecticut State University	38	100%	71%
Western Connecticut State University	26	62%	56%

TABLE 2.3: Summary of Metering at the Campuses

[1] Factors in buildings used in calculations of Energy Use Intensity only, as described in Section 2.1.
[2] Note only received campus level data, campus may have individual accounts, but there is no record for this report.
[3] Founders Hall is the only building with its own account, but it is being renovated and therefore was not factored.
[4] 100% in FY 15
[5] Note only received campus level data, campus may have individual accounts, but there is no record for this report.

2.3.2 ENERGY USE INFORMATION MANAGEMENT SYSTEM

Depending on resources available, the complexity of each campus' BMS system capabilities vary. Some campuses also make use of energy management software to track and understand energy use. Table 2.4 summarizes the campuses existing management systems.

Campus	Building Management System (BMS)/Building Automation System (BAS)/ Work Order (WO) System	Energy Management Software
Asnuntuck Community College	COGZ - Work Order System	None
Capital Community College	Siemens BMS	None
Gateway Community College	Alerton ABS	PV Modbus Interface-monitoring (broken)
Housatonic Community College	Alerton ABS	EnerNOC
Manchester Community College	BMS Siemens	None
Middlesex Community College	Alerton	None
Naugatuck Valley Community College	Johnson Controls Metasys	None
Northwestern Connecticut Community College	Mixture of Siemens and Johnson Controls Metasys - Work Order System, Email System, NO PM Program, Self Perform Controls	None
Norwalk Community College	Siemens and Andover Controls	Yes
Quinebaug Valley Community College	Continum Andover BMS System	None
Three Rivers Community College	Alerton ABS (Future planned upgrade to BMS)	None
Tunxis Community College	Two independent BMS systems are used for the campus with the intention of consolidating to a single system.	None
Central Connecticut State University	TVC Control System for Energy Center	None
Eastern Connecticut State University	Alerton BMS, North HP SCADA/FLEX Distributed Control Preferred Instruments (for load shedding)	Energy Dashboard, Encelium Energy Management
Southern Connecticut State University	Automated Logic	Ameresco Building Analytics, Energy Reports (Automated Logic Building Energy Analytics)
Western Connecticut State University	Johnson Controls, SchoolDude Maintenance Direct (Work Order System)	EnerNOC, SchoolDude Utility Direct

TABLE 2.4: CSCU BMS and Energy Management Software Types

BUILDING SET POINTS

CSCU campuses do not have system wide standard for building temperature set points. Some campuses with BMS will set their heating setpoint to 68 °F and the cooling setpoint to 74 °F or might have temperature and/or flow setpoints from the boilers set based on outdoor temperature.

2.3.3 OPERATIONS & MAINTENANCE

O&M practices vary between campuses. Some will outsource everything to a third party, while others do everything except major repairs in-house. O&M staff at some campuses are limited with only one or two staff available. O&M is an integral activity within Energy Management, but it is often more than one or two staff can handle, especially for larger campuses. Additional information on best practices and types of O&M strategies for maintaining building systems is located in the Appendix B.

2.3.4 COMMISSIONING / RETROCOMMISSIONING

There are over 230 buildings across the CSCU campuses, with more buildings planned to come online in the coming years. Newer buildings often integrate more high-tech building automaton systems and equipment. Commissioning and recommissioning are necessary processes, especially to recalibrate existing systems and take advantage of savings. The four Universities own and operate approximately 70% of the buildings that make up the CSCU building inventory. Each of these campuses have recently implemented recommissioning projects or partaken in retrocommissioning programs, listed below.

- **Central:** The campus completed a three phased retrocommissioning program between 2011 to 2014. Energy Conservation Measures as a part of the initiative included chilled water pump optimization, variable frequency drive installations and optimizing fan operations. Each of the projects had a return on investment of less than 2 years.
- **Eastern:** The campus has an active retrocommissioning program that started seven years ago in coordination with their electric utility, Eversource. One of their most recent projects was completed on their Science Building. The Eversource program is described more in depth in their individual campus chapter.
- **Southern:** The campus employs a Monitoring Based Commissioning program that examines energy efficiency opportunities in existing buildings through targeted adjustments to Building Automation Systems.
- **Western:** Works with EnerNOC on an ongoing basis for continual building improvements.

Even though state regulations require commissioning for new or major construction, it is not always properly completed as was evident at the Gateway New Haven campus. There, improper and incomplete commissioning has rendered 3 of the 6 ice storage tanks not useable. Middlesex has large windows at a relatively new building already failing because building envelope and factory acceptance testing did not expose the flaws until years after installation. Full execution of commissioning should to be a goal of all projects by any means necessary. Proper commissioning will not only ensure longer life of equipment, but also energy savings throughout the life of the equipment and/or systems. Training is another aspect of commissioning that is often lacking.

2.3.5 ENERGY EFFICIENCY DESIGN STANDARDS

As a state entity, the CSCU campuses are subject to state building guidelines and efficiency standards. The campuses comply with the 2005 State Building Code. The State of Connecticut's energy efficiency standards are documented in Regulation Section 16a-38k-1 through 9: The Establishment of High Performance Building Construction Standards for State-Funded Buildings. The regulations require new / major renovation buildings to attain a high building performance ranking equivalent to United States Green Buildings Council (USGBC) Leadership in Energy and Environment Design (LEED) Green Building Rating System™-Silver.

The guideline requires public higher education institutions undergoing new construction that are projected to cost $5M, with $2M in state funding or more, or renovations that are projected to cost $2M or more and are state funded, to comply with:

- Twelve mandatory requirements;
- Six additional mandatory measures; and,
- Minimum twenty-eight of fifty-nine optional strategies.

Listed below is a summary of the **Regulation Section 16a-38k.**

16a-38k-3 Mandatory Building Project Requirements (Twelve (12) Mandatory Standards)**:**

1. Commissioning
2. Integrated Design Process
3. Energy Performance > 20% better than Building Code/ American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 90.1-2004
4. Energy Star products
5. Project Manager-Facilitator (Owner's Rep.) to develop Indoor Air Quality management plan
6. Use low-flow fixtures to consume 20% less water than base level calculations
7. Recycle area
8. Erosion and Sediment control
9. No Smoking in building
10. Integrated Pest Management Plan
11. No Chlorofluorocarbon (CFC) -based refrigerants
12. Building ventilation to meet ASHRAE 62.1 or Building Code (more stringent)

16a-38k-5 Additional Mandatory Building Project Requirements for Schools (Six (6) Additional Mandatory Requirements):

1. Acoustical Standards as required per CGS 10-285g
2. Outside air intakes at least 25 feet from hazards (chimneys, vents, cooling towers, parking lots, loading docks, etc.)
3. Only electronic ignition on gas-fired appliances (no pilot lights)
4. Low Volatile Organic Compounds (VOCs) certification of materials (adhesives, paints, carpet, ceilings, etc.)
5. Perform Phase I environmental site assessment (per ASTM #E1527) and subsequent actions as required.
6. HEPA vacuum prior to occupancy

16a-38k-6 Building Standard Strategies (Minimum of 28 of the 59 optional strategies):

Eleven strategies are available for demonstrating compliance within the energy efficiency and renewable energy category. Fourteen strategies are available for improving the indoor environment. Many example strategies are recommended EEMs as part of the Energy Master Plan. Some include fuel cells, waste heat recovery, demand control ventilation, and solar power, to name a few.

- Energy Efficiency & Renewable Energy
- Indoor environment
- Water efficiency
- Recycling, Reuse, and Sustainability
- Site Selection and Development
- Operations and Procedures/Innovation

16a-38k-7 Alternative Strategies

Permits LEED for Schools silver rating or NE-CHPS rating system/ certification but also incorporates the requirements of 16a-38k-3, 16a-38k-5, 16a-38k-8, and 16a-38k-9.

A complete summary of the regulations applicable to state-funded school building projects can be found here: *http://www.sde.ct.gov/sde/lib/sde/PDF/dgm/sfu/forms/highperformanceschoolconstruction.pdf*

Connecticut Building Standard Guidelines Compliance Manual for High Performance Buildings is a summary handbook intended to act as a guide for implementing the regulation: *http://www.ct.gov/deep/lib/deep/energy/buildingstandards/compliancemanualhighperformancebuildings.pdf*

2.4 RENEWABLE AND ALTERNATIVE ENERGY

Several campuses have implemented renewable energy and alternative energy projects on their campuses, partially summarized below. Appendix C contains reference information on various types of renewable and alternative energy technologies and their respective benefits.

- **Eastern:** (3) 800-foot Vertical Well Geothermal System, Solar Powered Lights at bus stops and at Crandall and Burnap Hall, and Level 2 Electric Vehicle Charging Stations; 400 kW Fuel Cell; 40 kW Solar PV
- **Central:** 1400 kW Fuel Cell: ; two 1250 kW internal combustion cogeneration units.
- **Gateway:** 60 kW Alternating Current (AC) Solar PV, 1000 sq. ft. of Solar Thermal Hot Water
- **Western:** 400 KW Fuel Cell

In 1998, Eastern installed the state of Connecticut's largest geothermal project, with three 800 foot wells. The install supports hot water at its high rise apartments. Eastern also has solar powered lights throughout the campus and EV Stations.

Gateway's LEED Platinum building decreases greenhouse emissions and provides savings through both solar PV and solar thermal. The New Haven campus North Building features 40 Viesmann flat-plate solar thermal collectors that heat two 500-gallon hot water tanks stored in the basement of the building. The system has been in operation since 2012. According to the facility manager, the system has operated well and exceed expectations, meeting the majority of the hot water and heating needs of the college throughout the entire year. It also significantly reduces the use of natural gas and fuel oil.

Several campuses are in the process of implementing and exploring alternative energy projects. Quinebaug Valley Community College just completed a geothermal system for a building addition. Southern, Middlesex/Western (combined RFP) and Quinebaug are also actively pursuing solar opportunities through a RFP process. Southern is specifically bidding three different PV projects, including a ground mount, roof mount and parking canopy. Over 1 MW of solar PV, including a supplementary site, was out to bid. Southern was provided no-cost technical assistance from the National Renewable Energy Laboratory (NREL) for assessing solar PV feasibility for the project. [1] The RFP close date was May 6, 2016, and determinations on the favorability of the responses are in progress.

CSCU has fuel cells installed on three different campuses, Central, Western and Eastern, which were outlined in detail in the Section 2.2.2. All three are leased and not owned by the campuses or by the CSCU.

2.4.1 SOLAR PHOTOVOLTAIC GUIDELINES

Solar is a particularly attractive type of renewable energy to pursue because incentives are available that allow site owners to realize savings with minimal to no capital investment. However, campuses in the past have had to be cautious about how installation is pursued especially for roof-mounted systems to meet guidelines prompted by CSCU's property insurance company, FM Global. The insurance company provides recommendations and guidance related to structural conditions, including roof mounted and ground mounted PV systems. Per FM Global, anchored systems should be used if the slope of the roof is greater than 2.4°. Ballasted systems which do not penetrate the roofing membrane can be used under certain conditions as determined by FM Global.

A non-exhaustive summary of FM Global's recommendations and some comments for roof mounted PV systems are listed below.

- Solar PV panels can be ballasted OR anchored, provided one of two prescribed calculation or testing methods are used for wind loading.
- Ballasting of solar panels is an approved method for roofs up to a 2.4° Slope, beyond that anchoring appears to be the option.
- If a roof is flat, i.e. less than 1° slope, it should be evaluated and analyzed including supporting roof framing, columns and bearing walls. A qualified structural engineer is required for any reinforcing of the roof. This typically adds cost to the installation.
- Anchoring to the structure is not preferred for standing seam roofs (SSRs), but rather clamping. Of course, the roof needs to be determined "adequate".
- If the roof is fastened (as opposed to ballasted), then the panels also need to be mechanically fastened.
- Roofs should not have any forms of roof aggregate or loose stones for ballasting to secure the panel racking to the roof.
- Roofing may need the addition of approved insulation before installation of new roof-mounted solar panels.

[1] More information on the NREL program available at: *http://www.nrel.gov/tech_deployment/tools_universities.html*

- FM Global recommends a thorough amount of O&M be performed, including but not limited to:

    a. Perform PV array insulation resistance tests every three years

    b. Perform a thermo-graphic survey for all electrical components annually

    c. Visually inspect inverters on a daily basis

    d. Test inverters annually

2.4.2 DISTRICT ENERGY / COGENERATION

Seven of the CSCU campuses utilize decentralized or building level heating and nine utilize central heat plants that serve multiple buildings as identified in Table 2.5.

Campus	Heating System	Cooling System
Asnuntuck Community College	Decentralized	Decentralized
Capital Community College	Decentralized	Decentralized
Gateway Community College	Decentralized	Decentralized
Housatonic Community College	Decentralized	Decentralized
Manchester Community College	Central Plants	Central Plants
Middlesex Community College	Central Plant	Central Plant
Naugatuck Valley Community College	Central Plant	Central Plant
Northwestern Connecticut Community College	Central Plant	Central Plant
Norwalk Community College	Decentralized	Decentralized
Quinebaug Valley Community College	Decentralized	Decentralized
Three Rivers Community College	Central Plant	Central Plant
Tunxis Community College	Decentralized	Decentralized
Central Connecticut State University	Central Plant	Central Plant
Eastern Connecticut State University	Central Plant	Decentralized
Southern Connecticut State University	Central Plant	Decentralized
Western Connecticut State University	Central Plant	Decentralized

TABLE 2.5: CSCU Campus District Heating/Cooling Systems

Heating systems that operate as a central plant are more likely to have large enough loads to be viable cogeneration projects. Cogeneration, otherwise known as Combined Heat & Power (CHP) or in some cases tri-generation, is a means of using a fuel source, often natural gas, to create electricity and hot water or steam simultaneously. Figure 2.14 provides a schematic of the process and energy flow. Appendix D contains additional information on the types of cogeneration systems, and benefits, for reference.

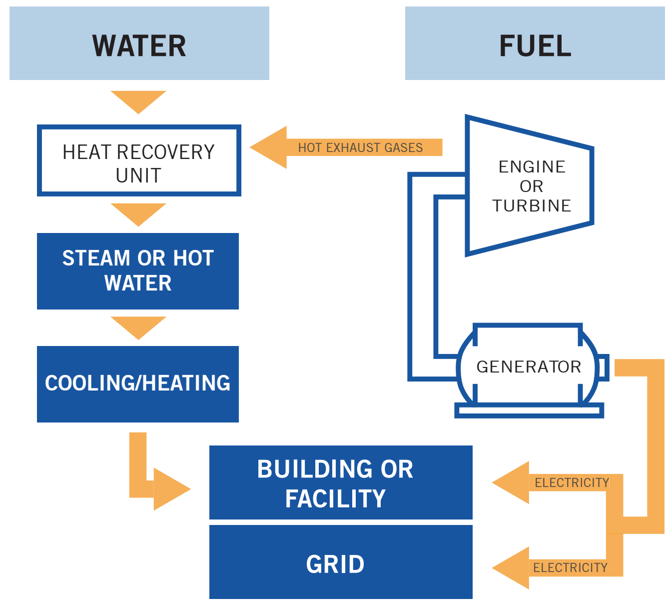


FIGURE 2.14: Combined Heat and Power Partnership

EXISTING COGENERATION

CSCU currently has cogeneration at three campuses, Central, Eastern and Western. Central has a 1.2 MW fuel cell and two 1.25 MW internal combustion engines. Eastern and Western both have a 400 kW fuel cell with useful heat captured and used on the campus.

CAMPUS SPECIFIC CHP SCREENING

Each of the campuses with a central plant, large load or steam/hot water distribution networks were screened for CHP potential. Table 2.6 was generated from monthly utility data and information gathered from campus visits. The potential is based on the base load and existing infrastructure, and the rankings were based on the following scoring:

- High- Month Base Load greater than 2 MMBtu/hr
- Medium – Month Base Load greater than 0.05 MMBtu/hr, less than 2 MMbtu/hr
- Low- Month Base Load less than 0.05 MMBtu/hr

CAMPUS	EXISTING INFRASTRUCTURE	MONTH BASE LOAD	CHP POTENTIAL	NEXT STEPS
CURRENTLY HAVE CHP				
Central Connecticut State University	Central HW heating/cooling plant with absorption & electric chilling +CHP	15.47 MMBtu/hr	Existing 2.5 MW (IC), 1.2 MW (Fuel Cell)	Maximize existing CHP through potential operational changes
Eastern Connecticut State University	Steam +Fuel Cell	1.01 MMBtu/hr	Existing 400 kW (Fuel Cell)	Maximize existing CHP
Western Connecticut State University Midtown Campus*	Central Plant Heating only +CHP at Science Building	0.14 MMBtu/hr @ Central Plant, Could increase with absorption chilling.	Existing 400 kW Fuel Cell at Midtown campus	Maximize existing CHP
CANDIDATES FOR CHP				
Naugatuck Valley Community College	Central HTHW heating/cooling plant w/absorption chilled water	2.35 MMBtu/hr	High	Investigate CHP Feasibility / Life Cycle Cost
Southern Connecticut State University[¥]	Central Plant HTHW on West campus with conversion to steam on East campus.	2.31 MMBtu/hr	High	Investigate CHP Feasibility / Life Cycle Cost
UNLIKELY CHP CANDIDATES				
Manchester Community College	Two central heating/cooling plants w/electric only chilling	<0.01 MMBtu/hr	Low	None
Middlesex Community College	Central HW heating/cooling plant w/electric only chilling	<0.01 MMBtu/hr	Low	None
Northwestern Connecticut Community College	Small District heating/cooling (electric) for 3 buildings	Currently <0.01 MMBtu/hr.	Low	None
Three Rivers Community College	Central HW heating/cooling plant w/electric only chilling	Currently <0.04 MMBtu/hr, could increase with absorption chilling.	Low	None

TABLE 2.6: CSCU Campuses with Central Plant or Steam/HW Distribution Networks

Note: Month Base Load is calculated simply as the lowest month total energy used multiplied by an assumed boiler efficiency of 80% and divided by the number of hours for the given month.

*Western has two campuses separated by approximately 3 miles. Only the Midtown campus has been evaluated for CHP since the Westside campus does not currently have access to natural gas. Western's natural gas billing structure at the Boiler House may support CHP well since a very high base rate (near $16,000/mo) is applied regardless of the gas use. Gas costs through Direct Energy range from approximately $0.67//CCF in the winter to $12.63/CCF in the summer.

*Southern has two campuses separated by a public road, Route 10. Only use of the existing heating infrastructure which connects both campuses was considered since the addition a chilled water loop will likely be cost prohibitive. Campuses with the highest potential were screened in greater detail and the results are included in the individual campus plans.

2.5 PROJECT IMPLEMENTATION

The ability to accomplish energy saving projects can be hindered or aided by the existing project completion process. At CSCU, campus expansion and renovation projects are generally guided by each campuses' master plan. There can be a large lag between when the project is needed, when the project is funded and ultimately when it is constructed. This period, many times years, can cause there to be outdated energy-related technologies when the actual project is implemented.

CSCU can contract with any supplier currently listed on the State of Connecticut DAS list for contract values up to $100,000. These suppliers have been qualified for specific services as listed on the DAS. There may be instances where there is not a contract type from the DAS applicable to the desired work to be performed, in which case the university or college can utilize a request for proposal (RFP) process. The RFP process can also be used outside of the DAS process if the university or college desires.

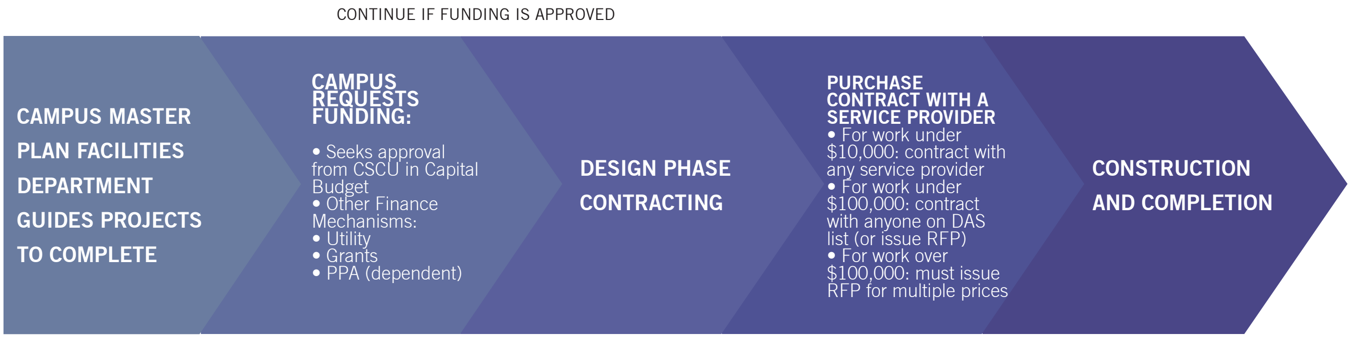
The RFP process must solicit three bids. The RFP process when used is for contracts over $10,000 in value. Universities or colleges can contract directly from any vendor for work under $10,000 in value.

The CSCU will support any CSCU college or university needing help in contracting. The CSCU Facilities contacts or purchasing agents are available to help.

The next image displays the energy project process:

- General Obligation Bond Process
- Self-funding through operating funds or capital funds with an energy line item

Where possible, the campuses seek outside funding such as through their gas and electric utilities and via PPA contracts.



2.6 FUNDING AND FINANCING

Implementation of energy projects is almost solely dependent on the funding available. The CSCU campuses make an effort to stay apprised of ways to finance projects that meet their fiscal year budgets and decrease burden on students. Figure 2.15 demonstrates the overall funding mechanisms currently available to the campuses.

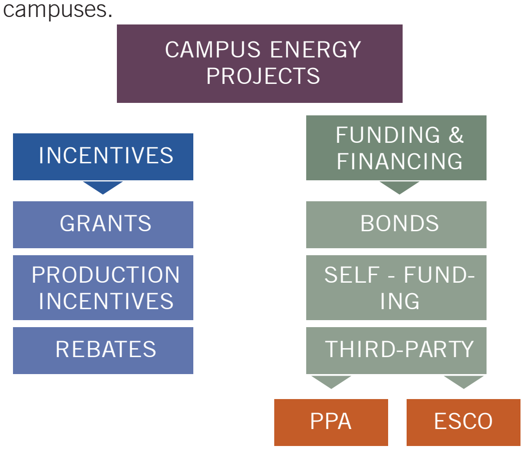


FIGURE 2.15: Funding, Financing and Incentive Types for Campus Energy Projects

Section 4 further describes the advantages and disadvantages of the various funding types. The CSCU develops capital budgets for the campuses based on the rollout of the prior year, high-cost program adjustments, enrollment projections, and tuition transfers. Campuses can request funding for energy-related projects through:

- Connecticut Health and Educational Facilities Authority (CHEFA) bonds (Universities only)
- CSCU 2020 for Capital Projects (Colleges & Universities)

2.7 COLLABORATION / PARTNERSHIP

Due to budget constraints and limited staffing availability, many of the campuses rely on outside resources to accomplish its energy goals. The CSCU Facilities will support any CSCU college or university needing help in contracting, for example. The Facilities Department CSCU staff, particularly the Project Management Staff, helps to support each campus to budget, plan and implement projects. The community colleges often rely on the office for technical guidance and project implementation. The Institute for Sustainable Energy at Eastern also provides support to the system with energy benchmarking and other services.

The campuses' electric utilities have also been proactive in identifying projects and provide substantial energy rebates and incentives, described in Chapter 4. Several campuses meet with their electric providers on a regular basis to discuss projects.

3

SYSTEM LEVEL ENERGY NEEDS

SYSTEM LEVEL ENERGY NEEDS

Facilities and Education Master Plans serve as roadmaps for campus development and aid in ensuring campuses can continue to provide exemplary resources to students. The CSCU campus plans also provide an indication of future energy use and needs based on the addition of planned infrastructure and projected changes in FTE enrollment. The campuses are in the midst of updating their current campus master plans, some dating back to 1998. Therefore, stakeholder input was important to understand where the campuses are headed, especially for those that still need their campus master plan updated.

To form a high level view of future campus growth and potential energy infrastructure needs, the following methodology was used:

- Projected future enrollment and projected building needs (GSF) were documented for campuses that had Master Plans with planning projection years past 2020
- For campuses that do not have an up to date master plan, information about planned building expansions was documented
- Based on the change in gross square feet between FY 2015 existing buildings and planned buildings, a qualitative value for Campus Building Growth was determined. Campus Building Growth was ranked as follows:

  a. Maintained: If the additional gross square footage change was less than 10%.

  b. Medium: If the additional gross square footage was between 10 and 50%

  c. High: If the additional gross square footage GSF surpassed 50%
- Based on knowledge of the campus existing infrastructure and the projected growth, a determination was made about the need to plan for future expansion.

Campus	FY 2015 Campus GSF	Fall 2013 FTE Enrollment (FY 2014)	Planning Projection Year	Fall FTE Enrollment based on Projection Year	Projected Space Need/ Planned Campus Expansion(GSF)	Campus Building Growth	Possibility for Energy Infrastructure Need to Accommodate Expansion?
Asnuntuck Community College	166,636	1,035	2020	NA	27,000 [2017]	Medium	Unlikely
Capital Community College	304,000	2,271	NA	NA	None Planned	Maintained	No
Gateway Community College	532,500	4,491	2020	8,330	To Be Determined	Maintained	No
Housatonic Community College	355,186	3,245	NA	NA	46,000 [2017]	Medium	Unlikely
Manchester Community College	473,662	4,450	2020	5,188	139,400	Medium	Unlikely
Middlesex Community College	122,237	1,711	2023	2,000 (825 for Meriden Center)	75,365	High	Yes
Naugatuck Valley Community College	598,276	4,374	2025	4,898	125,995	Medium	Unlikely
Northwestern Connecticut Community College	184,042	816	NA	NA	24,000	Medium	Unlikely
Norwalk Community College	350,765	3,854	NA	NA	NA	NA	NA
Quinebaug Valley Community College	143,282	1,095	NA	NA	11,000 [2016]	Maintained	No
Three Rivers Community College	295,644	2,752	NA	NA	None Planned	Maintained	No
Tunxis Community College	258,099	2,582	NA	NA	Reorganization only	Maintained	No
Central Connecticut State University	2,195,884	9,376	2020	12,207	1,776,619 (ASF)	High	Yes
Eastern Connecticut State University	1,808,915	4,778	2025	6,012	239,077	Medium	Unlikely
Southern Connecticut State University	2,152,440	8,834	2025	NA	294,000 (ASF)	Maintained	No
Western Connecticut State University	1,811,803	4,944	NA	NA	6,950	Maintained	No

TABLE 3.1: Campus Future Growth

3.1 ENERGY RESILIENCY

It is important for the campuses to have the energy infrastructure needed for sustainable expansion and reliable energy to support everyday functions and student learning. Factors impacting energy reliability include:

- High peak days
- Transmission constraints
- Extreme weather events
- Climate change

In 2015, the campuses underwent a hazard mitigation planning process to determine campus vulnerabilities to hazard events. One of the key findings was the need for expanded generator capacity in lieu of winter weather events, hurricanes and other hazards, which in the past have hindered or shut down campus operations. As CSCU expands it is vital for the campuses to have consistent power whether through generators, local power or micro grids.

FIGURE 3.1: Hazard - Downed Electric Wire

FIGURE 3.2: Hazard - Flooding

FIGURE 3.3: Hazard - Snow Storm

4 FINANCING / FUNDING OPPORTUNITIES

FINANCING / FUNDING OPPORTUNITIES

The aforementioned recommendations are largely dependent on payback. Often times, finding the means to financially execute an energy project is one of the biggest hurdles to project implementation. There are a variety of opportunities available to CSCU to finance and/or fund energy conservation projects. It is recommended that the campuses continue to pursue the outlined financial methods to help lower upfront costs for energy efficiency and renewable energy projects.

4.1 THIRD PARTY / POWER PURCHASE AGREEMENTS

As a public entity, CSCU is not able to take advantage of certain tax incentives such as the Investment Tax Credit and Production Tax credits, which have in the past been a main driver for renewable energy projects in Connecticut. However, working with developers who can take advantage of tax incentives is an option CSCU has pursued in the past. Entities that desire on-site generation without capital costs and associated maintenance often enter into power purchase agreements (PPAs). With this type of financial structure, the developer is responsible for obtaining the capital for project development, while the entity hosting the renewable energy site enters into a long-term agreement with lower electric rates. The host entity may also be able to monetize environmental attributes, depending on the structure. Eastern, Western and Central have entered into PPAs for their fuel cells and a few campuses are in the process of exploring solar opportunities through PPAs. This type of funding structure is recommended for the campuses to continue to pursue, especially related to renewable energy. Some advantages and disadvantages of PPAs are presented below:

Pros:

- Limited to no upfront capital cost
- No maintenance costs
- Locked in electric prices over long-term
- Customer may be able to maintain environmental attributes to go towards a renewable portfolio
- Budget Certainty

Cons:

- Risk of decreasing electric prices over long-term
- Not able to claim ownership of the system

4.2 LOANS

As a public university and community college system, the CSCU campuses are not authorized to obtain loans in a traditional sense. However, the campuses can have access to loan structures through third parties, in which the loans are built into the agreement. The state of Connecticut offers some programs with loans catered specifically to energy project agendas. For instance, Connecticut Green Bank, formerly known as Clean Energy Finance Investment Authority (CEFIA), attracts investors to deliver long-term private capital. The goal of the quasi-public agency is to promote investment in clean energy sources by developing financing programs with loans, leases, and credit enhancements. Links to the program can be found in the opportunities matrix at the end of the memorandum. The advantages of loans are shown below.

Pros:

- Limited upfront capital needed
- With good credit, can be a shorter process to access loans
- Many loan options

Cons:

- Interest rates
- Long payback period
- Limited by balance sheet

4.3 THIRD PARTY / ENERGY SERVICE COMPANIES

Other third party funding can be leveraged through the use of Energy Service Companies (ESCOs). Unlike traditional ESCOs, Connecticut offers their Energy-Savings Performance Contracting (ESPC) program. This program, under the umbrella of the Department of Environmental Protection (DEEP)'s Lead by Example Initiative and Energize Connecticut, allows for financing of a variety of projects outside of capital budgets. There is flexibility in the funding structure, as it also allows for cost savings from future operating budgets, self-funding and use of bonds. The program supports aggregation of larger projects with longer payback such as renewable energy and smaller projects, like lighting retrofits, to create an averaged smaller payback timeline.

The program offers a list of designated Qualified Energy Services Providers (QESP) that complete the program's work. These QESPs are under contract through the Department of Administrative Services. The campuses can select any of the qualified companies to complete an investment grade energy audit, then finalize the ESPC contract to make the energy project a reality. The steps of the performance contracting process are shown in Figure 4.1.

STEP 1: SELECT QUALIFIED ENERGY SERVICE PROVIDER

STEP 2: INVESTMENT GRADE ENERGY AUDIT

STEP 3: ENERGY FINANCING

STEP 4: FINALIZE ESPC CONTRACT

STEP 5: MEASURE AND VERIFY

FIGURE 4.1: Performance Contracting Process

The investment grade audit is provided at no upfront cost to the customer, provided the customer proceeds with energy measures. The audit price is ultimately rolled into project financing. However, it should be noted that the audit requires a fee if the customer decides not to pursue any projects through the program. More information about the program can be found at *http://www.ct.gov/deep/cwp/view.asp?a=4405&Q=513642.*

Some advantages and disadvantages for pursuing third-party funding, such as through the ESPC, are presented below:

Pros:

- Paid through savings
- No-cost audit (as long as additional measures are taken)
- Projects with longer payback can be bundled with projects with shorter payback
- Project construction can be completed quicker than traditional state procured projects

Cons:

- Projects must meet a certain payback period, otherwise they will not qualify
- Must choose from existing DAS approved contractors
- Requires an application process, which may be lengthy without adequate resources
- Operating cost savings are not realized in the early years as they are used to cover initial capital investment

4.4 INCENTIVES

There may be various funding sources available for the CSCU campuses to potentially pursue as they consider implementing various action items from this planning effort. Table 6.1 summarizes incentive programs that may be available to the campuses. Rebates and production-related incentives are types of financial avenues to be explored for energy-related projects. Low-interest loans are also included in the table.

CLASS III RECs

Agency: State

Technology: CHP

Description: In Connecticut, Cogeneration/CHP may qualify for Class III Renewable Energy Credits, in which the system can submit NEPOOL credits for monetary revenue quarterly. This incentive helps to meet Connecticut's Renewable Portfolio Standards. According to the eligibility requirements for Class III sources, the CHP unit must:

- Have an operating efficiency of at least 50%
- Contribute at least 20% of their energy output to electricity and at least 20% of their energy output to thermal energy
- Be installed on or after April 1, 2007
- Have a monitoring and verification plan (M&V)

Amount: Depends on market price, never exceeding $55/MWh

Link: *http://www.ct.gov/pura/cwp/view.asp?a=3354&q=415186*

ENERGY OPPORTUNITIES

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: Energy Efficiency

Description: Incentives are available through Connecticut's Investor Owned Utilities. Funding is available for upgrades when replacing or modifying inefficient, functioning equipment such as lighting, HVAC, chillers, motors, controls, water heaters and commercial cooking equipment.

Amount: Financial incentives are provided up to 40% of the installed costs. Zero-interest or low-interest rate financing. The program also offers "express rebates" for common measures for fast and convenient savings. Up to 80% of installed costs" with "Up to 80% of installed costs may be available if the project is a "Comprehensive Project," defined as containing more than one end use (Heating, Cooling, Lighting, etc.).

Link: *http://www.energizect.com/your-business/solutions-list/Energy-Opportunities*

OPERATIONS AND MAINTENANCE

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: O&M

Description: Utility company will identify opportunities for O&M. Energy efficiency measures suggested may be eligible for incentives to offset a portion of installed project cost. Examples: Repairs to defective steam traps, improvements to compressed air systems, rewiring of lighting circuits. Financial and technical assistance through the program helps customers make smart energy decisions and take advantage of advanced operation and maintenance practices and technology. This program is not intended for normal preventive maintenance and repetitive procedures or to subsidize major equipment purchases.

Amount: The program uses an incentive strategy. When there is a choice between standard-efficiency equipment and building components or a high-efficiency option that exceeds minimum building code requirements, the Agency evaluates the high efficiency option and propose a financial incentive to offset the higher costs typically associated with premium efficiency design. Find details on current incentive structures on utility's website.

Link: *General: http://www.ct.gov/pura/cwp/view.asp?a=3354&q=415186, Eversouce: https://clm.nu.com/clmtrs2/OnlineServices/CIWebInterestForm.aspx?company=CLP&pgm=EC; United Illuminating*

CHP DISTRIBUTED GENERATION RIDER

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: CHP, Fuel Cell

Description: Connecticut's investor-owned natural gas distribution companies provide a distributed generation rider. Under the rider, some distribution charges may be waived with the installation of a distributed generation system such as CHP system.

Link: *https://www.cngcorp.com/wps/wcm/connect/f68d3f80431291 82ab83af42207de083/21-Rider+DG.pdf?MOD=AJPERES&CACHEID=f68d3f8043129182ab83af42207de083*

NATURAL GAS WATER HEATING REBATE

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: Natural Gas Water Heater

Description: The Connecticut Energy Efficiency Fund has rebates for replacement of old equipment or installation of equipment during new construction with high-performance natural gas water heating equipment. The rebate cannot exceed 50% of the total Equipment cost. Additionally, steam boilers for used or rebuilt equipment are not eligible for a rebate incentive.

Amount: Depends on the equipment; please see the link.

Link: *http://www.energizect.com/your-business/solutions-list/Natural-Gas-Water-Heating-Rebate & https://efi.secure.force.com/client/FormCTHECIV1 & http://programs.dsireusa.org/system/program/detail/3941*

ENERGY CONSCIOUS BLUEPRINT

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: New Construction/ Major Renovation/ New-Replacement Equipment Energy Efficiency

Description: Financial incentives are designed to offset the premium cost of purchasing and installing energy-efficient electric and natural gas equipment.

Amount: Amounts are not explicitly stated on the site; it is suggested to follow up with utility.

Link: *http://www.energizect.com/your-business/solutions-list/Energy-Conscious-Blueprint*

CONNECTICUT GREEN BANK

Agency: State

Technology: Renewable Energy

Description: Green Bank either has (or has the ability to source) capital needed to finance renewable energy projects through a loan structure.

Link: *http://www.ctgreenbank.com/*

NATURAL GAS HEATING EQUIPMENT REBATE

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: Natural Gas Heating Equipment Rebate

Description: Rebates are available for the installation of qualifying high-performance gas heating equipment. High-efficiency natural gas furnaces and boilers can achieve an AFUE or thermal efficiency of up to 98 percent, compared to 70-80 percent with conventional equipment.

Many are designed to recover heat energy that is discharged into the flue and return it to the heat exchanger for maximum efficiency. That means most of the energy they use goes into producing heat, instead of literally going up the chimney. Features of high-efficiency natural gas furnaces and boilers include:

- Condensing flue gases in a second heat exchanger for extra efficiency
- Sealed combustion
- 82-98 percent AFUE or thermal efficiency

Amount:

Condensing Gas Boiler: $8/ Input MBH
Non-Condensing Gas Boiler: $4/ Input MBH
Condensing Gas Furnace: $4/ Input MBH
Condensing Gas Unit Heater: $2 /Input MBH
Gas Fired Absorption Heat Pumps: $500 /Ton
Natural Gas Infrared Radiant Heaters: $500- $850 /Unit

Link: *http://www.energizect.com/sites/default/files/C0222-2016-CI-Gas-Heating-Equipment-Rebate-2016-03-WEB.pdf*

NATURAL GAS INFRARED HEATER DEBATE

Agency: Utility (Eversource, UI, CNG, SCG)

Technology: Natural Gas Heating Equipment Rebate.

Description: Through the Connecticut Energy Efficiency Fund, rebates of $500-$850 per unit go towards the installation of low- or high-intensity natural gas infrared heater without paying a premium price.

Amount: $500-$850/ unit

Link: *http://www.energizect.com/your-business/solutions-list/Natural-Gas-Infrared-Heater-Rebate*

EXPRESS SERVICE LIGHTING REBATE

Agency: EnergizeCT

Technology: Lighting

Description: Rebates offered through designated utility for energy-efficient lighting, collaboration with Consortium for Energy efficiency, DesignLights Consortium and ENERGY STAR.

Amount: $5 to $180 per qualified energy-saving light fixture.

Link: *http://www.energizect.com/government-municipalities/programs/Express-Service-Lighting-Rebate*

THE COOL CHOICE CENTRAL AIR CONDITIONING REBATE PROGRAM

Agency: Norwich Public Utilities

Technology: HVAC

Description: Rebates for Electric heat pumps, single packaged units, split systems (must meet ARI specifications) and dual enthalpy economizer controls when installed with new, qualifying equipment.

Amount: $50 to $150 per ton for high-efficiency HVAC.

Link: *http://www.energizect.com/government-municipalities/programs/Cool-Choice-Rebate*

NORWICH PUBLIC UTILITIES - COMMERCIAL ENERGY EFFICIENCY REBATE PROGRAM

Agency: Norwich Public Utilities

Technology: Heat pumps, Air conditioners, Motor VFDs

Description: Norwich offers rebates, for upgrades of inefficient to efficient lighting. As part of their energy efficiency program, they also offer rebates for variable frequency drives installed on fans, pumps or process equipment.

Amount:

Heat pumps: $150- $300
A/C: $300/ton
Motor VFDs: $1000

Link: *http://www.norwichpublicutilities.com/index.php/for-my-business/efficiency-business & http://www.norwichpublicutilities.com/images/2015_CI_Efficiency_Program_Brochure.pd*

0% INTEREST LOAN PROGRAM

Agency: Norwich Public Utilities

Technology: Energy Efficiency

Description: By collaborating with local banks, Norwich Public Utilities offers a 0% loan program for energy efficiency upgrades for a term of up to 7 years. NPU pays the interest on the loans.

Link: *http://www.norwichpublicutilities.com/images/2016_0_Interest_Loan_Brochure.pdf*

NEW CONSTRUCTION PROGRAM

Agency: Norwich Public Utilities

Technology: Energy Efficiency

Description: Norwich Public Utilities offers rebates on the incremental cost difference between standard code and high efficiency lighting and equipment for new construction projects

COMMERCIAL AND INDUSTRIAL KITCHEN EQUIPMENT REBATE PROGRAM

Agency: Utility (Eversource, UI)

Technology: Energy Efficient Food Service Equipment, Commercial Refrigeration Equipment.

COMMERCIAL AND INDUSTRIAL KITCHEN EQUIPMENT REBATE PROGRAM

Agency: Utility (Eversource, UI)

Technology: Energy Efficient Food Service Equipment, Commercial Refrigeration Equipment.

Description: Energize CT offers rebates for natural gas cooking equipment to industrial, commercial and industrial customers. Gas rebates are only available to customers who are on firm gas rates. Customers of Eversource Energy, United Illuminating, Connecticut Natural Gas, or Southern Connecticut Gas are eligible for the rebate.

Amount: Incentives vary by size and equipment. Rebates offered cannot exceed 50% of the total equipment cost.

Pre-approval from the utility is required if the total rebate is greater than $5,000.

Link: *http://www.energizect.com/your-business/solutions-list/Commercial-Kitchen-Equipment-Rebate*

ZERO EMISSION RENEWABLE ENERGY CREDIT (ZREC) PROGRAM/LOW EMISSION RENEWABLE ENERGY CREDIT (LREC)

Agency: Eversource, UI

Technology: Renewable Energy/ Distributed Generation

Description: Eversource and United Illuminating offer the ZREC and LREC renewable energy program. Eversource & UI customers who install new, qualifying renewable energy projects -- ranging from rooftop solar panels to fuel cells -- have an opportunity to sell the qualified Connecticut Class I renewable energy credits (RECs) created from their projects to Eversource & UI under a long-term, 15-year contract. 1 REC is equivalent to 1000 kwh of electric output. Projects must be smaller than 1 MW to receive a ZREC contract, and smaller than 2 MW to receive a LREC contract.

Amount: Eversource/UI: There will be three annual LREC solicitations with a starting price cap of $200/REC, and the opportunity for two additional annual solicitations if PURA authorizes them.PURA has the option to modify the price cap after the first year's solicitation. $3.2 million in annual funding for LREC solicitation. $6.4 million for ZREC.

Link: *https://www.cl-p.com/Home/SaveEnergy/GoingGreen/Renewable_Energy_Credits/*

INTEREST RATE BUYDOWN PROGRAM

Agency: CT Department of Energy and Environmental Protection (DEEP)

Technology: Distributed Generation

Description: Low interest loans for customer-side DG. The interest rate is subsidized so it will be 1% below the customer's applicable rate or no more than the prime rate.

Amount: The combination of the projects should be $1 million or greater after subtracting any monies received from other funding sources.

Link: *http://www.ct.gov/pura/cwp/view.asp?a=3356&Q=504090&puraNav_GID=1702 & http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CT40F&re=1&ee=0*

AVAILABLE RESOURCES

Funding, particularly for grants, can be deadline dependent and subject to change depending on the legislative landscape. To monitor new or changing programs, the following sites are useful to check periodically:

- Energize CT: *http://www.energizect.com/your-business/find-a-solution#results*
- Dsire: *www.dsireusa.org*
- Connecticut Green Bank: *http://www.ctcleanenergy.com/* (CEFIA)
- Department of Energy and Environmental Protection (DEEP): *http://www.ct.gov/deep/cwp/view.asp?a=4405&Q=513760&deepNav_GID=2121*;
- Department of Energy: *http://energy.gov/public-services/funding-financing*

Energize CT in particular is a useful resource for locating funding opportunities. Their search engine is comprehensive and can be narrowed by subject. Figure 4.2 is an image of their website.

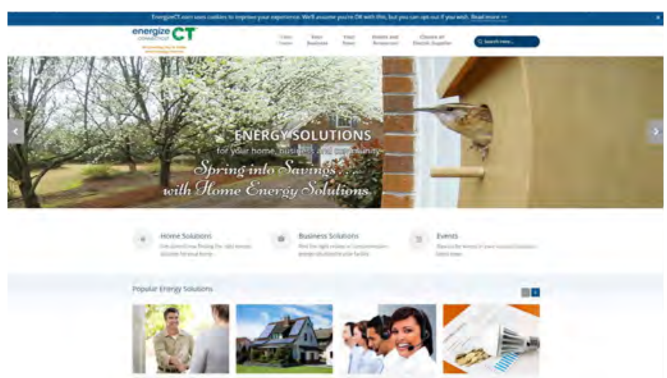


FIGURE 4.2: Energize CT Website

5 SYSTEM LEVEL RECOMMENDATIONS

SYSTEM LEVEL RECOMMENDATIONS

Based on data analysis, observations and conversations with campus and CSCU stakeholders, recommendations for a strategic energy plan and management program were developed. The recommendations aim to delineate a path that builds upon the CSCU's current programs to decrease cost and energy use, while increasing reliability. Implementation involves priority one to three initiatives with priority one initiatives occurring first. Below is a summary of the system-wide goals for the Energy Master Plan, in the five-year period after the plan's adoption, for reducing energy spending and energy use intensity.[1] The goals involve reducing each campus' energy intensity that is above the Northeast median EUI to at least 104 kBtu/sf. These goals are aspirational, based on implementing the recommendations summarized in the graphic, and not guaranteed outcomes. Following the graphic are specifics related to each of the goals.

SUMMARY	TODAY		5-YEAR GOAL
AVERAGE ENERGY USE INTENSITY (ANNUAL)			
UNIVERSITIES	**125** kBtu/SF	→	**104** kBtu/SF
COMMUNITY COLLEGES	**100** kBtu/SF	→	**90** kBtu/SF

PRIORITY 1

- DEVELOP PROCUREMENT APPROACHES
- CREATION OF FUNDING STRUCTURE
- ENERGY MANAGER / SUPPORT FOR DATA MANAGEMENT
- DATA MANAGEMENT AND MONITORING
- CREATION OF STEERING COMMITTEE
- • POLICIES
  • POWER PURCHASE AGREEMENTS
  • EEM PROJECTS WITH 1 YEAR ROI
- IMPLEMENTATION OF REVOLVING FUND

PRIORITY 2

- COGENERATION
- ENERGY PROJECT DATABASE
- TEMPERATURE GUIDE
- PROJECTS WITH PAYBACK GREATER THAN 1 YEAR

PRIORITY 3

- METERING

CSCU ACTION   CAMPUS ACTION   CSCU + CAMPUS ACTION

FIGURE 5.1: CSCU ENERGY MASTER PLAN ROADMAP

[1] Given the EMP energy reduction goals, it is estimated there is opportunity to achieve cost avoidance of approximately $4.5 million in the 5-year timespan. Assumed strategies for achieving cost savings include: EUI savings resulting from campuses implementing recommended EEM projects, solar PV PPA savings, electricity and natural gas procurement savings, capturing on-going incentives like Renewable Energy Credits (RECs) and capacity management savings. Actual energy cost savings must be considered with other capital expenses, budgets and operational priorities.

5.1 ENERGY PROCUREMENT AND FUNDING

5.1.1 DEVELOP INTEGRATED PROCUREMENT APPROACH

The CSCU is in the midst of procuring natural gas and electricity supply using a fixed price structure. Alternatively, a flexible procurement option would require CSCU to spend more time monitoring market conditions (most likely through a third party or new hired position). Due to the time requirements and infrastructure required to implement an integrated procurement approach, is not a tenable option for the upcoming procurement cycle.

For future energy procurement after this Energy Master Plan is completed, CSCU should explore a layered fixed price procurement strategy. Instead of buying long term, diversity in supply should be explored, as short as one year and as long as three year contracts. For instance, this may include 12, 24 and 36 month contracts reviewed as they elapse. Revisiting energy procurement annually is important to rebalance the mix of contracts. Layered fixed price procurement is somewhat more time and resource intensive due to multiple contracts, but this approach minimizes timing risks and allows for more flexible addition of new buildings.

It is advantageous for CSCU to have all of its procurement contracts in one centrally located place. Administratively, this saves time and helps determine which accounts may be more beneficial to bundle and which accounts to exclude. Evaluation and/or audits of all aspects of energy costs (i.e. supply, distribution, demand) is recommended annually to operate campus facilities at decreased costs. Depending on the energy contract and if rates are locked or not, the evaluation frequency may range from yearly to monthly. As more sophisticated controls and procedures are put in place, daily review may become a long term goal.

FIGURE 5.2: Solar Photovoltaic (PV) Installation

Immediate Steps to take:

- Prepare for current Energy Procurement RFP as was done in the past
- Begin to evaluate possibility of more incremental/layered procurement

Players/Resources:

- CSCU Finance Department
- CSCU Facilities Department
- Campus Facilities Department

5.1.2 CLARIFY FUNDING AND FINANCING PATHWAY

As outlined in Section 4, there are funding opportunities available to the campuses, some of which have been used previously and others, such as the ESPC program, which have yet to be explored. In order to take full advantage of available programs the CSCU should identify a formal funding plan for energy project implementation. The plan should include contact names, partnerships and the preferred/ most useful financing based on project type.

The CSCU should consider designating a staff member to monitor funding programs and complete annual research on opportunities to update the campuses. The CSCU should communicate the funding options that can be used by the campuses as projects are explored. It is also recommended as part of the plan to determine if there is budget available for an energy manager.

Immediate Steps to Take:

1. Outline the amount of energy budget to be allocated towards energy manager as opposed to energy projects
2. Identify additional or all funding pathway(s) for campuses to do energy work

Players/Resources:

- CSCU Finance Department
- CSCU Facilities Department

5.1.2.1 GREEN REVOLVING FUND (GRF)

Campus facility and building managers and others involved with energy-related expenditures do not typically have their energy projects savings reallocated into their budgets. Instead energy project savings are directed to general campus operating funds which may or may not be reallocated to the project originator.

This limits the campus' motivation to implement energy projects. To overcome this perception, a system level rather than campus level revolving fund structure is recommended allowing for savings reinvestment criteria to be better aligned. This will ensure savings are reinvested into energy projects, rather than being re-allocated for other, non-energy related, campus needs.

Since the green loan fund will originate at the system level, it may be important for the campuses involved to recognize direct benefit from the savings. The campus may share in operating savings or from implementing new warrantied equipment. CSCU will work with the campuses, on a case-by-case basis, to determine the timeline and dispersion of savings depending on project payback. The outcome is to replenish the fund with project savings.

Immediate Steps to take:

- Create proposal on the operation and structure of the revolving fund. Include:
  - **a.** how funds can be used;
  - **b.** who will select projects;
  - **c.** how projects will be selected; and
  - **d.** what the legal status of the fund will be.
- Determine the guidelines for the project
- Determine the maximum payback period, size of fund and when repayment will begin.

Players/Resources:

- CSCU Finance Department
- CSCU Administration

5.2 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

5.2.1 ENERGY MANAGER ROLE

For consistent energy management, the CSCU should create a role for a centralized person to initiate and monitor energy related measures. The CSCU energy manager's responsibility would include the following:

- Monthly tracking, analysis and reporting of energy use to identify potential usage anomalies and work with campus energy champions to mitigate causes
- Oversight of energy procurement of electricity and natural gas (including development of RFPs), negotiation with vendors and ultimate management of the contract.
- Coordinating standards and procedures across the campuses and aid in energy management of costs.
- Identifying and implementing energy conservation and greenhouse gas (GHG) reduction projects through the campus Facilities Departments.
- Involvement in renovation and new construction projects to ensure inclusion of energy performance targets, energy efficient building practices and use of renewable energy technologies
- Studying the benefits and feasibility of potential energy policies and projects.
- Assessing effectiveness of implemented policies and projects.
- Seeking feedback from campuses to improve and update system-wide energy policies, standards and practices.

Additionally, each campus should designate an energy champion who can act as the liaison between the campus and CSCU Energy Manager.

A difficult problem for campus energy managers is trying to reduce energy costs for a building or part of campus when the costs are accounted for as part of general overhead. One solution to this problem has been for top management to allocate energy costs down to "cost centers" in the campus budget. Managers then have a direct incentive to control energy costs to improve the overall cost-effectiveness of the production center. Details about how this would be accomplished will be discussed with CSCU stakeholders.

Immediate Steps to take:

- Examine options to identify a qualified (C.E.M. or equivalent) CSCU Energy Manager
- Designate an Energy Champion at each campus
- Allocate energy costs into "cost centers"

Players/Resources:

- CSCU Facilities Department
- Campus Administration

5.2.2 DATA TRACKING AND BENCHMARKING

CSCU should create a template for energy consumption and costs for reporting purposes across all campuses. For instance, CSCU should consider developing a database similar to DEEP's energy collection initiative. Each campus has its own form of energy data tracking, many of which originate from excel files from their respective finance offices. When the CSCU went out to procure energy they assessed a list of energy accounts, represented in a different form than at the campuses. Instead, there should be one spreadsheet or application to track data across all campuses.

Important information to include in the tracking is utility type, account number, service address, physical address, associated use/ building, energy consumption (in the same units) and cost by month. This practice will keep metrics consistent across campuses and can aid in supporting future procurement by keeping account information in one place. Each campus should designate a person to review energy data monthly and report it to the Energy Manager Quarterly. For ease of use in the long term, an investment in a visual energy dashboard is recommended. Energy use dashboards located and train in a public area of the building being monitored is also a great way to help encourage energy efficient behavior of faculty, students and staff.

CSCU campuses should utilize BMS Systems to track data where possible. Most of the existing CSCU BMS systems have the ability to track data. However, even though a data point can be viewed in the BMS, it is not necessarily being tracked and may not be accurate. Data logging must be properly setup to monitor energy use and store pertinent data. Sensors should be calibrated per the manufacturer, sometimes as often as every year.

Where a BMS is not available, stand-alone BTU-meters and electrical load loggers are recommended for accounts , considering cost, accuracy and advancements of meters. Tracking the energy use through utility bills will factor in the efficiency of the energy equipment. The benchmarking as part of this Energy Master Plan relied heavily on utility reports and monthly bills. When bills are used for energy data tracking, communication between finance (billing) and facilities departments are crucial.

Once the data is tracked, the campuses should continue to monitor metrics involved in reporting, including EUI, $/GSF, $/FTE and others. When comparing year over year, or month over month, it is important data is weather normalized to take into account the impact weather has on energy consumption. As part of the tracking process, the benchmarking data can also be reviewed on a monthly basis and compared to previous years. These metrics should be used as a catalyst to implement projects on campus.

Campuses should continue to monitor energy use for a continuous cycle of energy improvement and follow the Plan-Do-Check Act model. This model is a good way to continually assess energy programs and follow through on energy initiatives.

<u>Immediate Steps to take:</u>

- Create system wide energy use tracking template/database
- Vet template with campuses
- Ensure Facilities and CSCU Facilities Department have direct access to utility data and spending.
- Benchmark campuses

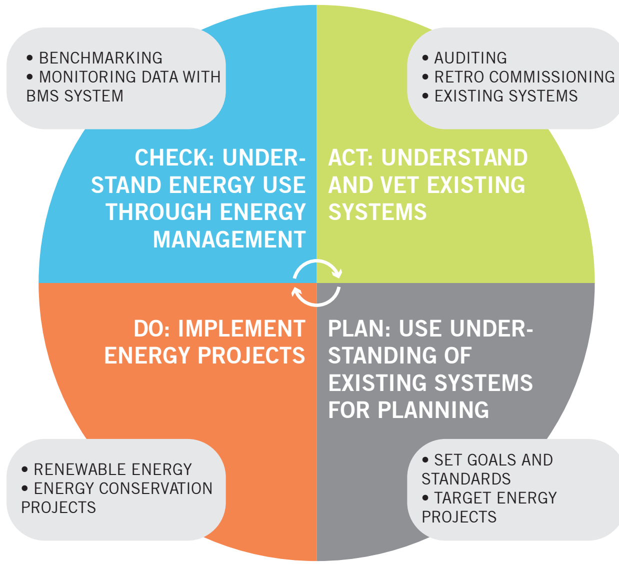


FIGURE 5.3: Plan-Do-Check Act Model

<u>Players/Resources:</u>

- Energy Manager
- Campus Finance Departments
- Campus Facilities Department
- Eversource CEP.
- Eastern's Institute for Sustainable Energy (ISE)

5.2.3 METERING

Energy submetering of all buildings' electrical use and thermal use is recommended at all CSCU campuses. Within buildings, energy monitoring should be considered for multiple thermal and electrical end uses such as preheating, heating, and reheating; humidification; service water heating; cooling; fans; pumps; lighting; and select plug and process loads. Energy monitoring for specific floors, or areas of a building can also help to better maintain operational performance over time. Energy monitoring can enable CSCU facility and building managers and engineers to more effectively identify energy problems and prioritize capital investments.

<u>Guiding Principles to Consider:</u>

- New Construction:

    a. Ensure new buildings have a separate energy submeter when connected to a central heating or cooling system.

    b. Include monitoring of every air handler, roof top unit, heating zone, electrical panel, pump, solar PV inverter, and thermal generator.

- Existing Construction:
    - **a.** Add BTU-Metering (flow meter with temperature in and out of a device) to every heat exchanger
        - **1.** Energy use is generally best monitored on the fluid side being heated rather than the fluid the heat is being transferred from. This is especially true for High Temperature Hot Water (HTHW) or steam central loops.
    - **b.** Add current transmitters (CTs) to every building electrical service panel feed
        - **1.** For enhanced monitoring include CTs on every major panel circuit
    - **c.** Use a plug load indicator such as a Kill-A-Watt® meter to estimate costs of non-critical equipment and unplug if cost is not justified
    - **d.** Install mini data loggers such as a HOBO® to track data deemed important such as:
        - **1.** Light on-off
        - **2.** Motor on-off
        - **3.** Temperature
        - **4.** Relative Humidity
        - **5.** Or any general 0 to 2.5-volt input

Players/Resources:

- Campus Facilities and/or Building Departments
- Eversource's C3 Platform which includes a benchmarking system

5.2.4 ENERGY COMMITTEE

Each campuses' energy capabilities are vastly different. Some campuses have more resources and are more advanced in their energy management, pursuit and implementation of energy reduction projects. It would be valuable for the CSCU to have an information sharing platform for all the campuses to learn from each other. Formation of an Energy Committee would encourage the continuation of unity across campuses and facilitate information sharing about a given campus' experience with a lighting contractor, a new BMS system or an innovative project. One representative from each campus that is well versed in the energy endeavors on campus is recommended to participate. Utility personnel should also be invited to stay apprised of new opportunities. When starting out, the meetings should occur fairly frequently, such as once a month, to establish consistency. Campuses should also do a brief documentation of existing projects and updates for tracking purposes.

Recognizing that the campuses are spread out geographically throughout the state, the energy committee could start out via conference call. However, the stakeholders should meet in person at least once a year in a central location.

Immediate Steps to take:

- Determine members of Energy Committee
- Assign a lead (Energy Champion)

Players/Resources:

- Eversource CEP
- Eastern's Institute for Sustainable Energy (ISE)
- Each Campus Facilities Department stakeholder or other point person
- CSCU

5.2.5 ENERGY PROJECT DATABASE

For ease of tracking energy-related efforts, the CSCU should consider creating an internal database/website or platform dedicated to energy. This will create a uniform project tracking system across campuses. The website or database should track past projects, upcoming projects and timelines. This platform can help with establishing potential energy project candidates for the revolving loan fund. A fully functioning database will encourage campuses to implement projects others have completed and create more awareness of opportunities. For instance, campuses can provide information on vendors or contractors that they have had positive and negative experiences in the past, as well as funding opportunities or other helpful information.

Immediate Steps to take:

- Identify resources available to develop project database
- Develop scope and cost to deploy database

Players/Resources:

- CSCU IT Department
- External consulting support, if necessary
- Energy Committee
- CSCU Facilities Department

5.2.6 COLLABORATION ACROSS CAMPUS DEPARTMENTS

Immediate Steps to take:

- Establish regular meetings or include energy into regularly scheduled business conversations

Players/Resources:

- Campus Facilities Departments
- Campus Finance and Procurement Departments
- Campus Academic Affairs
- Campus Administration
- CSCU

5.3 OPERATING POLICIES AND ENERGY STANDARDS

Facility and building managers will benefit from a consistent application of operating policies. The intent of recommended policies/standards are to coordinate and streamline energy operating procedures across the system. A system-wide strategy provides a clear framework of expectations to help support energy driven improvements and consistency across all campuses. Operating Policies and Energy Design Standards are tools for achieving higher energy performance. The below sections outline policies and standards recommended for CSCU.

5.3.1 TEMPERATURE GUIDELINES

Adjusting system set points can have one the quickest returns on investment since little to no capital is needed to realize energy savings. Set points can be adjusted for a multitude of points with modern BAS/BMS. Where a building energy management system is not available, stand-alone, programmable thermostats or independent controls can be purchased for as little as $50. CSCU should consider producing temperature guidelines that may include building set points related to offices, classrooms, residences and teaching labs (as applicable). The guideline can serve as a tool for campuses, and should reemphasize current Connecticut statutes of cooling and heating ranges as well as ASHRAE's set points. Some temperature guidelines to consider are as follows:

- A recommended temperature guideline which is used successfully at other colleges and universities to save energy while maintaining comfort is a 68°F heating set point and 77°F cooling set point.
- Certain laboratory or similar spaces may need set points adjusted to be cooler or have a smaller temperature band and may in turn use more energy. Garage or maintenance spaces should have a lower heating set point between 60°F and 65°F, or even lower if tolerable by staff.
- Air stratification in spaces with high ceilings, such as atriums, may benefit from the addition of ceiling fans, while garages with infrared heating technology should consider installing infrared thermostats to better account for the combined effect of ambient and radiant surface temperatures.

Strict temperature set point policies rather then guidelines may cause occupant discomfort and amplify the need for HVAC upgrades such as VRF systems, increased zoning in buildings, or building envelope improvements such as window draft sealing. The savings from energy efficient temperature set points will more than offset the cost of most building improvements required for occupant comfort.

It is important to remember set points are only good if the equipment is calibrated and working properly. AHUs may have all the correct set points, but if a damper linkage is loose or a pressure transmitter is clogged, appropriate set points can do nothing to save energy. Preventive maintenance and calibration of sensors and thermostats is imperative to achieve effective set points.

Building commissioning should have adjusted available set points with occupant comfort and energy efficiency in mind. Because commissioning does not always take place, or was not done properly the first time, or systems and space uses change, existing building commissioning will help optimize the set points, and detect and correct problems as they are found.

Immediate Steps to take:

- Engage administration early in the purpose and benefits of temperature standards.
- Use Appendix B as reference for different temperature standards

Players/Resources:

- Campus Facilities Departments
- CSCU Facilities Department
- CSCU Administration
- Energy Steering Committee

5.3.2 LEVERAGE LIGHTING UPGRADES

A general finding from the walkthroughs at each campus was that there continue to be opportunities for lighting upgrades. Lighting technology rapidly improves and tend to have a quick payback. It is recommended for the campuses to reevaluate the latest lighting technology every 5 years. Campuses should pursue lighting opportunities that have a payback of 5 years or less with utility incentives.

The electric utilities continue to have incentives and rebates for lighting, and these should be continuously monitored while working with utility representatives. Savings from lighting projects often help bring down the payback for other projects.

Players/Resources:

- Campus Electric Utilities
- Campus Facilities Departments
- CSCU Facilities Department

5.3.3 COMMISSIONING POLICY OR STANDARDS

This policy will reinforce the importance of building commissioning for new construction and renovations as required in § 16a-38k-3a of the Connecticut Compliance Manual for High Performance Buildings. The policy should include methodologies to enforce proper closeout of commissioning by identifying deficiencies in previous projects. Timeframes for existing building commissioning (EBCx) should also be covered. An ideal policy would necessitate a plan for training staff in preventative maintenance and new system operations. Training specific to the systems involved should be provided as part of commissioning and documentation should be complete and thorough. The policy may include guidelines for selecting building candidates for EBCx, such as consideration of unjustified, high EUIs, newer equipment and a building with accessible, up-to-date building documentation. Some example policy requirements may include:

a. Immediately retrocommission any buildings or systems built within the last 12 years that have not already been commissioned

b. Recommission existing buildings at a minimum of every 5 years

c. Employ continuous commissioning on all buildings greater than 100,000 square feet.

Players/Resources:

- CSCU Facilities Department
- CSCU Administration
- Energy Steering Committee

5.3.4 ENERGY DESIGN STANDARDS

A consistent set of energy design standards across the campuses is recommended. The standards may be structured around existing ANSI/ASHRAE Standards and the Connecticut Compliance Manual for High Performance Buildings. Requirements for larger renovation projects or new construction may be rolled down to smaller renovation and equipment upgrade projects.

In addition, CSCU should begin to identify building energy performance levels and targets (kBtu/square foot) to optimize building performance and energy use.

For the most up-to-date information, a review of updates to energy efficiency design standards is recommended every three years. Building Standard Guidelines should be used for renovations and upgrades in addition to all new construction projects as mandated by State and Local Code. The specific guideline for the State of Connecticut is, Connecticut Building Standard Guidelines Compliance Manual for High Performance Buildings, and can be found at:*http://www.ct.gov/deep/lib/deep/energy/buildingstandards/compliancemanualhighperformancebuildings.pdf*

Although not a standard, the Energy Management Handbook, 8th Edition, by Steve Doty and Wayne C. Turner, is an excellent resource for all facilities and energy managers.

Guiding Principles to Consider:

- Ensure contractors, designers and engineers selected for a project have a full understanding of all applicable design standards
- Ensure applicable energy design standards are commissioned properly so systems operate as intended by standards
- Consider establishing building energy performance targets that must be met in new construction and renovation projects

Players/Resources:

- CSCU Administration
- Campus Facility or Capital Planning Departments
- Connecticut Division of Construction Services (DCS)

5.3.5 REVISION OF EXISTING STANDARDS

It is advisable for campuses revise existing standards with an energy use perspective. For instance, electrical standards can be revised to incorporate best available energy efficiency technology, including recommendations of LEDs. HVAC standards may be revised to include specification around active controls in special spaces with CO2 and occupancy sensors. These standards should be streamlined across all campuses.

Immediate Steps to take:

- Update standards to incorporate best practices

Players/Resources:

- Campus Facilities Departments
- CSCU Facilities Department
- Energy Committee

5.3.6 ENERGY AUDITS

Energy audits are often necessary to find, prioritize, and validate energy and cost saving opportunities. CSCU should consider creating a standard that would encourage energy audits for all buildings older than 2005, when the current building standards were created. Energy audits are recommended to be completed through Connecticut's Energy-Savings Performance Contracting (ESPC) program, discussed further in the financing/ funding opportunities section. The ESPC program is unlike a traditional ESCO program, in that projects are not tied to the savings. If this path is chosen, this could provide CSCU with flexibility in. The projects suggested should be cataloged in a project list for future reference.

Immediate Steps to take:

- Benchmark campuses on a building level to the fullest extent possible as additional energy meters are installed.
- Conduct ASHRAE Level II or similar energy audits where preliminary analysis of energy use indicates a higher than average intensity
- Implement recommissioning activities every 5 years which will include many of the monitoring/metering/testing aspects of a Level II audit

Players/Resources:

- Campus Facilities Departments
- CSCU Facilities Department

5.3.7 LIFECYCLE COST ASSESSMENT FOR ENERGY PROJECTS

The CSCU should consider adopting a policy for implementing feasibility studies to look at lifecycle and operating costs of Capital Projects. Currently campuses can choose not to look at lifecycle costs for their capital projects. The CSCU should consider a threshold amount when instituting a feasibility study. For instance, if the Capital Project is projected to use energy costing over $100,000 then a feasibility study should be implemented to ensure that the payback is as stated. This standard will provide an impetus to ensure a project will provide the return expected. Parameters that should be considered include: project costs, energy savings, and operations and maintenance costs as well as project timeline.

5.3.8 OCCUPANCY STANDARDS

An occupancy standard provides guidelines on the use of existing space to prevent unnecessary over conditioning of unused or unconsolidated spaces.

For instance, guidelines may specify that classroom spaces must be designed for a certain percent occupancy when in use. It can also suggest that space must be used for its assigned purpose, and otherwise should be under review. Working with the administration to consolidate classes and optimize schedules should be considered.

Immediate Steps to take:

- Evaluate current occupancy guidelines

Players/Resources:

- Campus Registrar's Office
- Campus Facilities Departments
- Campus Administration Department

5.4 RENEWABLE AND ALTERNATIVE ENERGY

5.4.1 SOLAR PHOTOVOLTAIC OPPORTUNITIES

By far, the largest energy spend on each campus is for electricity. Renewable energy, onsite as well as offsite, provides an opportunity to decrease costs while supporting energy resiliency and sustainability goals. Specifically, it is recommended that the campuses continue to pursue solar PV opportunities. Each campus plan outlines specific solar opportunities that campuses should consider in the future inclusive of high priority and lower priority placement of panels. Before pursuing a solar option, electric load should be reduced as much as possible through energy efficiency and other recommended measures.

The CSCU should continue its role as arbitrators of the RFP solar process. It is recommended to bundle solar opportunities greater than 100 kW to attract larger investors.

Guiding Principles to Consider:

- Ensure the existing roofing system is compatible with the PV system and will provide at least 20 additional years of useful service.
- Ensure the roofing warranty is not compromised by the PV system installation coverage.
- Follow guidelines and standards set by FM Global to ensure the PV system will weather storms and not void insurance coverage.
- Anticipate and prepare for additional rooftop traffic on membrane surfaces.

- Compare the life-cycle cost through competitive bids for ballasted and mechanically adhered systems.
- Ensure installing contractors have a sound understanding of commercial roofing systems and practices to best approach the project.
- Pursue off-site/net-metering applications when on-site opportunities are limited, not cost effective or if more carbon reduction/cost savings are needed.

Players/Resources:

- FM Global
- CT Green Bank
- ZREC Program
- CSCU

5.4.2 COGENERATION

Cogeneration is a beneficial option for increasing localized electric generation in combination with creating useful thermal. Currently the universities and Naugatuck Valley are the only candidates for CHP due to their centralized systems. A campuses grow, the CSCU should periodically reassess opportunities for CHP.

When screening for the feasibility of CHP, the following conditions make CHP an attractive option for a campus:

- Low natural gas prices and high electric utility rates,
- A constant thermal demand throughout the year,
- Campuses with a central plant with district heating and cooling,
- Utility or state incentives that support CHP, and
- Ease of installation with existing headers and availability of space.

Campuses which have central plants and demand throughout the year are considered preferred sites for CHP. District heating and cooling through a central plant are usually necessary to make efficient use of a CHP since an accumulation of smaller building loads are connected through a central hub and economies of scale help reduce the project cost per kW.

Specific recommendations for the campuses moving forward are in the individual campus plans. A major financial instrument for CHP is Connecticut's Renewable Energy Credits Class III. When pursuing a CHP project, the campuses should immediately consider the requirements for registration of the site as it can be a lengthy process. This includes understanding how energy generation will be adequately metered to capture RECs. It is recommended for CSCU to be the intermediary for CHP pursuits, including administering applicable RFP CHP procurement processes.

Players/Resources:

- Campus Facilities Departments
- Distributed Generation Rebate Rider
- RECs
- Campus Facilities Departments

5.5 NEXT STEPS

With the programmatic recommendations provided in this Energy Master Plan, CSCU has an approach to accomplish broad reaching energy improvements. Energy reductions will aid in advancing fiscal responsibility, promote sustainability and improve energy reliability. The recommendations mentioned would not be possible without the collaborative effort of all the campuses. Each CSCU campus has diverse energy use patterns as a result of varying campus sizes, resources and program offerings. The subsequent chapters provide an individual assessment of each campus, and additional recommendations for streamlining energy management and decreasing energy use at the campus level.

APPENDIX A: ENERGY PROCUREMENT MEMORANDUM

As part of the Energy Master Plan, the way the CSCU System procures energy is being examined. This includes an inventory of current energy contracts, with an eye on costs, contract deadlines, and contract structure. The purpose of this memorandum is to examine the benefits of a procurement strategy.

While there are the standard delivery charges for fuel and electric that cannot be avoided, energy supply prices frequently fluctuate, providing an opportunity to procure energy in a way to control costs. The right procurement fit can afford flexibility and ultimately savings.

To understand what aspects of the energy charges the customer has strategic control of, it is necessary to know the components of the energy bill.

WHAT IS IN A UTILITY BILL?

Customers that are served by an investor owned utility are regulated under Connecticut's Public Utility Regulatory Agency (PURA). The electric and natural gas delivery rates are approved by PURA and then incorporated into the customer's bill, dependent on the customer's rate class. These amounts are static and only adjusted after the distributed utilities go through a formal regulatory process to request an increase in rates, and when PURA reviews and deems the increase fair to the rate payers.

ELECTRICITY

In the case of electricity, customers are both charged on a kWh basis as well as a kW basis. Figure 1 and Figure 2 are examples of the static delivery charges by Eversource, formerly CL&P, for a small general electric service in 2016.

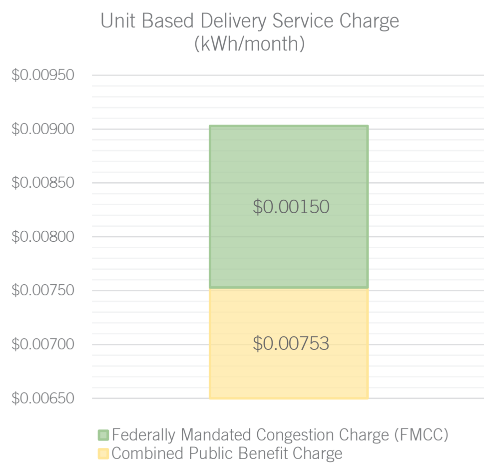
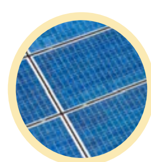


FIGURE 1: 2016 Small General Electric Service Eversource Static Delivery Charges

FMCC: A federally mandated charge related to the reliability of supply delivered by the electric system.



Combined Public Benefit Charge: Represents a combination of the Conservation and Load Management charge, Renewable Energy Investment Charge and Systems Benefits Charge.

Transmission: The charge for delivery of electricity over the high-voltage power lines from the generation company to Eversource.

Distribution: Eversource charges for delivery of electricity over poles and wires to homes and businesses.

Competitive Transition Assessment (CTA): The charge that allows the electric distribution company to recover restructuring-related stranded costs.

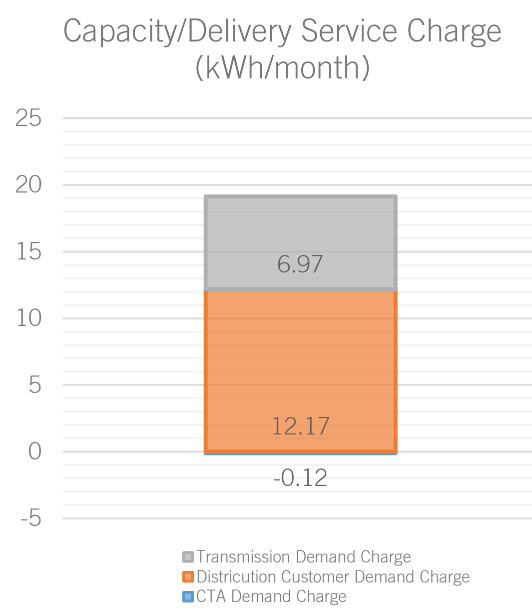


FIGURE 2: 2016 Small General Electric Service Eversource Static Delivery Charges

Depending on the rate class, charges can also vary on time of use and kVA and have a standard flat charge, but are still mandated by PURA. Other than active consumption reduction, flexibility for the customer may be provided in competing rates for supply, which can be shown as follows on the itemized line of a bill:

Allocated use for 16 days	**(Jun 30 to Jul 16)**	
Generation Detail	**DIRECT ENERGY BUSINESS**	
Generation Srvc Chrg**	**641.60KWH x $0.075560**	**$48.48**
Subtotal		**$48.48**

FIGURE 3: Sample Electric Supply Charge on Utility Bill

NATURAL GAS

Similar to electric, natural gas has standard rates depending on the rate class and charges aimed to cover administrative costs as well as infrastructure maintenance. Following is a Eversource (formerly Connecticut Natural Gas Corporation) bill example.

Current Supplier: Connecticut Natural Gas Corporation			
Customer Charge		$	47.50
Delivery Charge	100.000 CCF @ $.549100	$	54.91
Delivery Charge	170.000 CCF @ $.150600	$	25.60
Peak Day Charge	18.000 CCF @ $.950000	$	17.10
Distribution Integrity Management Program	18.000 CCF @ $.173800	$	3.13
Sales Service Charge	18.000 CCF @ $.303500	$	5.46
Purchased Gas Adjustment	270.000 CCF @ $.341900	$	92.31
Conservation Adjustment Mechanism	270.000 CCF @ $.046000	$	12.42
Decoupling Adjustment	270.000 CCF @ $.032100-	$	8.67cr
System Expansion Adjustment	18.000 CCF @ $.017900-	$	0.32cr
Total Gas Charges		$	249.44

FIGURE 4: Eversource Natural Gas Bill Example

Charge descriptions from the sample bill are explained further below:

- **Customer Charge** — A fixed monthly charge designed to recover the Company's basic administrative expenses associated with maintaining and servicing a customer account.
- **Delivery Charge** — A charge for moving natural gas across the Company's distribution lines to a customer's home or business.
- **Peak Day Charge** — A charge for providing local pipeline space to accommodate the customer's highest daily usage.
- **Distribution Integrity Management Program** — A charge for expenses related to any pipeline replacement for cast iron and bare steel mains and services each year. This factor is established annually including prior year true-up as approved by PURA.
- **Sales Services Charge** — A fee designed to recover unique costs from those customers that receive their gas supply directly from the Company.
- **Purchase Gas Adjustment** — A charge that collects the total cost of gas consumed. This rate will change monthly as approved by PURA.
- **Conservation Adjustment Mechanism** — A charge that collects the cost of conservation programs available to customers. This factor is established annually.
- **Decoupling Adjustment** — A factor established annually to enable CNG to collect distribution system revenues as approved by PURA in rate case proceedings.
- **System Expansion Adjustment** — A factor established annually related to costs of expanding the natural gas infrastructure.

Additional charges that may be found on a bill include:

- **TSC On-site Demand Cost** — A transportation services charge that is designed to recover unique administrative costs specific from those customers that receive their gas supply from a third-party supplier.
- **TSC Shifted Cost** — A transportation service charge that is designed to recover supplier of last resort costs from those customers that receive their gas supply from a third-party supplier.
- **Daily Demand Metering Charge** — A fixed monthly charge for the cost of providing daily usage information.

While some of the charges cannot be altered, procurement on the supply side provides an opportunity to see savings.

ENERGY MARKETS

Energy Markets are dynamic and dependent on various market drivers, which can result in fluctuating supply prices under the local distribution companies.

Market Drivers include:

- Pipeline Development
- Transmission Development
- Natural Gas Storage Levels
- Short and Long Term Weather
- Renewable Energy
- Environmental Concerns

Particularly in New England, electricity prices are often tied to natural gas supply as natural gas is more frequently used now for generation of electricity, not only for heating requirements. In the short period between 2000 and 2015, the electric supply mix in New England has changed substantially, as shown in the image from ISO-NE. Currently, almost 50% of the supply mix is natural gas.

FIGURE 5: ISO-NE Supply Mix 2000 vs. 2015

New England does not have an unlimited supply of natural gas due to pipeline constraints. Additionally, as oil and coal-fired generation plants close or retire in the near future, the need for natural gas infrastructure is projected to increase. Since natural gas is needed for both a baseload supply for electric generation as well as for heating, the projected weather for winter months can have a large impact on pricing. If the winter is forecasted to be harsh, more natural gas can be allocated to electric supply reserves, driving up the cost for heating due to an expected shortfall for heating purposes. The Figure 6 image from ISO-NE shows the price disparity in winter and summer in comparison to the Midwest, where there are less natural gas constraints. The Midcontinent ISO prices stay relatively flat compared to a more than double price of electricity in ISO New England. The price of natural gas quadruples.

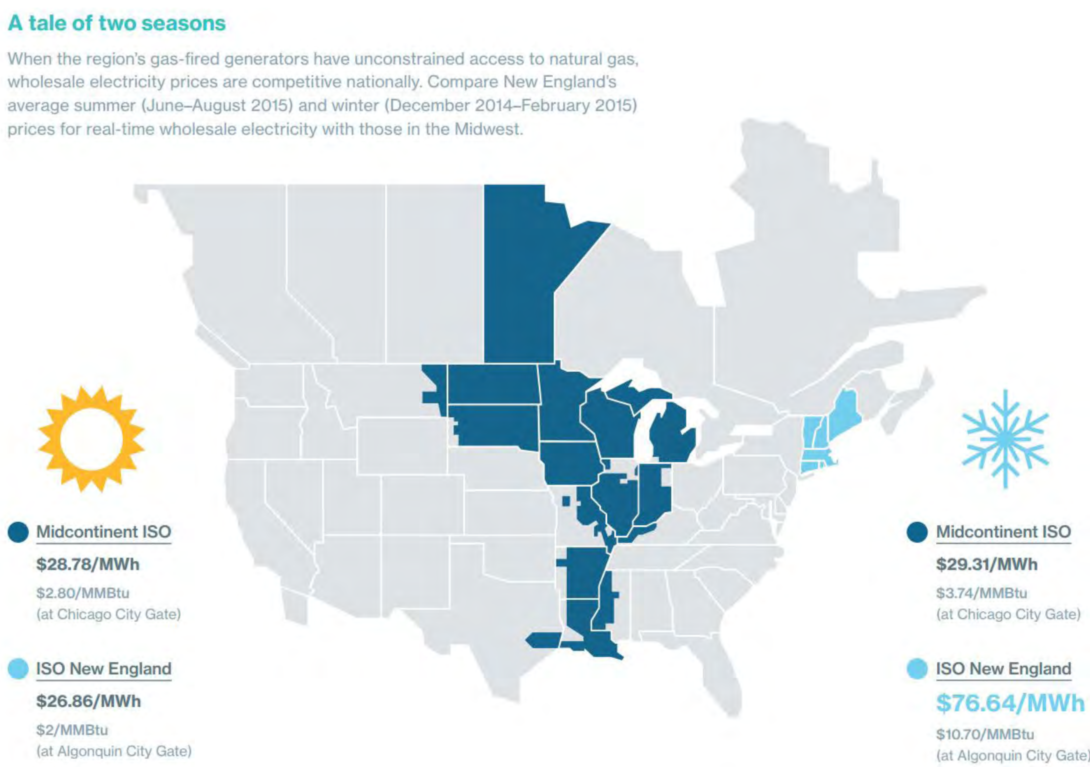


FIGURE 6: ISO-NE Summer and Winter Pricing Comparison

Understanding these trends and procuring energy from a supplier can benefit the customer by locking in prices in a volatile market.

TYPES OF PROCUREMENT STRATEGIES

Customers that choose to participate in competitive markets have options in considering how they want to balance risk and budgetary requirements. There are various procurement contract types that a customer can enter that range from fixed to variable described below:

1. **Fixed:** Customer enters into a contract with a set price of the energy commodity over a certain term, as CSCU has done in the past. With a 100% fixed scenario, the customer can choose to go out to bid for a certain term (normally 12, 24 or 36 months) with a fixed price.

2. **Layered fixed price:** Rather than choosing a bulk purchase over a time period, the customer can purchase percentages or layers of energy at varying times. Buying smaller percentages of energy can provide more flexibility enabling the customer to enter the market at different times to take advantage of possible lower prices.

Layering Option from FirstEnergy Solutions

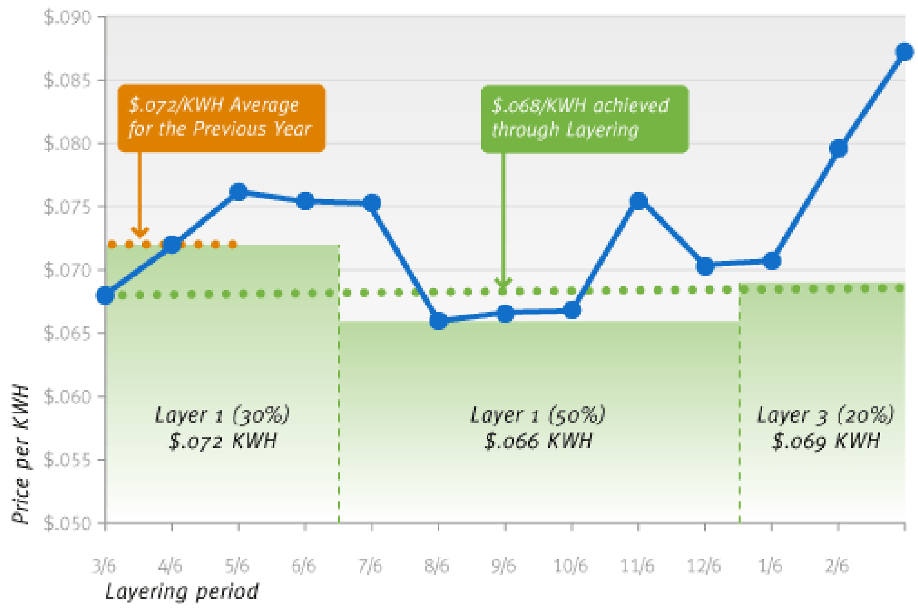


FIGURE 7: Layering Option Depiction

ADVANTAGES

- Control energy costs with a set budget
- Provides stability in a market with fluctuating energy prices
- Ideal if operating with limited administrative or management resources

DISADVANTAGES

- Market risk; if energy prices fall, contract is still locked in
- Generally, have to pay a fee if you want to end contract early

3. Flexible or Index: This strategy allows the customer to monitor the energy market and participate when it seems advantageous to them, paying a variable rate for the energy commodity. Instead of buying at one point in time and locking the price in, this strategy is more actively managed through contracts with continuous purchasing.

ADVANTAGES

- Get the best market rate by monitoring the market
- Not fixed with one supplier

DISADVANTAGES

- Requires more time and resources to ensure the most advantageous prices
- Requires frequent market monitoring
- More risk, less predictability

A combination of the two strategies can also be used, in a blended structure. For instance, the customer can fix 60% of their energy while the remainder is flexible with a variable price rate. Different types of procurement strategy are displayed in the image below from Compete Coalition, adapted from a Constellation study on procurement strategies.

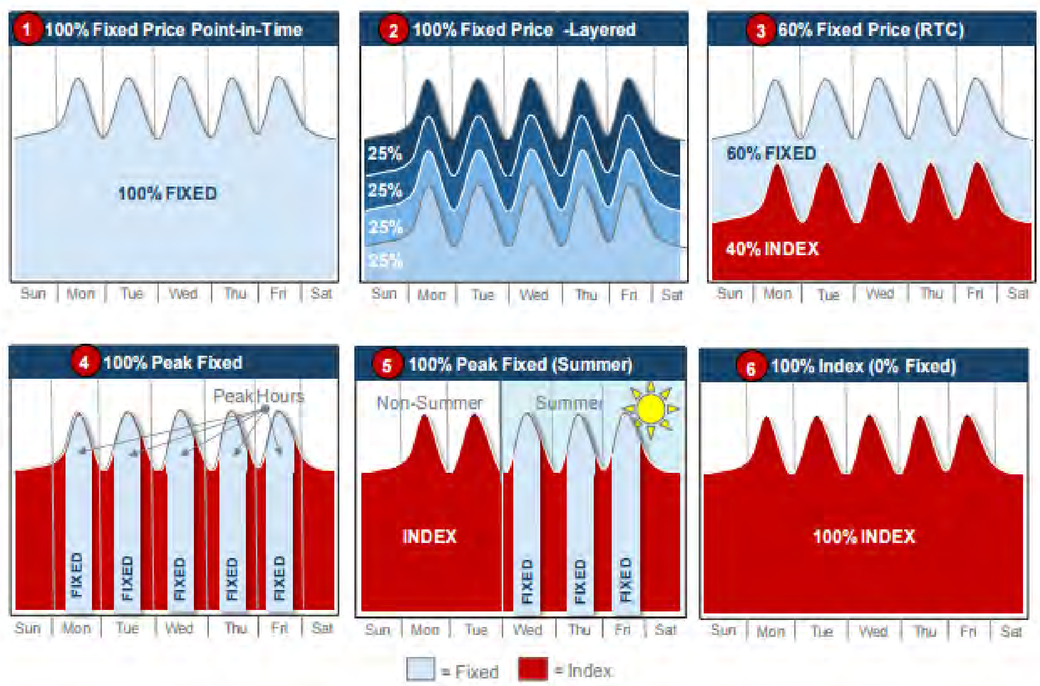


FIGURE 8: Depiction of Six Electric Pricing Plans

It is important to determine the customers' existing consumption patterns and risk appetite first and then decide on a procurement strategy. The most important component of a procurement strategy is developing a RFP. RFP(s) for energy procurement should be structured to ensure equitable, transparent and comparable pricing. A typical RFP includes:

- Site information and accounts
- Proposal Requirements
  - a) Service type (firm)
  - b) Delivery Point
  - c) Term/Start Date
  - d) Pricing
  - e) Delivery Tolerances
- Usage
- Proposal Instruction, Evaluation Criteria and Schedule
- Terms and Conditions
- Insurance Requirements
- Other vendor recommended opportunities

As part of and through the RFP process, the key to effective procurement is to understand the goals and the constraints of CSCU. Considering the magnitude of the spend on electric and gas, it would be highly advantageous for CSCU to develop a management process around procurement. Steps for this include:

1. Consolidate purchased commodity data
2. Determine goals
    a) Fixed Price (or what portion at fixed rate)
    b) Duration
    c) Attributes
3. Develop RFP
4. Issue RFP

Based on our review of the CSCU system and the management time a more complex procurement strategy may require, CSCU is likely best suited to a "passive" mixed duration strategy at fixed prices. This would include a mix of 12, 24 and 36 month contracts that would be reviewed as they elapsed. Ideally revisiting energy procurement once a year to rebalance the mix of contracts. Further discussion and evaluation will be required to determine the best approach but the same process of competitive evaluation as previously conducted and outlined above is the best practice.

POWER PURCHASE AGREEMENTS

Another form of energy procurement, in particular for distributed generation projects that have tax incentives or other attributes that are not routinely monetized, is the power purchase agreement (PPA). Entities that desire on-site generation without capital costs and associated maintenance, often enter into PPAs. With this type of financial structure, the developer is responsible for obtaining the capital for project development, while the entity hosting the renewable energy site enters into a long-term agreement with lower electric rates. Below is example of how a PPA structure can work.

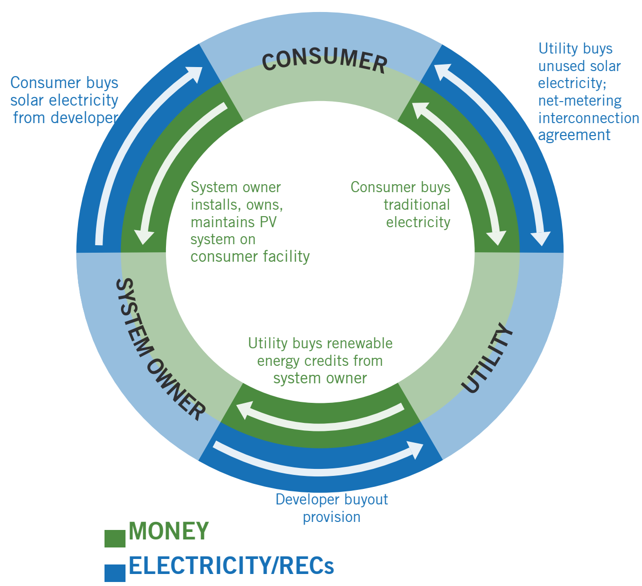


FIGURE 9: PPA Terms and Financial Structure

APPENDIX B: OPERATING POLICIES AND ENERGY DESIGN STANDARDS MEMORANDUM

The purpose of this memorandum is to present a range of operating policies and energy design standards that may be implemented to address energy use and reduce energy consumption over time. Operating Policies and Energy Design Standards are tools for achieving higher energy performance. Some recommendations are design-based and must be implemented as part of a construction / renovation project, while others are operations based and can be implemented over time.

1.1 AUDITING

The result of an audit typically includes analysis of energy use data and creation of a list of energy efficiency measure (EEM) recommendations.

There are several formal levels of Energy Audit as defined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)), each corresponding to a higher level of complexity, thoroughness and investment of time and resources as shown in Figure 1.

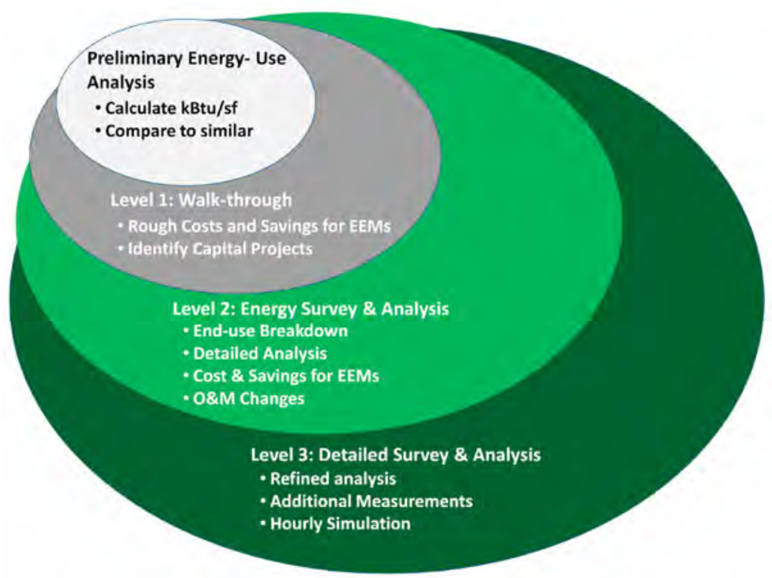


FIGURE 1: Relationships of ASHRAE Energy Audit Levels 1, 2, and 3

Source: ASHRAE-D-90450- Procedures for Commercial Building Energy Audits, Second Edition

Consistent Preliminary Energy-Use (PEU) screenings were provided with campus and building level energy use where data as well as targeted Level I walk-through energy audits. Each type of audit includes the following:

Level I: Site Assessment or Preliminary Audits

- Assessment of energy data accrued from energy bills,
- Campus visit for visual inspection of prioritized buildings or features,
- Identification low-cost/no-cost recommendations, and
- Identification of capital improvements,

Level II: Energy Survey and Engineering Analysis Audits

- All aspects of a Level I audit plus:
- Review mechanical and electrical design and condition practices,
- Measure key parameters,

- Analyze capital measures (savings and costs, including interactions), and
- Meet with owner/operators to review recommendations
- The last task associated with a Level II audit will be scheduled either in person or remotely as time allows for each CSCU campus

Level III: Detailed Analysis of Capital-Intensive Modification Audits, Investment Grade

- All aspects of a Level II audit plus:
- Comprehensive recommendations along with investment grade financial return on investment calculations,
- Detailed cost estimate for ECM recommendations provided by a cost estimator / contractor,
- Preliminary system designs and sizing may be required to develop an accurate cost estimate,
- Perform detailed system modeling,
- Provide schematic layouts for recommendations, and

Level III audits include additional testing/monitoring of energy data through a metering program General guiding principles when considering energy auditing are:

- Have Level 1 audit features be a continuous process, review energy and identify capital improvements on a yearly basis.
- Conduct a Level 1 audit, if never performed, and if at least 2 years of utility billing data are available.
- Conduct a Level 2 energy audit for buildings that have:
  a) a combined conditioned area of 25,000 square feet or larger, and
  two years of utility billing history are available, and
  b) Monthly electric demand is greater than 60 kW, and
  c) Building end-use data is available or can be collected.
- Conduct a Level 3 energy audit:
  a) When previous audits identify a system or building which has evident room for improvement and a need to target specific high energy use systems.
  b) Before large capital expenditures take place on a system that does not have a clear return on investment.

1.2 STRATEGIES TO IMPROVE ENERGY USE

1.2.1 COMMISSIONING

Building commissioning is an intensive quality assurance process that ensures the building operates as intended and building staff are sufficiently prepared to operate and maintain its systems and equipment. Retrocommissioning, or recommissioning, applies to existing buildings and is recommended for CSCU campuses as it can improve performance and operational savings and not always carry a significant capital cost. Existing Building Commissioning (EBCx) can either be retro-commissioning, where the building has never been commissioned in the first place, or re-commissioned, where the existing building has been previously commissioned. The process focuses on Operations & Maintenance (O&M) opportunities and improves how building equipment and systems function to address key issues identified in the audit completed for the Energy Master Plan. Some of the types of issues identified by commissioning are described in Table 1 below.

Problem Type	Example
Design	Incorrect equipment sizing
Installation	Construction debris blocking ventilation pathways
Software	Incorrect sequence of operations or control algorithms
Hardware/Manufacturing	Incorrect sensors
Component Failure	Faulty control boards in building automation systems
Startup	Air in water system, Improperly adjusted daylighting controls

TABLE 1: Potential Issues Associated with Commissioning

Source: Lawrence Berkeley National Lab, The Cost-Effectiveness of Commercial-Building Commissioning, 2004.

The Lawrence Berkeley National Laboratory completed a commissioning study in 2009. The projects included in the study identified over 10,000 energy related problems which resulted in 16% median energy savings with payback time from 1.1 to 4.2 years. The study noted projects with a comprehensive approach to commissioning achieved five-times the savings of projects with a constrained approach. A comprehensive approach is one that is performed by commissioning professionals having both extensive design and engineering experience, covering electrical, mechanical, HVAC, and building envelope systems. Typically, the most labor intensive and costly part of commissioning is the planning and investigation of issues.

The life cycle cost comparison without and with commissioning in Figure 2 shows how the upfront cost of commissioning is offset over the life of the building and equipment.

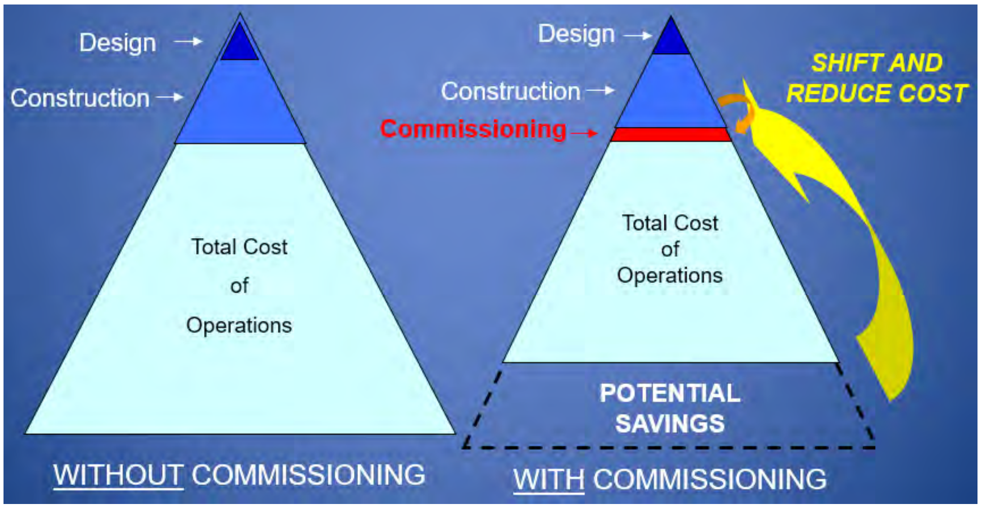


FIGURE 2: Life Cycle Cost: A Comparison

The EBCx Process is summarized in the process flow diagram (Figure 3) below.

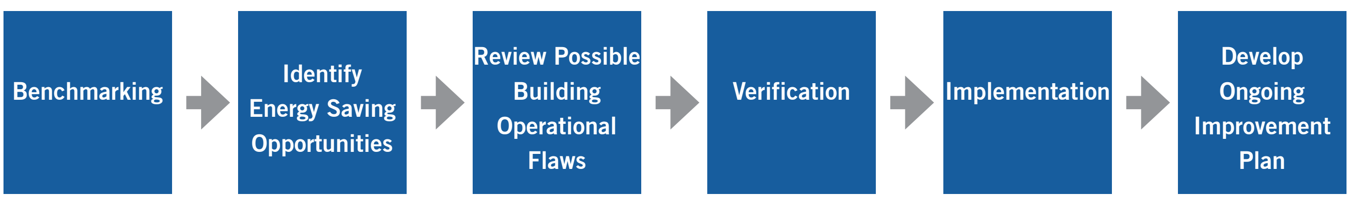


FIGURE 3: EBCx Process

The first step in the EBCx process involves benchmarking a building's energy performance. The lower the performance rating, the greater opportunity for improvement. Next, specific opportunities for energy savings can be identified during a site visit by a certified commissioning provider. Some of these opportunities may include:

- Systems that simultaneously heat and cool, such as constant and variable air volume reheat,
- Economizers with broken linkages, malfunctioning actuators and sensors, and improper control settings,
- Pumps with throttled discharges,
- Equipment or lighting that is on when it may not need be,
- Improper building pressurization, either positive or negative,
- Variable frequency drives (VFDs) that operate at unnecessarily high speeds, and
- VFDs that operate at a constant speed when the load should be varying

The commissioning provider will work with the campus to develop a scope of work to address the identified issues.

The next step in the EBCx process is to investigate why the systems may be operating as they do. Facility documentation to be reviewed includes original design documents, equipment lists, building drawings, controls documentation, operations and maintenance manuals, and testing, adjusting, and balancing reports. The systems under review undergo diagnostic monitoring to help pinpoint where the problems are occurring. Data is gathered using the existing building energy management system (EMS) or with portable data loggers when the EMS does not record the required variables. The system, or particular pieces of equipment, will also undergo functional testing to record its performance in all key operating modes.

After all of the recommendations have been implemented, it is important to verify the results. Verification ensures all of the work was completed correctly and establishes a new baseline for energy performance and cost savings estimates. As part of the EBCx effort, adjustments and fine-tuning may be made to the building systems.

The EBCx process is not complete after the recommendations have been applied and verified. A plan needs to be put in place to continue the benefits over time. This plan should include training the energy staff in the new system operations, preventative maintenance, performance tracking, and periodic recommissioning or ongoing commissioning of the building. Recommissioning follows the same steps as EBCx and should be considered every 3 to 5 years for buildings that experience few changes and sooner for buildings that implement new energy systems or change occupants before the 3-year period.

For ongoing commissioning, monitoring equipment is left in place to allow for ongoing diagnostics. Monitoring Based Commissioning (MBCx) is connected remotely to the BAS and typically includes automated data analysis, reporting, and alarming. Additional energy savings that could be experienced are outlined in Figure 4.

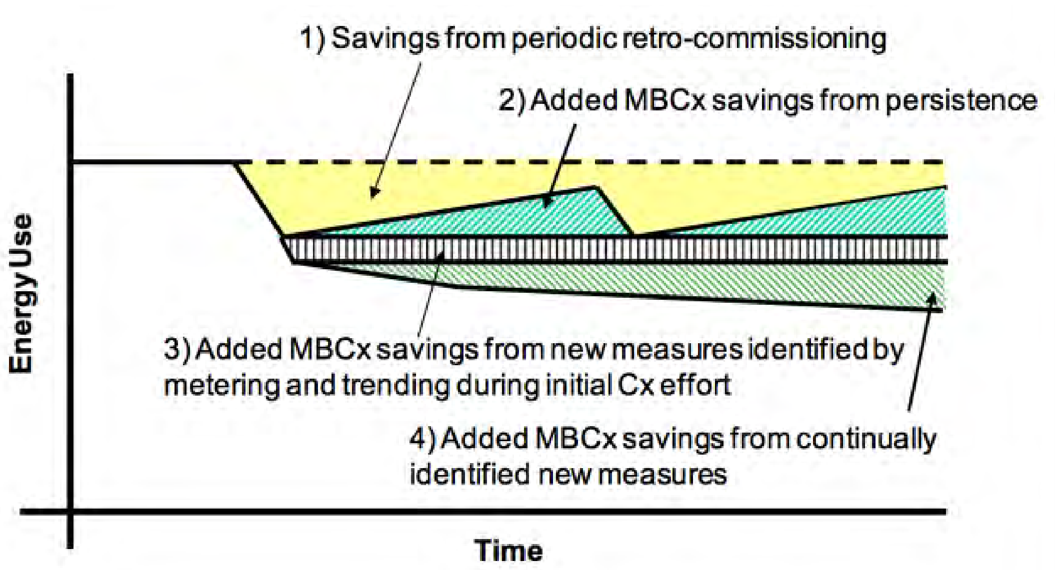


FIGURE 4: Additional Energy Savings from MBCx

Source: (LBL-2009)

EBCx goes beyond preventative maintenance and involves a commissioning process with efficiency improvements as an added goal. Continuous commissioning and MBCx are akin to predictive maintenance as they use proactive monitoring to discover improvements.

Industry guidelines are continuously improving and should be used or referenced in commissioning specifications for both new and existing construction. Commissioning guidelines include:

- ASHRAE Guideline 0-2013 – Defines commissioning process
- ASHRAE Guideline 1-2009 – Technical requirements for Cx
- ASHRAE Standard 202-2013 – Establishes minimum requirements for Cx

- ASHRAE Guideline 13-2014 – Specifying Building Automation Systems
- ASHRAE Guideline 0.2P – The Commissioning Process for Existing Systems and Assemblies (in-progress)
- ASHRAE Guideline 1.2P – The Commissioning Process for Existing HVAC&R Systems (in-progress)
- ASHRAE 1.3P – Building Operation and Maintenance Training for the HVAC&R Commissioning Process (in-progress)
- ASHRAE 1.4P – Procedures for Preparing Facility Systems Manuals (in-progress)
- NIBS Guideline 3 – Building Enclosure Commissioning Process

General guiding principles when considering Building Commissioning include:

- New construction:
  a) Specify and enforce comprehensive commissioning for a median energy savings of 13% or a 4.2 year payback (Evan Mills, LBL, 2009)
  b) Potential savings in the total cost of operations will more than offset the cost of commissioning.
  c) Expect an upfront cost of 0.5 to 3.0% of the fully marked-up construction cost of the system being commissioned or $0.30/sf or 1% of total construction costs.

- Existing construction:
  a) Implement comprehensive commissioning for a median energy savings of 16% or a 1.1 year payback (Evan Mills, LBL, 2009)
  b) Expect a cost of $0.50/sf to $3.50/sf depending on scope, size, and complexity of buildings.
  Building candidates should be selected with preference towards buildings with:
    - Management support and commitment,
    - A motivated and available building staff,
    - An unjustified, high EUI,
    - An Energy Management Control System,
    - No major system problems,
    - Easily accessible and up-to-date building documentation, and
    - Newer equipment (12-years or less)
  c) Recommissioning should occur every 3-5 years.
  d) Implement continuous commissioning to realize the greatest benefit.

1.2.2 ENERGY MONITORING

Energy monitoring is the key component to track and reduce energy use over time. It includes the use of energy demand meters applied to single buildings, and specific loads within those buildings.

Within buildings, energy monitoring should be considered for multiple thermal and electrical end use categories such as preheat, heating, and reheat; humidification; service water heating; cooling; fans; pumps; lighting; and select plug and process loads. Energy monitoring for specific floors, or areas of a building can also help to better maintain operational performance over time. Energy monitoring can enable facility managers and engineers to more effectively identify energy problems and prioritize capital investments.

General guiding principles when considering Energy Monitoring include:

- New Construction:
  a) Ensure new buildings have a separate energy submeter when connected to a central heating or cooling system.
  b) Include monitoring of every air handler, roof top unit, heating zone, electrical panel, pump, solar PV and thermal generator.

- Existing Construction:
  - a) Add BTU-Metering (flow meter with temperature in and out of a device) to every heat exchanger, especially those connected to a central plant.
  - b) Add current transmitters (CTs) to every building electrical service panel feed
    - - For enhanced monitoring include CTs on every major panel circuit
  - c) Use a plug load indicator such as a Kill-A-Watt® meter to estimate costs of non-critical equipment and unplug if cost is not justified
  - d) Install mini data loggers such as a HOBO® to track data deemed important such as:
    - - Light on-off
    - - Motor on-off
    - - Temperature
    - - Relative Humidity
    - - Or any general 0 to 2.5-volt input

1.2.3 BUILDING SET POINTS

Adjusting system set points can have one the quickest returns on investment since little to no capital is needed to realize energy savings. Set points can be adjusted for a multitude of points with modern Building Automation Systems (BAS). Where a building energy management system is not available, stand-alone programmable thermostats or independent controls can be purchased for as little as $50. The following lists are examples of adjustable set points to be considered.

- Building space/zone settings:
  - a) Heating set points
    - - 68°F, lower the more energy efficient (per ASBO International's School District Energy Manual)
  - b) Cooling set points
    - - 78°F, higher the more energy efficient (per ASBO International's School District Energy Manual)
  - c) Ventilation set points (i.e. Flow Rate, Humidity, Carbon Monoxide, Carbon Dioxide, Fume hood sash position)
    - - Space dependent, refer to ASHRAE 62.1-2016 for minimum flow rates
  - d) Lighting set points
    - - Lighting can be controlled with set points through a BAS, independent timers or photo sensors. Set points should be adjusted at least quarterly if on a timer. Photo sensor sensitivity also can be adjusted so that natural light can be used as much as possible.

- HVAC Controls
  - a) Air Handling Unit (AHU) or Roof Top Unit (RTU) Power
    - - Power down equipment when not needed via scheduling.
  - b) Setback and setup temperatures
    - -Increase supply air or water temperatures only when needed, such as when preparing building space temperatures on a Monday morning after a weekend/night setback
  - c) Dead Band
    - - Adequate temperature setting gap between cooling and heating modes
  - d)Economizer Settings
    - - If an AHU or RTU is equipped with an economizer, ensure setting allows the economizer mode to activate when the outside conditions allow.
  - Static Pressure Reset
    - - Reduce fan speeds to realize lower operating costs while meeting space demands.

- Boiler system settings
  - a) Outdoor temperature resets
    - - Lower heating loop temperatures as much as possible based on outdoor temperature to meet space heating requirements.
  - b) Boiler outlet temperature or pressure (steam)
    - - Maximum of 180°F for typical hydronic systems. 140°F Maximum for condensing boilers. Lower the better
  - c) Boiler return temperature
    - - Largely dependent on the manufacturer. Should be < 120°F for condensing boilers, otherwise only standard boiler efficiencies will be achieved. Lower the better unless cautioned against by the manufacturer for thermal shock concerns.
  - d) Blowdown set points
    - - For larger steam boilers, adjust the blowdown rates so that water quality requirements can be met based on TDS or other means without dumping excessive boiler water.

- Chiller system settings
  - a) Chilled water reset
    - - Raise the temperature setting based on control valve position, outdoor air temperature, and/or AHU damper positioning.
  - b) Cooling water reset
    - - With water cooling chillers, take advantage of lower cooling tower return water temperatures by adjusting the temperature set point to low as recommended by the manufacturer.
  - c) Water-side economizer settings
    - Some chillers are equipment with built-in economizer modes or systems may have a chiller bypass when water cooled. When the outdoor air wet-bulb temperature is several degrees below the chilled water loop temperature, economizing or free-cooling should be activated.

- Pump and valve settings
  - a) Variable flow pump speed
    - - Reduce flow rates until control valves in the system are fully open.
    - - Reduce flow rates based on outdoor temperature. More temperate weather usually does not need as high of a flow rate through the system piping. Be sure to exceed the equipment manufacturer minimum flow rates. Reduce flow rates if the temperatures in and out of equipment are significantly less than design. If inlet/outlet temperature deltas are regularly less than 5°F, the system may suffer from "low Delta-T syndrome" and may need a specialist to recommission or even redesign the system.
  - b) Circuit setters / triple-duty valves with variable flow pumps
    - - Fully open flow throttling devises such as triple duty valves, balancing valves, circuit setters, and dampers when used in conjunction with a VFD.

It is important to remember set points are only good if the equipment is calibrated and working properly. AHUs may have all the correct set points, but if a damper linkage is loose or a pressure transmitter is clogged, appropriate set points can do nothing to save energy. Preventive maintenance and calibration of sensors and thermostats is imperative to achieve effective set points.

Building commissioning should have adjusted available set points with occupant comfort and energy efficiency in mind. Because commissioning does not always take place, or was not done properly the first time, or systems and space uses change, existing building commissioning will help optimize the set points, detect and correct problems as they are found.

1.3 OPERATIONS & MAINTENANCE

Operations & Maintenance (O&M) can be one of the single largest factors to achieve energy efficiency. As covered in the commissioning section, O&M should be thoroughly covered by commissioning efforts. Building set points as previously discussed are also O&M considerations. Additional considerations and guiding principles for O&M staff are listed below:

- Air Systems
    a) Take advantage of natural ventilation where possible and applicable
    b) Clean or replace filters at least quarterly

- Hydronic Boiler Systems
    a) Ensure water quality is checked and monitored regularly and treated by a qualified water quality professional
    b) Isolate offline boilers
    c) Regularly clean, blowdown, or replace strainers

- Steam Systems
    a) Ensure water quality is checked and monitored regularly and treated by a qualified water quality professional
    b) Implement team trap repair/replacement/program (the typical life expectancy of a trap is only eight years, at which point 7.5% can fail per year on average)
        - When beginning the program, complete an initial inventory of the traps that need more frequent inspection and eventually replace as needed
        - A steam trap maintenance program should, at minimum, include an inventory to record results from an annual survey, of which steam traps have been repaired, and when.
        - For large campuses invest in automatic steam trap survey equipment which connects to the BMS

- Chiller Systems
    a) Ensure water quality is checked and monitored regularly and treated by a qualified water quality professional
    b) Regularly clean, blowdown, or replace strainers

1.4 ENERGY EFFICIENCY DESIGN STANDARDS

Energy Design Standards are for both existing and new construction. Below are some common energy and sustainability standards (latest publication date as of May 2016):

- ANSI/ASHRAE Standard 62.1-2016, Ventilation for Acceptable Indoor Air Quality
- ANSI/ASHRAE/IES Standard 90.1-2013, Energy Standard for Buildings Except Low-Rise Residential Buildings
- ANSI/ASHRAE/IES/USGBC Standard 189.1-2014, Standard for the Design of High-Performance Green Buildings

Standards, such as ASHRAE 62.1, can address ventilation rates and set points for both new and existing construction. Newer editions have methods of determining minimum airflow rates with a conscious effort to continuously reduce energy use. The latest edition also includes specifics for demand control ventilation (DCV) which is a recommended ECM at many CSCU campuses. The standard should set consistent ventilation rates and set points for all building and program types such as academic classrooms, laboratories, dining halls, etc.

ASHRAE Standard 90.1 has been a benchmark for more than 35 years and will address everything from lighting densities to pipe sizes and equipment efficiencies for new construction and can be useful for retrofit equipment installations.

Standard 189.1 provides total building sustainability guidance for designing, building, and operating high-performance green buildings. From site location to energy use to recycling, this standard sets the foundation for green buildings by addressing site sustainability, water use efficiency, energy efficiency, indoor environmental quality (IEQ), and the building's impact on the atmosphere, materials and resources.

All of the aforementioned standards can be purchased through https://www.ashrae.org/resources--publications/bookstore/. Each of the standards listed above also have an available guide with best practices and additional insight for architects, design engineers, contractors, commissioning agents, and energy managers.

A review of updates to energy efficiency design standards is recommended every three years as this is the typical revision cycle. Although not a standard, the Energy Management Handbook, 8th Edition, by Steve Doty and Wayne C. Turner, is an excellent resource for all facilities and energy managers.

1.4.1 STATE AND LOCAL CODE

Building Standard Guidelines should be used for renovations and upgrades in addition to all new construction projects as mandated by State and Local Code. The specific guideline for the State of Connecticut is, Connecticut Building Standard Guidelines Compliance Manual for High Performance Buildings, and can be found at:

http://www.ct.gov/deep/lib/deep/energy/buildingstandards/compliancemanualhighperformancebuildings.pdf

The document is an excellent resource with sound energy efficient best practices listed as mandatory requirements for new construction of a state facility that is projected to cost $5M or more or school renovations that are projected to cost $2M or more and state funded.

1.4.1.1 EXISTING BUILDING/RENOVATION

Many ECM's listed for various campuses would be already implemented if the buildings were recently built or substantially renovated. An example is where a central plant provides energy to multiple buildings or in cases where multiple buildings are fed from the same fuel source, new construction or major renovation shall include metering and other such equipment necessary to evaluate energy and water consumption.

1.4.1.2 NEW CONSTRUCTION

The extent of the *Connecticut Building Standard Guidelines Compliance Manual for High Performance Buildings* goes beyond just ASHRAE Standard 90.1 and the Connecticut State Building Code by stating the base minimum energy performance for all building projects shall be at least 21% better.

Buildings shall be designed to meet the minimum ventilation requirements of the current ASHRAE Standard 62.1 using the Ventilation Rate Procedure for mechanical systems. If the current Connecticut State Building Code contains more stringent requirements, it shall be used to meet minimum ventilation requirements. There are many Building Standard optional strategies in the guideline. Eleven strategies are available for demonstrating compliance within the energy efficiency and renewable energy category. Fourteen strategies are available for improving the indoor environment. Many example strategies are recommended ECMs as part of the Energy Master Plan. Some include fuel cells, waste heat recovery, demand control ventilation, and solar power, to name a few.

General guiding principles for Energy Design Standards include:

- Ensure contractors, designers and engineers selected for a project have a full understanding of all applicable design standards
- Ensure applicable energy design standards are commissioned properly so systems operate as intended by standards

APPENDIX C: RENEWABLE ENERGY MEMORANDUM

The purpose of this memorandum is to present the preliminary findings of the Energy Master Plan for renewable energy. The document includes an overview of the range of possible renewable energy system types, and identifies various types of renewables for the campuses.

1.1 TECHNOLOGY

There are several different forms of on-site renewable energy that may be applicable for CSCU campuses. Some generate electricity and others thermal energy, which displaces natural gas and fuel oil use. This section provides a brief overview of the different technologies on the market today.

1.1.1 SOLAR

Two types of solar energy technologies were assessed: solar photovoltaic (PV), and solar thermal energy (STE). Roof mounted PV is the main focus of this memorandum based on its advantages listed in the following sections. Other mounting configurations may have applications depending on the circumstances.

1.1.2 SOLAR PHOTOVOLTAIC (PV)

Solar PV converts sunlight directly into electricity. Solar panels are typically made from solar cells combined into modules that hold about 40 or 70-cells depending on the desired configuration. Solar cells are not 100% efficient in part because some of the light spectrum is reflected, some are too weak to create electricity (infrared) and some (ultraviolet) create heat energy instead of electricity.

TYPES AND REQUIREMENTS

Solar panel technology is constantly evolving; prices are decreasing while efficiencies are increasing. Table 1 shows the most common module types for solar PV. The approximate efficiency values shown below are from PVWatts® technical documentation. Module costs are shown as unit less relative values to March 2016 pvXchange module prices since prices frequently change.

Type	Approximate Efficiency	Approximate Module Cost
Standard (Crystalline Silicon)	15%	$ 1.00
Premium (Crystalline Silicon)	19%	$ 1.34
Thin Film or Flexible	10%	$ 0.50

TABLE 1: Solar Module Types and Characteristics

It should be noted that thin film PV can also act as a waterproofing membrane for rooftop installations or may even be applied to windows. Thin film PV attaches directly to the roof surface with adhesives so there are no roof penetration and can be walked on if need be. Thin film PV has also proven to surpass premium silicon PV efficiency in laboratory testing (2013) and the higher efficiency products may be commercialized in the near future. An example of thin film PV installed can be seen in Figure 1.

FIGURE 1: Photovoltaic Waterproofing

FIGURE 2: Ballasted and Fastened Solar PV

The most common mounting configurations are ballasted (with concrete pavers) PV racks and mechanically fastened racks (Figure 2) which connect directly to the structure below the roof. The mounts shown here are anchored to the roof deck.

FM Global, CSCU's current property insurance provider provides recommendations and guidance related to structural conditions, including roof mounted and ground mounted PV systems. Per FM Global, anchored systems should be used if the slope of the roof is greater than 2.4°. Ballasted systems which do not penetrate the roofing membrane can be used under certain conditions as determined by FM Global.

RECOMMENDATIONS

- A non-exhaustive summary of FM Global's recommendations and some comments for roof mounted PV systems are listed below.
- Solar PV panels can be ballasted OR anchored, provided one of two prescribed calculation or testing methods are used for wind loading.
- Ballasting of solar panels is an approved method for roofs up to a 2.4° Slope, beyond that anchoring appears to be the option.
- If a roof is flat, i.e. less than 1° slope, it should be evaluated and analyzed including supporting roof framing, columns and bearing walls. A qualified structural engineer is required for any reinforcing of the roof. This typically adds cost to the installation.
- Anchoring to the structure is not preferred for standing seam roofs (SSRs), but rather clamping. Of course, the roof needs to be determined "adequate".
- If the roof is fastened (as opposed to ballasted), then the panels also need to be mechanically fastened.
- Roofs should not have any forms of roof aggregate or loose stones for ballasting to secure the panel racking to the roof.
- Roofing may need the addition of approved insulation before installation of new roof-mounted solar panels.
- FM Global recommends a thorough amount of O&M be performed, including but not limited to:
    a) Perform PV array insulation resistance tests every three years
    b) Perform a thermo-graphic survey for all electrical components annually
    c) Visually inspect inverters on a daily basis
    d) Test inverters annually

COSTS

Pricing can vary significantly based on many factors including but not limited to, PV module, scale, racking system, union labor, and development costs. Most CSCU campuses will fall in the commercial-scale system category where economies of scale are driving prices below $3 per watt DC. Figure 3 shows the range of costs that can contribute to overall system price for roof and ground mount systems based on size as of Q1 2015. It is important to note that many factors influence PV installation costs. In Connecticut, relatively high labor prices, public project requirements, design standards and other factors may significantly increase the installed cost of solar up to $1.00 per watt. At the same time, solar PV prices continue to decrease as the technologies mature which may lead to additional price reduction in the costs of materials outlined in Figure 3.

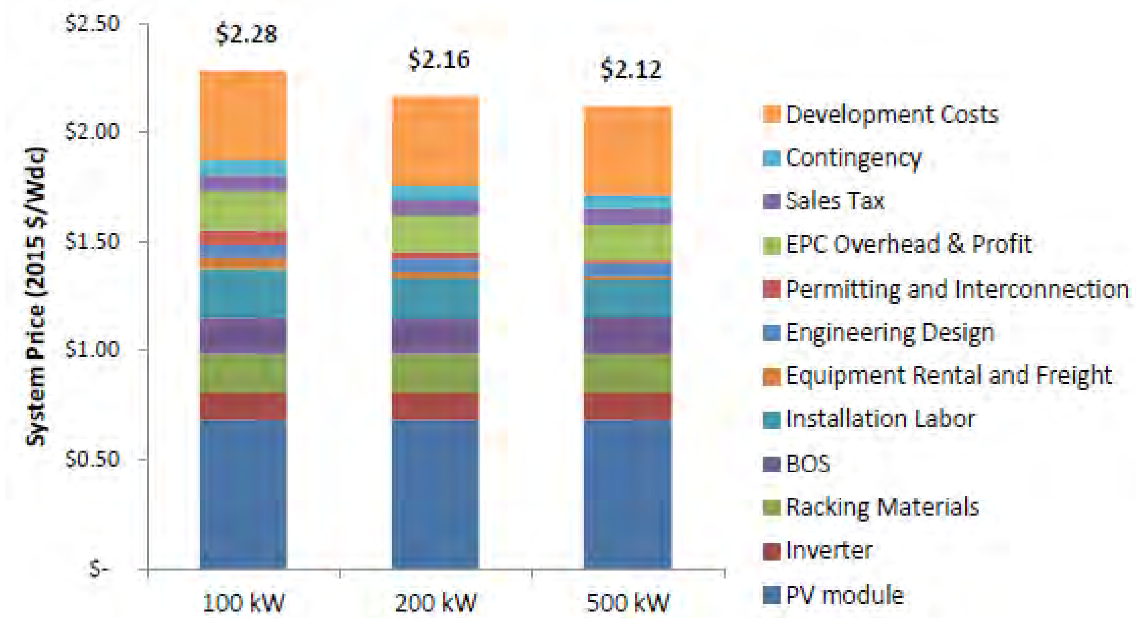


FIGURE 3: National Commercial PV System Cost Types

Source: U.S Photovoltaic Prices and Cost Breakdowns: Q1 2015, NREL 2015

Recent trends indicate higher-voltage string-inverter-based systems with larger 72-cell modules provide the lowest total installed cost for rigid panels, thin-film technology excluded. A broader and recent overview of costs compared with other renewable energy technologies is covered in a subsequent section.

The cost numbers above, although over a year old at the time of this report, should be considered as guidance only. Because of various electrical safety, fire safety, and building safety concerns, engineering design costs for roof design and wind loading on existing building may add considerable cost. Even if a building is recently built, a value engineered roof that only meets and does not exceed code minimums will likely fall short when evaluated for a purely ballasted array.

A large part of assessing PV depends on the intended type of installation, since this relates to cost, appearance, and infrastructure requirements. Advantages and disadvantages of different installation types are presented below.

ROOF MOUNTED

ADVANTAGES

- Typically, the lowest cost installation option
- Minimal to no aesthetic impact in most instances
- Uses existing, underutilized space, “Found space”/ no land opportunity cost

DISADVANTAGES

- May require replacement of roof membrane as a concurrent project
- Insurance and roof warranty considerations, including roof loading
- May be more appropriate for buildings that have older roofs that are due for replacement
- Maintaining roof water-tightness
- Meeting building codes
- Existing equipment/penetrations limit layout

GROUND MOUNTED

ADVANTAGES

- Moderate cost, requires steel support dunnage and foundation requirements
- Adequate structural capacity

DISADVANTAGES

- Low value use of finite campus land/very high opportunity cost
- Potential visual impacts on campus aesthetics

PARKING GARAGE / LOT CANOPY

ADVANTAGES

- Provides site and occupant amenity by shading otherwise exposed cars from sun and precipitation
- Minimal to no visual impact
- For parking lots that are not planned as future building sites - “Found space”

DISADVANTAGES

- Added cost for supporting steel structure, longer ROI
- Existing garage must have the structural capacity to support the added weight
- Sufficient water management can be costly

1.1.3 SOLAR PV ASSESSMENT WITH PVWATTS®

When evaluating for solar opportunities, is important to consider space availability, shading and structural integrity. PVWatts® is a free online tool developed by the National Renewable Energy Laboratory (NREL) for a quick feasibility analysis of solar energy potential. The tool allows the user to enter in system parameters, use historic data from weather stations and view financial analyses. Note however, capacity estimates produced by this tool are often 50-100% higher than what can actually be implemented in the field.

This tool can be useful in capital planning. To show the simplicity of the tool, we have taken Western’s O’Neill Center Field House as an example for a PVWatts® assessment. The field house’s roof was replaced in 2014, has no shading and limited mechanical equipment making it an ideal candidate for a roof mounted system. PV Watts allows the user to outline the possible system size to determine potential system capacity, as shown in the Figure 4.

FIGURE 4: PVWatts® Outlining Tool Example

Space around roofing edges and control joints, at least four feet, should not be included when figuring out the usable roofing area. Alternatively, the user can manually enter in the DC kW system size. The DC kW system size can be calculated from the following equation:

$$\textit{Size (kW)} = \textit{Array Area } (m^2) \times 1\ kW/m^2 \times \textit{Module Efficiency } (\%)$$

Module type, array type, system losses, tilt, and azimuth are usually defaulted to reasonable values. The economics of solar are dependent on site constraints. Solar is generally deployed to optimize economics as opposed to output but for Connecticut, optimum values or comments for each are shown below:

- Module Type- Premium, are the most efficient and prices continue to drop. Although other options such as thin film may be cheaper and rapidly improving in efficiency. At the time of this report, there are very few commercial thin film installations. FM Global has only approved two thin-film flexible PV modules per FM 4476 at this time:

    a) Derbisolar by Derbigum Americas, Inc.; and
    b) Photovoltaic Module Systems by Soprema Inc. (USA)

    At this time, premium efficiency panels are considered the best option for CSCU since the efficiency gain will outweigh the added panel cost over the lifetime of the equipment. Thin-film should be monitored for commercial development and will be suitable for rooftops where heavier rigid panels are not appropriate.

- Array Type- Fixed (roof mount), Although multi and single axis ground mounted tracking units can collect more energy, the added cost is not usually worthwhile and not feasible for roof mounted arrays. Moving from fixed to 2-axis tracking would improve potential energy captured from approximately 71% to 100%.

- System Losses- 14-16% is typical and, perhaps towards the higher end, in Connecticut depending on snow accumulation and removal. System losses includes soiling, shading, snow, mismatch, wiring, connections, light-induced degradation, nameplate rating, and availability. Inverter DC-AC conversion efficiency is not included in this input and instead is under Advanced Parameters with a default value of 96% efficiency.

- Tilt- 35 deg, a near 35-degree tilt is optimum for solar arrays around the longitude where Connecticut is located.

- Azimuth- 180 deg, a near 180 degree facing direction clockwise from true north provides the greatest energy conversion. Some reports, especially in California, are recommending an azimuth 200 degrees and greater, driven by a want for greater energy conversion to reduce the electric grid load/demand during peak cooling hours; however, this is not recommended in Connecticut since the sun is not as reliable and the grid is not as stressed.

- Initial Economics- For the CSCU system, the initial economics given in PVWatts® should not be relied upon as the program makes assumptions about loan amounts and duration, tax rates, and depreciation that may or may not apply. Third party ownership and complex utility rates can significantly change the relative value of the PV system.

The system information screen, with example parameters are shown in Figure 5.

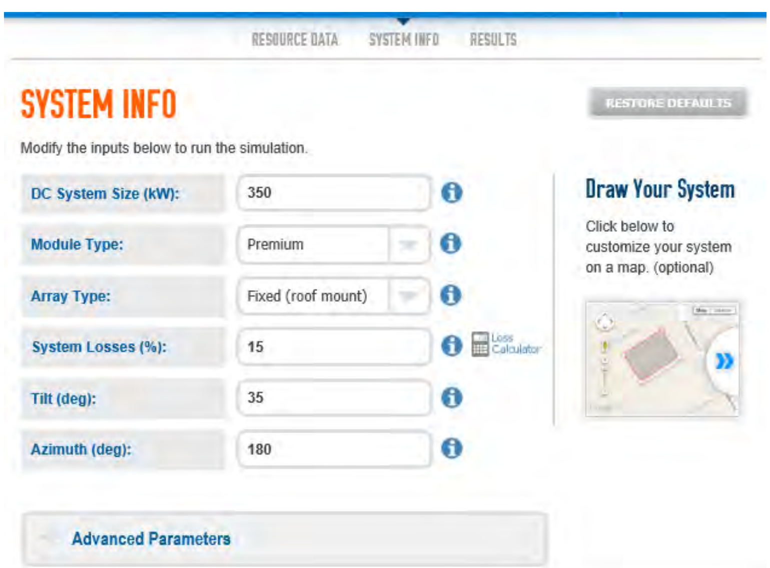


FIGURE 5: PVWatts® System Information Screen

Additional advanced parameters include DC to AC size ratio, inverter efficiency, and ground coverage ratio and can be used to evaluate specific equipment options. More details can be found in the Technical Reference from the PVWatts® website at *http://pvwatts.nrel.gov/pvwatts.php.*

Based on the aforementioned information, the program then generates an estimate for the kwh savings. The O'Neill Center could accommodate a system size of approximately 350 kW generating 455 MWh a year based on the PVWatts® estimate, presented in Figure 6.

RESOURCE DATA SYSTEM INFO RESULTS

RESULTS

Print Results

454,980 kWh per Year *

System output may range from 444,288 to 466,445kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m² / day)	AC Energy (kWh)	Energy Value ($)
January	3.20	29,472	3,734
February	3.93	32,558	4,125
March	4.35	38,985	4,939
April	5.19	44,259	5,608
May	5.42	46,394	5,878
June	5.55	45,162	5,722
July	5.50	45,807	5,804
August	5.38	44,677	5,661
September	4.77	38,921	4,931
October	4.29	37,123	4,703
November	3.04	26,217	3,322
December	2.78	25,404	3,219
Annual	4.45	454,979	$ 57,646

FIGURE 6: PVWatts® Results Screen for a 350 kW system at Western's O'Neill Center

The Energy Value given is assuming an average cost of electricity purchased form the utility of $0.13/kWh.

Based on the results shown above, the following rules of thumb can be approximated:

- 1 kW DC of rooftop solar capacity can generate approximately 1,300 kWh per year.
- For optimally configured arrays in Connecticut with no spacing (as assumed by PVWatts® in practical applications normally 30-60% of the PVWATTS estimation can be achieved)

    a) 56 to 72 square feet of roof area is needed per 1 kW DC of panels, depending on efficiency.

    b) Each square foot of roof can generate about 18 to 23 kWh per year, equal to about $2 to $3 for most campuses.

Some general guiding principles when considering a PV system, include:

- Ensure the existing roofing system is compatible with the PV system and will provide at least 20 additional years of useful service.
- Ensure the roofing warranty is not compromised by the PV system installation.
- Follow guidelines and standards set by FM Global to ensure the PV system will weather storms and not void insurance coverage.
- Anticipate and prepare for additional rooftop traffic on membrane surfaces.
- Compare the life-cycle cost through competitive bids for ballasted and mechanically adhered systems.
- Ensure installing contractors have a sound understanding of commercial roofing systems and practices to best approach the project.

1.1.4 SOLAR THERMAL (STE)

Solar thermal energy (STE) technology harnesses solar energy to generate thermal energy / hot water and subsequently reduce natural gas and fuel oil use. Solar thermal collectors can utilize a heat transfer fluid such as glycol to transfer heat to building water through a heat exchanger, or directly to water or air. There are three basic types of solar thermal collectors: flat plate collectors, integral collector storage (ICS) systems, and evacuated tube systems.

Only the two most common collectors, flat plate and evacuated tube, were selected for comparison since ICS systems are generally suited for milder climates. Solar thermal systems can be third-party financed through purchase power agreements in a similar manner to solar PV where the energy converted is tracked and sold to the facility at a specified rate per unit of heat.

Flat plate solar thermal collectors are the most common and lowest cost system type and are generally recommended for CSCU. Cases for evacuated tube collectors are at residence halls or gymnasiums where a high thermal load could be seen earlier or later in the day or where used for space heating. Evacuated tube systems are more efficient and can generate higher temperatures more consistently throughout the day and year. Conditions in the northeast usually favor evacuated tube systems due to several factors, but various glazing options can make flat plate collectors also well suited. The advantages and disadvantages of flat plate and evacuated tube solar thermal collectors are outlined below:

FLAT PLATE SOLAR THERMAL COLLECTORS

ADVANTAGES

- Lower cost collectors
- Produces hot water at a temperature sufficient for most domestic hot water needs
- Easily mounted to existing roof structures
- Durability

DISADVANTAGES

- Does not produce steam and will not reliably perform above 135°F
- Lower efficiency
- May require additional racking to achieve an optimal panel angle
- Difficulty producing hot water in colder climates (<50°F) depending on glazing
- Prone to condensation over time
- May require larger thermal storage tanks since most energy is collected mid-day.

EVACUATED TUBE SOLAR THERMAL COLLECTORS

ADVANTAGES

- Can produce steam and can meet higher temperature water needs up to 200°F
- The cylindrical evacuated tubes are designed to operate better in the absence of direct sun and shady conditions
- Less sensitive to sun angle and orientation
- Self-insulating due to thermos-like vacuum design.
- Collect heat starting earlier and ending later in the day

DISADVANTAGES

- Higher cost system with collectors costing 20-40% more
- Requires a more complex installation and arrangement of tube collectors

Flat plate and evacuated tube solar thermal collectors have different appearances as seen in Figure 7, with flat plate on the left and evacuated tube on the right. The spacing and shape of the tubes seen on the right allows the sun to be collected for more hours of the day.

FIGURE 7: Flat Plate and Evacuated Tube Solar Thermal Collectors

Although solar collector efficiency curves may be used in an initial evaluation method, they do not account for seasonal radiation, angle of the sun, system losses, or control strategies. The life-cycle cost of any particular system including long-term energy output as well as capital and operating costs should be evaluated before installing any STE system.

While solar thermal can benefit a customer through energy reductions, solar thermal performance is not always optimal. One of the major causes of poor system performance is heat loss from storage tanks. A maximum capacity loss of 1-2% is recommended as a target heat loss value to balance insulation costs and acceptable heat loss.

The performance and cost relationships between solar thermal availability, collector design, storage design, and load are highly interactive. For this reason, the designer of any solar thermal system should be experienced and have a track record of many successful installations. A well designed and engineered system should have a better ROI than solar PV; however, poor design, integration, and maintenance can often offset any benefits solar thermal may have over solar PV.

Some general guiding principles when considering an STE system, include:

- Consider flat-plate collectors as the preferred technology where cost needs to be low as possible and demand peaks are near or after mid-day.
- Consider evacuated tube collectors as the preferred technology for residence halls or gymnasiums where domestic hot water needs are greater earlier and later in the day.
- Conduct a cost-effectiveness study for any selected technology using an appropriate analysis tool such as:
    a) SOLCOST
    b) RETSCREEN
    c) TRNSYS
- Plan to have about 1-2 gallons of thermal storage per a square foot of collector area
    a) Consider using multiple off-the-shelf 120 gallon ASME certified tanks and compare costs with a larger custom single tank for smaller systems less than 300 square feet of collector area
    b) Insulate so that no more than 1-2% of the energy is lost in storage
- Optimize storage size and controls using software such as TRNSYS
- Poor planning and implementation can lead to a zero return on investment
- Consider combining a STE system with ground-source geothermal
- Use well designed arrays which are pitched and feature self-balancing parallel rows to allow drain-back through gravity, rather than glycol, for freeze protection.

1.2 WIND

Wind power converts kinetic wind energy into electricity by using wind turbines. The majority of wind turbines have two or three blades around a rotor, which is mounted to a tower. The wind causes the rotor to spin like a propeller, giving power to a generator which produces electricity. Horizontal-axis wind turbines have their rotor facing parallel to the ground as seen in Figure 8.

FIGURE 8: Horizontal-axis wind turbine

FIGURE 9: Vertical-axis wind turbine

Scale of power generation can also vary, with relative sizes shown in Table 2.

Scale	Approximate Power Generation per Turbine (kW)
Utility	100-4000 kW+
Commercial	10-100 kW
Residential/Micro Wind Turbine	<10 kW

TABLE 2: Wind Power Generation Scale

Figure 10 shows the annual average wind speed in Connecticut at 80m. For utility scale wind turbines, wind speeds around 6.5 m/s and greater annually are adequate for generation. Based on the map, locations along the shoreline and in Litchfield County generate around 6.5 m/s and are considered the most suitable conditions for wind power.

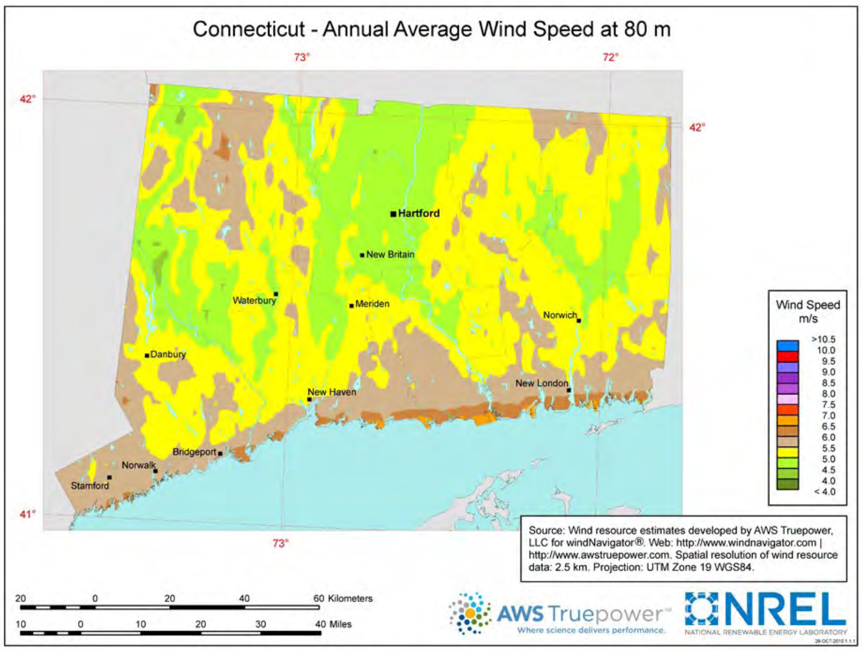


FIGURE 10: Connecticut NREL Wind Speed Map

Examples of wind energy in Connecticut include the wind turbine garden at the York Hill campus of Quinnipiac University and the wind turbine project in Colebrook. When siting wind turbines there are many factors to consider other than wind availability, such as zoning requirements, noise regulations and general community perspective about the project.

Building-integrated-wind-turbines (microwind) are a way of installing smaller than utility scale turbines at a higher elevation than otherwise possible, to achieve greater wind speeds. These turbines can be more favorable in urban settings, atop tall buildings, for local electricity generation. Vertical axis turbines may be a suitable option for small scale generation as they are often more aesthetically pleasing and tend to create less noise. Considerations when siting microwind projects include ensuring there is adequate wind speeds for generation, and structural support to handle additional load.

Figure 11 shows the Museum of Science in Boston, Massachusetts installed several building-integrated wind turbines, including vertical and horizontal axis turbines. Each were rated around 6 kW at a wind speed of 11 m/s. More locally, Yale University also did a pilot project in 2009 with the 10 1 kW AeroVironment wind turbines, set to generate approximately 25 MWh of electricity a year.

FIGURE 11: Museum of Science Building-Integrated Wind Turbines

The following sections highlight the advantages and disadvantages of the two main types of wind turbine installations: ground mounted and roof mounted.

GROUND MOUNTED WIND TURBINES (HORIZONTAL OR VERTICAL)

ADVANTAGES

- Significant power generation if wind conditions are suitable

DISADVANTAGES

- Variable nature of wind
- Large tower not compatible with most college campus settings
- Noise / acoustics

ROOF MOUNTED WIND TURBINES (HORIZONTAL OR VERTICAL)

ADVANTAGES

- Moderate power generation if wind conditions are suitable
- New construction can be engineered to support loads

DISADVANTAGES

- Variable nature of wind
- Less suitable for existing buildings given structural loading
- Less power generated than larger ground mounted turbines

The WCSU Westside Campus is the only location believed to have sufficiently consistent winds to merit a feasibility study. At this time, on-site wind generation for CSCU campuses is not recommended for a number of reasons. Unlike solar arrays, where the future generation of energy is highly predictable and consistent, wind generation is highly variable and inconsistent. It is quite difficult to accurately model wind conditions on a site, in most instances an anemometer (wind speed measurement tool) needs to first be installed for at least one year to collect wind speed data needed to determine feasibility. Lastly, unlike solar arrays the relationship between blade length and power production is exponential and so only large, very tall wind turbines typically have good ROIs.

Some general guiding principles when considering wind turbine systems, include:

- Wind turbine system do not typically have a worthwhile ROI strictly financially speaking.
- Maintenance costs need to be considered.
- Consider wind turbines if integrated in to building design and if to be used as a teaching tool for STEM programs and if at least one years' worth of data can be logged for a specific location

- Wind can be evaluated in special cases like Western but soft costs are significant to explore these options with limited revenue generation
- Some arrangements of multiple buildings can create a wind tunnel effect and may be worth considering for placement of a vertical axis wind turbine.

1.3 BIOFUELS / BIOGAS

Biofuels refer to fuels derived from biomass, organic materials from agricultural and domestic waste. Sources of biomass include food crops, agriculture or forestry residues, grassy and woody plants, oil-rich algae, organic components of municipal and industrial waste, and fumes from landfills. Biogas refer to biofuel gas produced by anaerobic digestion, which breaks down biodegradable materials creating biogas, or fermentation of organic matter. Biofuels and biogas can be used to produce heat and power and reduce thermal energy use. Compared to burning of fossil fuels, biofuels and biogas can be considered carbon neutral, renewable energy sources. Some of their advantages and disadvantages are below:

ADVANTAGES

- Reduces thermal energy use which offer the greatest opportunity to lower carbon emissions
- Can sometimes be used interchangeably in system with natural gas or fuel oil, for example a boiler can be configured as duel fuel.

DISADVANTAGES

- Needs a consistent biofuel / biogas source which may not always be available in the region. For example, a nearby landfill with a biogas harvest system installed
- Can require more complex funding arrangements

1.4 ALTERNATIVE ENERGY TECHNOLOGIES

1.4.1 FUEL CELLS

Fuel cells convert the chemical energy from a fuel such as natural gas, biogas or hydrogen, into electricity through a chemical reaction that produces lower emissions or other harmful outputs. Fuel cells can be used as a source of heat and electricity for building. CSCU has fuel cells installed on three different campuses, and are outlined in detail in the Procurement Memorandum. All three are leased and not owned by the campuses or by the System Office. The benefits and disadvantages of fuel cells are summarized below:

ADVANTAGES

- Depending on the relative cost of the fuel source it may offer long term utility cost savings if a campus can produce electricity at a rate cheaper than the grid
- State incentives may be available due to CT's fuel cell industry
- Provides a measure of resiliency in the loss of electricity during storms

DISADVANTAGES

- Requires significant capital investment for first cost
- CSCU campuses have reported some operational challenges with their existing fuel cells
- Power output decreases over time and requires a major overhaul after approximately 10 years.

Some general guiding principles when considering fuel cells, include:

- Ensure the building(s) connected to a fuel call can use the heat generated for the majority of the year
    a) This not only increases the ROI, but at least 50% efficiency must be maintained on a quarterly basis to collect certain credits.
- Fuel cells have a significantly higher capital cost than internal combustion (IC) CHP counterparts.

1.4.2 GROUND-SOURCE HEAT PUMPS

Ground-source geothermal Cooling/Heating systems use the consistent temperature of the earth, underground water, or surface water to provide heating, cooling and hot water for both residential and commercial buildings. Water is circulated through polyethylene pipes in closed loops below the earth or water surface. Open loop systems, such as what Eastern has, are also an option which can help reduce capital and pumping costs. However, open loops are now less likely to be permitted by CT DEEP and can suffer from fouling from naturally occurring materials.

The most likely geothermal system for a campus would be closed loop. Closed loops can be buried vertically or horizontally, or submersed in a pond. Horizontal loops are often considered when adequate land surface is available and are buried at a depth between 4-10 feet while vertical loops range from 75-300 feet deep. The loops are connected to a water source heat pump which is typically between 1-10 R-Ton, while some manufactures have systems up to 50 R-Ton. For reference, one refrigeration Ton (R-Ton) is equivalent to a cooling rate of 12,000 Btu/hr (the amount of energy to melt one ton of ice over 24 hours).

Ground-source heat pumps can achieve much greater efficiencies than their air-source counterparts or fossil fueled boiler and are preferred for heat driven northeastern US climates. They operate with a heating coefficient of performance (COP) in the range of 3.0 to 4.5 (300-400% efficient in converting electricity to useful heat), whereas conventional hydronic boilers operate with efficiencies in the range of 80% to 97%. A cross-section showing geothermal system wells connected to a commercial building is shown in Figure 12.

Note this depiction is not to scale.

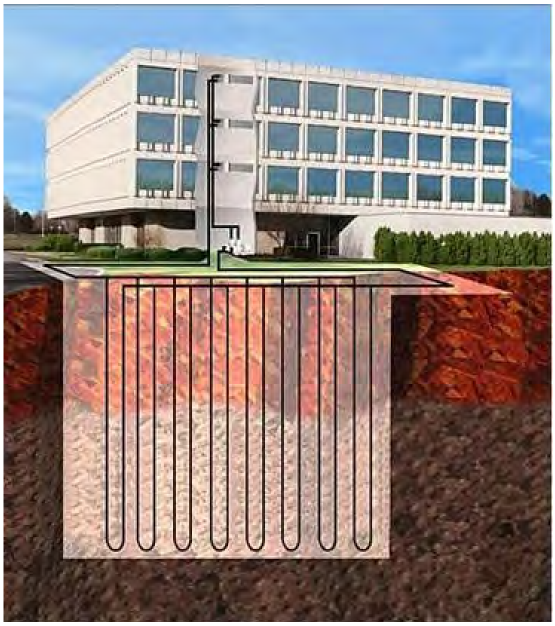


FIGURE 12: Geothermal Cooling/Heating System

ADVANTAGES

- Provides heating and cooling to building with little operational cost
- Displaces existing equipment in building so there may be an opportunity for cost savings. For example, a cooling tower may no longer be needed, boilers can be downsized.
- System is considered low maintenance, much of the equipment is buried underground and protected from damage

DISADVANTAGES

- Well warranty can be more limited than building equipment like cooling towers, requiring redundant MEP systems and negating cost savings
- Ground temperature fluctuation requires in-depth analysis for system design

Some general guiding principles when considering ground-source heat pumps, include:

- Evaluate for all new construction
- Consider for replacing existing heating/cooling equipment at end of useful life
- In areas where natural gas is not available, ground source heat pumps may be economical
- Consider use when the cost of electricity (per Btu) is less than 3.5 times that of fossil fuels (per Btu)
    a) 1 kW = 3412.1 Btu/hr

1.5 RENEWABLE ENERGY INSTALLED COSTS

Installed costs for all of the aforementioned technologies can vary significantly depending on variables including location, labor rates, specific project obstacles, and many others. Figure 13 and Table 3 show recent capital cost estimates for renewable energy technologies. It is critical for purposes of planning to understand that capital cost alone is not the most important consideration in evaluating renewable technology options. Several factors will influence the viability of renewable energy projects such as incentives, grants or tax credits. These costs are included for reference when evaluating future projects.

The estimates are shown in dollars per installed kilowatt of generating capacity. For example, one could estimate a 50 kW solar PV array could cost $175,000 at $3,500 per installed kW using Figure 13. The figures provide a compilation of available national-level cost data from a variety of sources.

The red horizontal lines represent the first standard deviation of the mean.

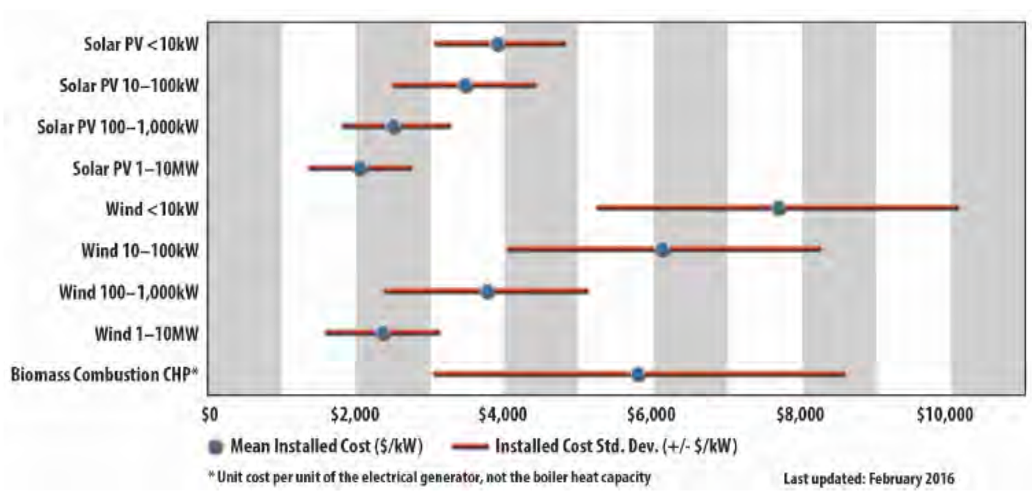


FIGURE 13: Renewable Energy Installed Costs

The estimates in Table 3 are shown in dollars per square foot of solar collectors or per unit capacity for thermal technologies.

Technology Type	Mean Installed Cost	Installed Cost Std. Dev. (+/-)
Solar Water Heat, flat plate and evacuated tube ($/ft^2)	$162	$61
Solar Water Heat, plastic collector ($/ft^2)	$59	$15
Solar Vent Preheat ($/ft^2)	$31	$14
Biomass Wood Heat ($/kW)	$575	$252
Ground Source Heat Pump ($/ton)	$7,765	$4,632

TABLE 3: Renewable Energy Installed Costs

The U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP) sponsored the distributed generation data used within these charts and can be found at *http://www.nrel.gov/analysis/tech_cost_dg.html*

1.6 RENEWABLE ENERGY OPERATIONS AND MAINTENANCE (O&M) COSTS

Operations and Maintenance (O&M) costs must be factored in when determining the best renewable energy options for a campus through life-cycle-cost analysis. Figure 14 and Table 4 provide a compilation of available national-level cost data. The estimates are shown in dollars per installed kilowatt per year. For example, one could estimate a 50 kW solar PV array could cost $1,000 per year in O&M at $20 per installed kW using the Figure 14. Similar to upfront installed costs, O&M costs will vary depending on location.

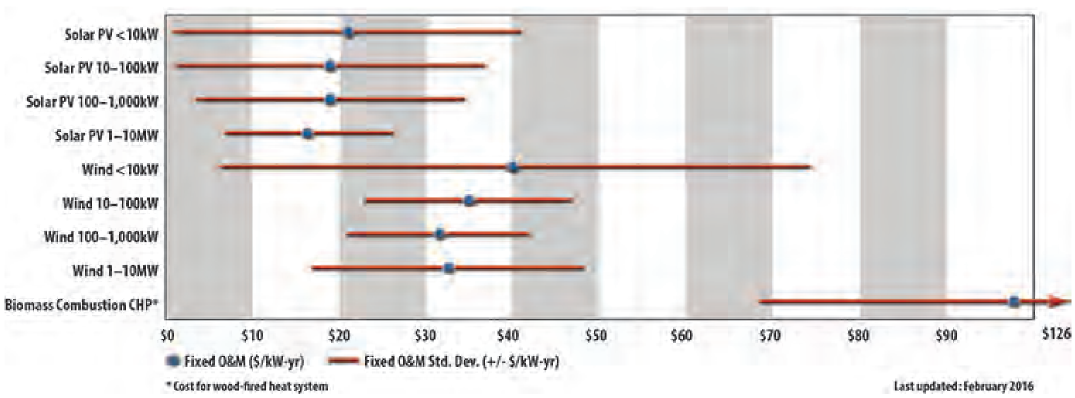


FIGURE 14: Fixed O&M Costs

	O&M
Solar Water Heat, flat plate and evacuated tube	0.5 to 1.0% initial installed cost
Solar Water Heat, plastic collector	0.5 to 1.0% initial installed cost
Solar Vent Preheat	1 Watt/ft^2 fan power
Biomass Wood Heat	$91/kW +/-$33/kW
Ground Source Heat Pump	$109 +/-94/ton

TABLE 4: O&M Costs for Thermal Technologies

The U.S. DOE FEMP sponsored the distributed generation data used within these charts and can be found at *http://www.nrel.gov/analysis/tech_cost_dg.html*

APPENDIX D: COGENERATION MEMORANDUM

1.1 OVERVIEW

Cogeneration, otherwise known as Combined Heat & Power (CHP) or in some cases tri-generation, is a means of using a fuel source, often natural gas, to create electricity and hot water or steam simultaneously. Figure 1 provides a schematic of the process and energy flow. Commercialized cogeneration technologies that can be installed at a campus to meet the electric needs include fuel cells, internal combustion (IC) engine generators, combustion gas turbines, micro turbines, or gas driven heat pumps. Heat recovered from the electrical production can be captured for useful purposes from steam generators, heat recovery hot water generators or liquid to liquid heat exchangers.

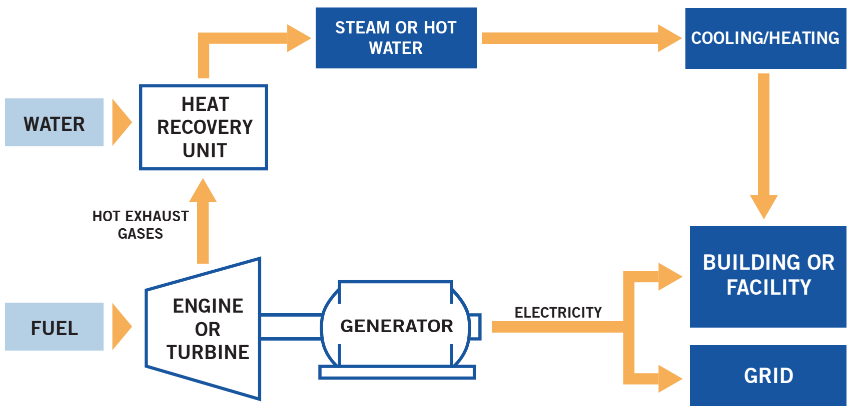


FIGURE 1: Cogeneration Schematics

Source: U.S. EPA – Combined Heat and Power Partnership

ADVANTAGES OF CHP

Cogeneration can be more efficient than grid sourced electricity when heat is captured and used productively. Transmission and distribution losses account for the majority of the difference in efficiency between grid power and a localized CHP system. CHP can be approximately 90% efficient if all of the recoverable energy is used versus only 60% efficient when using a traditional boiler and the electric grid for the same amount of energy. Figure 2 provides a comparison of the efficiency gains when cogeneration is implemented.

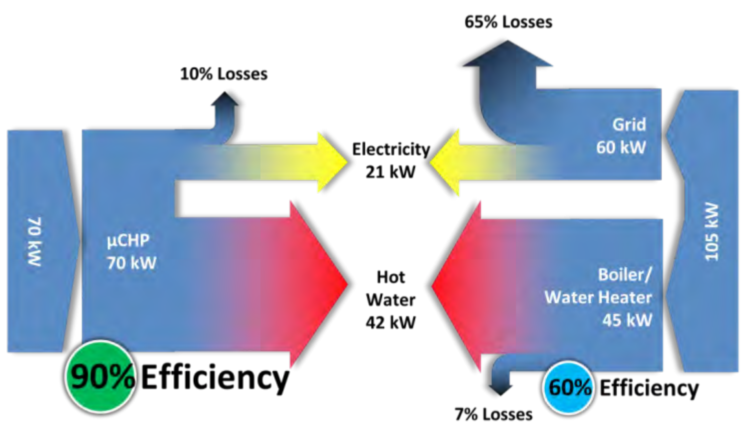


FIGURE 2: Cogeneration Versus Grid / Boiler Energy Production Efficiency

1.2 CHP FEASIBILITY

When screening for the feasibility of CHP, the following conditions make CHP an attractive option for a campus:

- Low natural gas prices and high electric utility rates,
- A constant thermal demand throughout the year,
- Campuses with a central plant with district heating and cooling,

- Utility or state incentives that support CHP, and
- Ease of installation with existing headers and availability of space.

Table 1: CHP Simple Payback (Years) with Utility Cost Variations provides a comparison of varying electric and natural gas prices to the potential benefit of CHP in terms of the simple payback in years.

Natural Gas ($/MMBtu) \ Electricity ($/kWh)	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.26
12.25				129.2	26.3	14.6	10.1	7.6	6.3	5.3	4.6	4.0	3.6	3.2	2.9	2.7	2.5
12.00				67.4	22.2	13.3	9.5	7.4	6.0	5.1	4.4	3.9	3.5	3.2	2.9	2.6	2.4
11.75				45.6	19.2	12.1	8.9	7.0	5.8	4.9	4.3	3.8	3.4	3.1	2.8	2.6	2.4
11.50				34.4	16.9	11.2	8.3	6.7	5.5	4.7	4.2	3.7	3.3	3.0	2.8	2.5	2.4
11.25			170.2	27.7	15.1	10.3	7.9	6.4	5.3	4.6	4.0	3.6	3.2	3.0	2.7	2.5	2.3
11.00			77.1	23.1	13.6	9.6	7.5	6.1	5.1	4.4	3.9	3.5	3.2	2.9	2.7	2.5	2.3
10.75			49.8	19.9	12.4	9.0	7.1	5.8	5.0	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.3
10.50			36.8	17.4	11.4	8.6	6.7	5.6	4.8	4.2	3.7	3.3	3.0	2.8	2.6	2.4	2.2
10.25		249.5	29.2	16.5	10.6	8.0	6.4	5.4	4.6	4.1	3.6	3.3	3.0	2.7	2.5	2.3	2.2
10.00		90.0	24.2	14.0	9.8	7.6	6.2	5.2	4.5	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.2
9.75		54.9	20.6	12.7	9.2	7.2	5.9	5.0	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.3	2.1
9.50		39.5	18.0	11.7	8.6	6.8	5.7	4.8	4.2	3.7	3.4	3.0	2.8	2.6	2.4	2.2	2.1
9.25	467.2	30.9	16.0	10.8	8.1	6.5	5.4	4.7	4.1	3.6	3.3	3.0	2.7	2.5	2.3	2.2	2.1
9.00	108.2	25.3	14.3	10.0	7.7	6.2	5.2	4.5	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0
8.75	61.2	21.5	13.0	9.3	7.3	6.0	5.1	4.4	3.9	3.5	3.1	2.9	2.6	2.4	2.3	2.1	2.0
8.50	42.7	18.6	11.9	8.8	6.9	5.7	4.9	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0
8.25	32.7	16.4	11.0	8.2	6.6	5.5	4.7	4.1	3.7	3.3	3.0	2.8	2.5	2.4	2.2	2.1	1.9
8.00	25.6	14.7	10.2	7.8	6.3	5.3	4.6	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9
7.75	22.4	13.3	9.5	7.4	6.0	5.1	4.4	3.9	3.5	3.2	2.9	2.6	2.5	2.3	2.1	2.0	1.9
7.50	19.3	12.2	8.9	7.0	5.8	4.9	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.9
7.25	17.0	11.2	8.4	6.7	5.6	4.8	4.2	3.7	3.3	3.0	2.8	2.6	2.4	2.2	2.1	1.9	1.8
7.00	15.1	10.4	7.9	6.4	5.3	4.6	4.0	3.6	3.2	3.0	2.7	2.5	2.3	2.2	2.0	1.9	1.8
6.75	13.7	9.7	7.5	6.1	5.2	4.5	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.1	2.0	1.9	1.8
6.50	12.6	9.1	7.1	5.8	5.0	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.3	2.1	2.0	1.9	1.8
6.25	11.5	8.6	6.8	5.6	4.8	4.2	3.7	3.3	3.0	2.8	2.6	2.4	2.2	2.1	2.0	1.8	1.7
6.00	10.6	8.0	6.5	5.4	4.6	4.1	3.6	3.3	3.0	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7
5.75	9.9	7.6	6.2	5.2	4.5	4.0	3.5	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7
5.50	9.2	7.2	5.9	5.0	4.4	3.8	3.4	3.1	2.9	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7
5.25	8.6	6.9	5.7	4.8	4.2	3.7	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.9	1.8	1.7
5.00	8.1	6.5	5.5	4.7	4.1	3.6	3.3	3.0	2.7	2.5	2.4	2.2	2.1	1.9	1.8	1.7	1.6
4.75	7.7	6.2	5.3	4.5	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7	1.6
4.50	7.3	6.0	5.1	4.4	3.9	3.5	3.1	2.9	2.6	2.4	2.3	2.1	2.0	1.9	1.8	1.7	1.6
4.25	6.9	5.7	4.9	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.6
4.00	6.6	5.5	4.7	4.1	3.7	3.3	3.0	2.8	2.5	2.4	2.2	2.1	1.9	1.8	1.7	1.7	1.6
3.75	6.3	5.3	4.6	4.0	3.6	3.2	2.9	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.6
3.50	6.0	5.1	4.4	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.6	1.5
3.25	5.8	4.9	4.3	3.8	3.4	3.1	2.8	2.6	2.4	2.2	2.1	2.0	1.9	1.8	1.7	1.6	1.5
3.00	5.6	4.8	4.2	3.7	3.3	3.0	2.8	2.6	2.4	2.2	2.1	2.0	1.8	1.7	1.7	1.6	1.5
2.75	5.4	4.6	4.0	3.6	3.2	3.0	2.7	2.5	2.3	2.2	2.0	1.9	1.8	1.7	1.6	1.6	1.5
2.50	5.2	4.5	3.9	3.5	3.2	2.9	2.7	2.5	2.3	2.1	2.0	1.9	1.8	1.7	1.6	1.5	1.5

Legend	
Simple payback less than 3 years:	
Simple pay back between 3 to 7 years	
Simple payback over 7 years:	
No return	

TABLE 1: CHP Simple Payback (Years) with Utility Cost Variations

Many assumptions including generator efficiency, operating hours, maintenance costs, existing boiler efficiency, and installation costs are factored into Table 2 as is therefore given only as an indication of the influence commodity pricing has on CHP economics.

Campuses which have central plants and demand throughout the year are considered preferred sites for CHP. District heating and cooling through a central plant are usually necessary to make efficient use of a CHP since an accumulation of smaller building loads are connected through a central hub and economies of scale help reduce the project cost per kW.

1.3 CONNECTICUT INCENTIVES FOR COGENERATION

In Connecticut, there are incentives available for CHP, making it an attractive option. Cogeneration may qualify for Class III Renewable Energy Credits (RECs), in which the system can submit NEPOOL credits for monetary revenue quarterly. This incentive helps to meet Connecticut's Renewable Portfolio Standards. According to the eligibility requirements for Class III sources, the CHP unit must:

- Have an operating efficiency[1] of at least 50%,
- Contribute at least 20% of its energy output to electricity and at least 20% of its energy output to thermal energy,
- Be installed on or after April 1, 2007, and
- Have a monitoring and verification plan (M&V)

The value of RECs varies with market pricing, never exceeding $55/MW. These incentives help to drive installation of CHP in the state.

[1] Efficiency is defined as the sum of the total useful electrical and thermal energy output divided by total operational electrical and fuel energy input) for that calendar quarter, and percentages of electricity and thermal energy with the efficiency standards as verified by the M&V plan submitted

Additionally, Connecticut's investor-owned natural gas distribution companies have an applicable distributed generation rider. Under the rider, some distribution charges may be waived with the installation of a CHP system. Charges may include a daily demand meter charge, delivery charge per ccf and others. More information on the distributed generation rebate rider can be found here on the cngcorp.com website.

CHP TYPES AND SIZING FOR TYPICAL CAMPUS USERS

Reciprocating engine or fuel cell CHP units are usually best suited for colleges and universities since combustion turbines generate more thermal energy than can be used by the campuses (exceptions are medical facilities). Although less common, campuses that have oversized steam boilers, or 150 psig or greater, can consider using a back pressure steam turbine to generate electricity on-campus. A major benefit to generating on-campus via CHP or fuel cells, is that the electrical demand charge, often 25% or more of bill, can be reliably reduced up to 95% of the time.

Although CHP engine/generators are available as small as 5kW electrical or 0.03 MMBtu/hr recoverable thermal, they are usually not cost effective from a planning standpoint when factoring in engineering and interconnections. Total installed cost for CHP systems typically range from $2,000 per kW to $4,000 per kW of installed generator size, depending on the manufacturer, technology, and complexity of the installation.

More typical for medium to large colleges and universities are CHP units of 200 kW and greater. A baseload of approximately 1 MMBtu/hr can support the continuous operation of a 200 kW CHP unit. This is approximately the same thermal load as a 65 R-Ton absorption chiller would require. Contributors to a year round thermal load are generally absorption chillers and to a small extent domestic hot water or other campus uses such as research or washing.

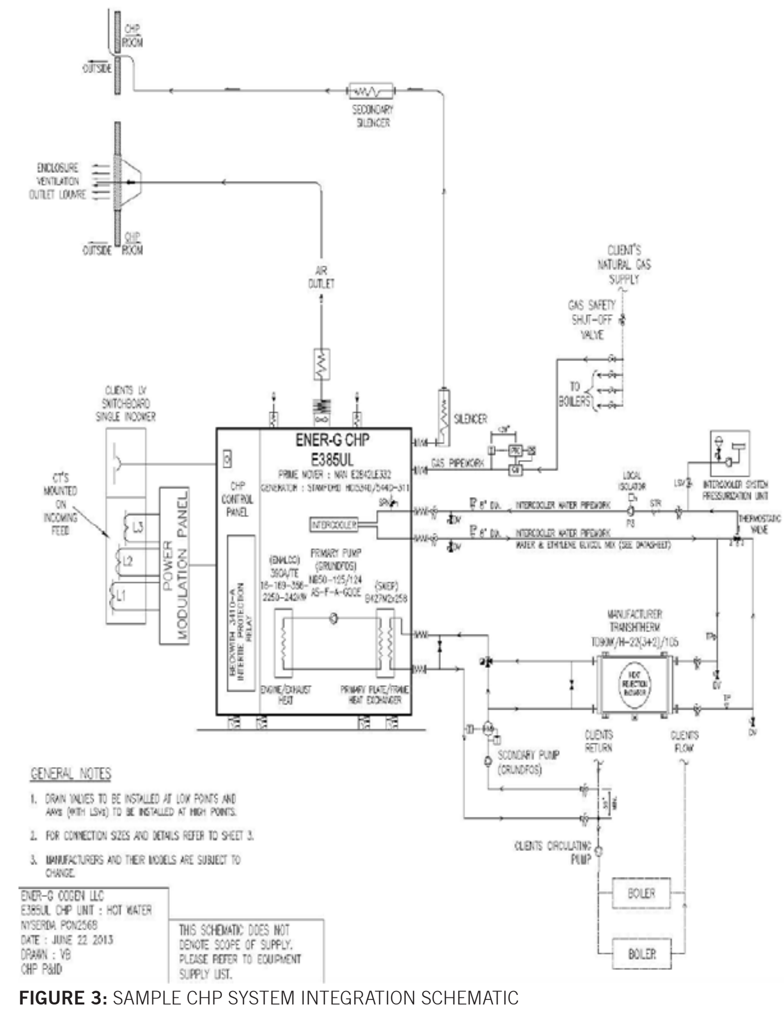


FIGURE 3: SAMPLE CHP SYSTEM INTEGRATION SCHEMATIC