6.13

CENTRAL CONNECTICUT STATE UNIVERSITY

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EXECUTIVE SUMMARY

The Central Connecticut State University (Central) Energy Master Plan aims to identify ways Central can improve energy use on campus, and be an active participant in Connecticut State Colleges & Universities (CSCU)'s energy management, reduction and conservation efforts. Central adopted a Climate Action Plan in 2009, exemplifying its commitment to energy conservation and sustainability.

The campus completed a number of significant energy projects to date including retrocommissioning, installation of a 1.4 MW fuel cell, multiple lighting retrofits and energy conservation projects.

Based on utility data, Central is a high energy user relative to other CSCU campuses and northeast median averages (See Figure 1).

Natural gas consumption at the Energy Center is a major contributor to Central's higher energy use. The use of absorption chillers and the fuel cell contribute to a large portion of natural gas used at the Energy Center. Natural gas also fuels Central's cogeneration units.

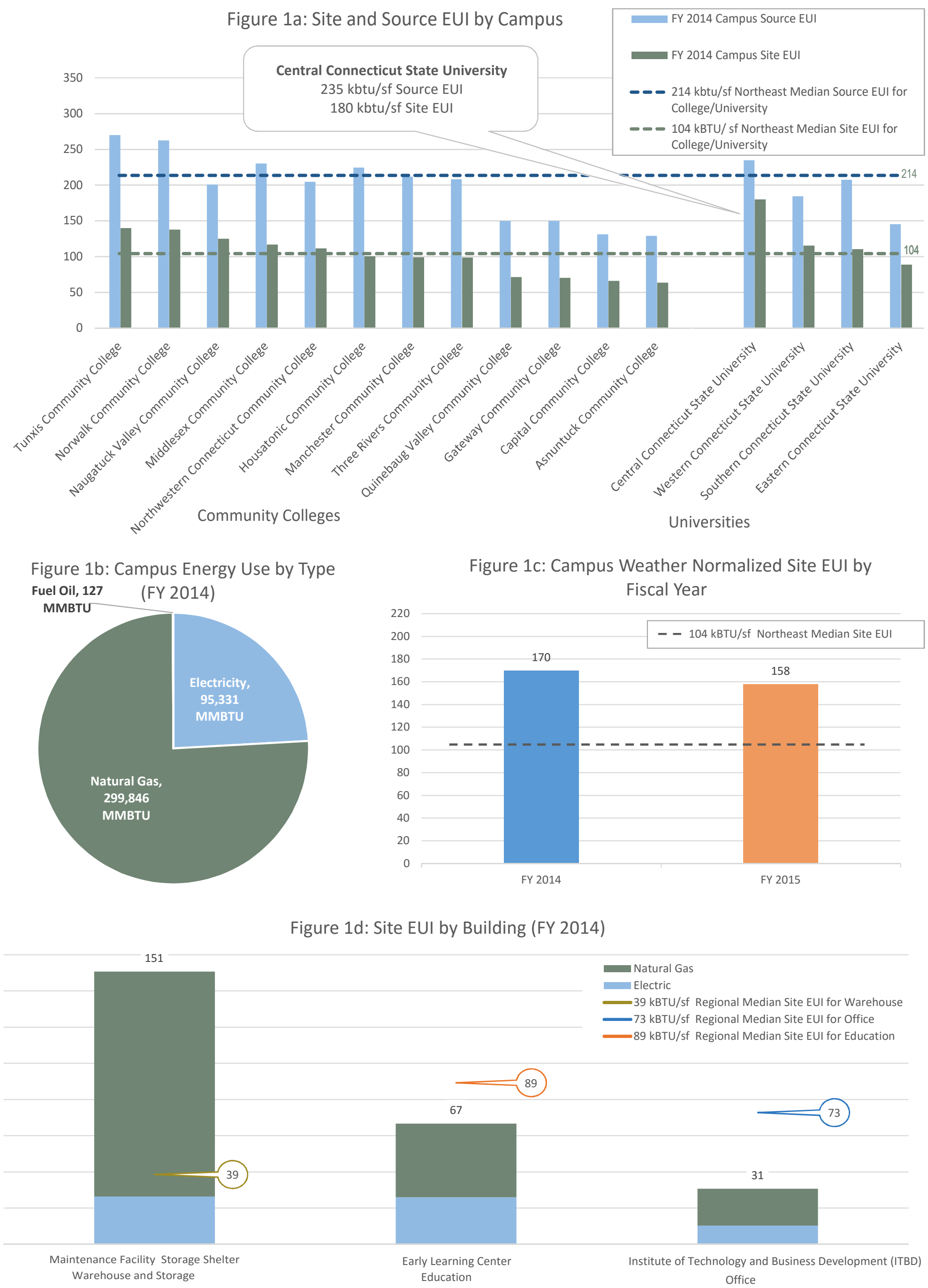


FIGURE 1: Energy Dashboard - Central Connecticut State University

In addition, energy intensive building functions, systems and deferred maintenance needs also contributes to higher energy use. Specifically:

- Over half of the campus buildings were constructed pre-1981, before building envelope and energy codes were implemented.
- Many of the buildings still use pneumatically operated HVAC equipment as opposed to Direct Digital Control (DDC). As renovation and construction projects occur Facilities upgrades systems to DDC when feasible.
- The campus has numerous buildings that serve energy intensive functions, such as laboratories, dining areas and central plants.
- Deferred maintenance from lack of historical funding has accumulated and impacts energy use due to dated and energy intensive systems and infrastructure.

Energy Spending

While Central has a high EUI, the campus also pays the lowest energy cost of the Universities on a gross square foot (GSF) basis partially owing to its large use of natural gas for the fuel cell and cogeneration, instead of electric. Table 1 provides a comparison of Central's energy spending compared to the average of CSCU campuses and the Northeast Region Commercial Sector. Central has a very favorable gas rate, about half that paid by the CSCU community college average, and approximately 30% lower than the CSCU universities' average. This favorable cost can be attributed to Central's natural gas supplier procurement contract.

	Central Connecticut State University		Average of CSCU University		Average of CSCU Community College		Northeast Region Commercial Sector
Cost per Square Feet	$	1.55	$	2.08	$	2.49	$	1.67 [1]
Cost per FTE Student	$	484.00	$	677	$	311	$	-
Avg. Cost per kWh Electricity from Grid	$	0.13	$	0.14	$	0.14	$	0.15 [2]
Avg. Cost per MMBtu Natural Gas	$	5.19	$	7.32	$	10.06	$	10.03 [3]
Avg. Cost per Gallon Fuel Oil		Unknown	$	3.77	$	3.46		
Total Operating Expenses (2014) [4]	$	223,005,573 [4]	$	-	$	-		
Total Energy Spending	$	4,541,967	$	-	$	-		
% of Operating Expenses		2.04%		2.67%		1.95%		

TABLE 1: Energy Cost Comparison (FY 2014)

The following sections outline opportunities that may reduce Central's energy use:

Utility Incentives/ Develop Plan for Energy Efficiency Measures (EEMs)

Central's electric utility is Eversource. Eversource offers energy project incentives, and currently provides an opportunity to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project." A comprehensive project is realized by implementing two or more Energy Efficiency Measure (EEM) projects at the same time. For example, one project could be a VFD on a fan and other could be LED lighting; both projects may be cost capped at 80% rather than just 50%. Note, natural gas saving projects with CNG can contribute to a Comprehensive Project with Eversource, but will not have the increased incentive amount.

Since incentives are based on incremental energy savings, further analysis and collaboration with Eversource is required to determine rebate amounts for each opportunity. Table 2 demonstrates the priority one and priority two projects Central should consider.

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - http://www.eia.gov/electricity/monthly/current_year/june2014.pdf
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm
[4] Connecticut Community Colleges Financial Statement with Supplementary Combining Information June 30, 2014 and 2013

Opportunity ID	Energy Efficiency Opportunity	Associated Building if Applicable	Cost	Payback w/rebate (Years)	Priority
CCSU-1	Consult with CNG (UIL) to incorporate Steam Trap Audit and Maintenance Program.	N/A	Varies	<1 - 2	1
CCSU-2	Establish hood management program and renovate fume hoods with energy efficient designs. At time of visit Fume Hood system venting consisted of approximately 45,000 CFM of conditioned air. Eversource Green Labs Initiative may be a resource if variable speed drives are added.	Nicolaus Copernicus Hall	Varies	Varies	1
CCSU-3	Review ventilation set points and controls for both air quality and efficiency. Engage with Eversource Green Lab Initiative for possible funding.	Nicolaus Copernicus Hall	Varies	Varies	1
CCSU-4	Complete Phase 2 retrocommissioning of the Energy Center. This phase consists of optimizing the campus wide chilled water loop system to include primary and secondary chilled water pumps and optimizing condenser water.	Energy Center (CCSU)	240,000	<1	1
CCSU-5	Work with the utility CNG to have the distributed generation rider added to the cogeneration account.	N/A	N/A	Varies	1
CCSU-6	Review utility rate demand and usage charges and compare with demand response credits and fuel costs to determine best operating strategy for on-site generators.	N/A	Varies	Varies	1
CCSU-7 - CCSU-10	Upgrade to LED lighting. Consult with Eversource on energy saving lighting upgrades.	Various	$384,609	2.5	1
CCSU-11	Upgrade lighting in residence hall to LED	Midcampus Residence Hall	Varies	2-6	1
CCSU-12	LED lighting upgrades and/or study. Consult with Eversource on energy saving lighting upgrades.	General Information (CCSU)	Varies	2-6	1
CCSU-13	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations. Also investigate solar PV on East Campus, dependent on future development plans	N/A	Varies	10-20	1
CCSU-14	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops, garages, or any other space where air is prone to stratification with ceilings >15' tall.	Grounds Building	Varies	3-6	2
CCSU-15	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops, garages, or any other space where air is prone to stratification with ceilings >15' tall.	Maintenance Facility Storage Shelter	Varies	3-6	2

CCSU-16	Add VFDs to cooling water pumps, ensure minimum flow requirement to chillers are met and use when "free cooling" after study.	Energy Center (CCSU)	$365,900	Varies	2
CCSU-17	Add cooling tower water side heat exchanger and pumps for free cooling after study.	Energy Center (CCSU)	$2,181,000	Varies	2
CCSU-18 - CCSU-27	Install CO2 occupancy controls on fans in residence halls.	Various	Varies	Varies	2
CCSU-28 - CCSU-37	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Various	$160 - $315 per thermostat	1-5	2
CCSU-38	Install occupancy sensors for lighting and/or ventilation. May be needed for up to 90% of campus.	All (CCSU)	Varies	3-7	2
CCSU-39 - CCSU-43	Convert pneumatic controlled HVAC systems to DDC with VAV.	Various	$228,000 - $520,700	Varies	2
CCSU-44	Explore solar PV coupled with a battery storage system to reduce electrical costs in partnership with the utility.	N/A	Varies	Varies	2

TABLE 2: Central Recommended Select Energy Efficiency Measures

In addition to the priority projects, next steps for Central are below:

Next Steps

Management

Central should continue to designate staff to review energy bills, including tracking energy use and comparing energy spend to available budgets.

Renewable Energy

Evaluate and pursue roof-top solar power purchase agreements (PPAs) on campus, and ground-mount PPAs for “East” Campus.

Cogeneration

Central may have an opportunity to realize savings by modifying the operation of its existing cogeneration system. Additional study is recommended to determine the potential cost savings by modeling the impact of consistent operation of the two generators on demand charges, fuel cell electricity reliability, increased maintenance of the cogeneration units and other cost factors which can offset some of the potential savings realized from increased operation. Additional savings may be able to be captured if the campus investigates and pursues Renewable Energy Credits (RECs), capacity payments and demand response associated with cogeneration. While RECs were previously investigated and denied, there is an opportunity to make a case for a change in operations that may allow the campus to now capture RECs, if successful.

By taking these steps, Central will be further positioned to decrease energy use, add renewable energy, optimize cogeneration opportunities for additional onsite power, and further progress toward their sustainability goals.

LED lighting upgrade projects are given a priority 1 designation assuming they are combined with other measures and qualify for a “Comprehensive Project” with Eversource. Note, natural gas saving projects with CNG can contribute to a Comprehensive Project with Eversource, but will not also have the increased incentive amount.

INTRODUCTION

As part of the Connecticut State Colleges & Universities (CSCU) Energy Master Plan, Central Connecticut State University's (Central) building infrastructure, energy use and energy management practices were assessed. The ultimate goal was to determine ways Central could improve its energy use on campus, and be an active participant in CSCU energy reduction efforts. This chapter identifies Central's historical energy use, future projected needs and energy recommendations.

FIGURE 1.1: Central Connecticut State University Student Center

FIGURE 1.2: Central Connecticut State University ITBD

1.1 CENTRAL OVERVIEW

Central is the largest of CSCU's four regional public universities, serving a diverse student body of approximately 12,500 undergraduate and graduate students. The campus is located at 1615 Stanley Street in New Britain, Connecticut. Spanning nearly 165 acres, Central houses approximately 40 buildings, including ten residence halls as well as 26 parking lots and four parking garages.

Central has one facility at its downtown location at 185 Main Street. The Institute of Technology and Business Development (ITBD) facility offers companies around the state development support through business outreach.

A list of campus buildings, not including other assets such as dugouts and press boxes, is included in Table 1.1.

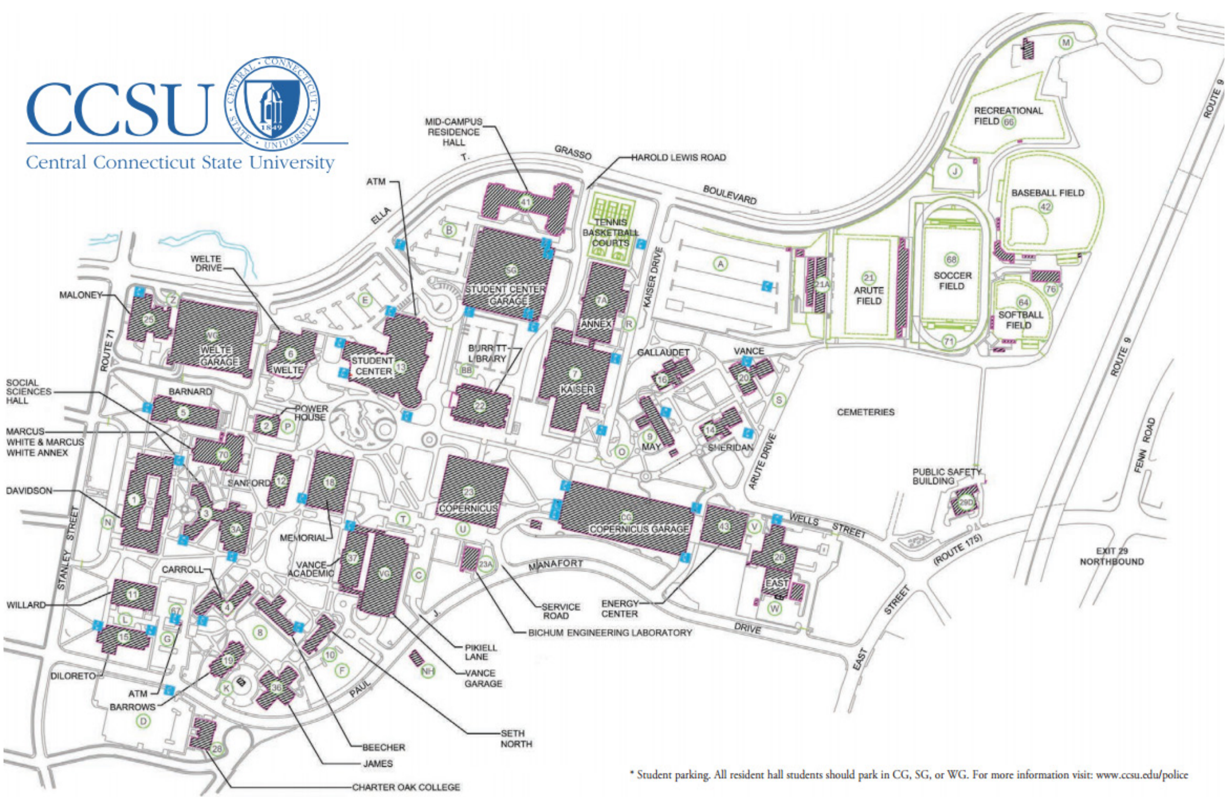


FIGURE 1.3: Central Connecticut State University Campus Map

Building	Year Built [Renovated]	Gross Square Feet	Building Function
Elihu Burritt Library	1972 [est 2020]	140,951	Administrative and Library
Anthony and Helen G. Bichum Engineering Laboratory	2012	4,822	Academic
James J. Maloney Hall	1979	57,208	Academic
Social Sciences Hall	2013	76,174	Academic
Inst. Of Tech and Business Development (ITBD)	1993 [2012]	109,558	Administrative
Student Center	1963 [2002]	121,164	Administrative
Emma Hart Willard Hall	1953 [est 2018]	60,125	Administrative and Academic
Frank J. DiLoreto Hall	1969 [est 2018]	45,476	Administrative and Academic
Henry Barnard Hall	1953 [2012]	80,793	Administrative and Academic
Herbert D. Welte Hall	1964	82,018	Administrative and Academic
Lawrence J. Davidson Hall	1923	115,293	Administrative and Academic
Marcus White Hall and Annex	1928	65,411	Administrative and Academic
Maria Sanford Hall	1959	38,558	Administrative and Academic
Nicolaus Copernicus Hall	1974	186,447	Administrative and Academic
Robert C. Vance Academic Center	2000	88,107	Administrative and Academic
Hitchcock-Young Pavilion	2012	4,305	Athletic Facility
Kaiser Hall Annex	1991	39,625	Athletic Facility
Harrison J. Kaiser Gym	1965	169,347	Athletic Facility
Recreational Field Support Facility	2011	95	Athletic Facility
Early Learning Center	2002	4,845	Childcare Center
Athletic Support Facility	2000	222	Facilities Management
Chemical Storage Facility		275	Facilities Management
East Hall	1980	46,777	Facilities Management
East Pump House	1994	1,080	Facilities Management
Energy Center	2004	33,705	Facilities Management
Grounds Building	1988	2,268	Facilities Management
Maintenance Facility Storage Shelter	2013	4,503	Facilities Management
Maintenance Recycling De-Icing Facility	2012	1,257	Facilities Management
North Pump House	1992	497	Facilities Management
Power House	1927 [1967]	13,165	Facilities Management
South Pump House	1994	497	Facilities Management
Central Police Building	2013	12,593	Police Department
Subtotal		1,607,161	
Mid-Campus Residence Hall	2015	220,000	Residence Hall
Catharine Beecher Hall	1963 [1998]	36,528	Residence Hall
Clarence Carroll Hall	1957 [1959]	55,317	Residence Hall
F. Don James Hall	1995	55,209	Residence Hall
Mildred Barrows Hall	1972	65,785	Residence Hall
Robert E. Sheridan Hall	1968	57,721	Residence Hall
Robert Vance Hall	1971	84,221	Residence Hall
Samuel J. May Hall	1963	40,851	Residence Hall
Seth North Hall	1956	32,124	Residence Hall
Thomas A. Gallaudet Hall	1969	64,162	Residence Hall
Hilltop Cafe	2016	22,000	Dining Hall
Memorial Hall	1971 [2015]	65,790	Dining Hall
Subtotal		799,708	
Total		2,406,869	
Garages			
Copernicus Parking Garage	1970	502,198	Parking Garage
Student Center Parking Garage	1987	267,826	Parking Garage
Vance Parking Garage	2000	150,882	Parking Garage
Welte Parking Garage	2003	369,846	Parking Garage
Subtotal		1,290,752	

TABLE 1.1: Central Campus Building Information

The Department of Facilities Management (Facilities) is responsible for all campus facilities and grounds and are guided by Central's Campus Plan, the Transform CSCU 2020 program, Climate Action Plan, and Strategic Plan. Facilities also oversees the Energy Center which supplies hot water, heating and cooling, and also has combined heat and power capabilities.

Central prides itself on its contribution to the state economy as 85% of graduates continue on to work and live in Connecticut. Central has earned national recognition from its selection by Princeton Review as one of "The Best Northeastern Colleges," one of "America's Best Value Colleges," and has been recognized for its commitment to sustainability by Central's inclusion on Princeton Review's list of "322 Green Colleges" in the nation. In 2007, Central completed its first Climate Action Plan with targeted energy reductions, including overall climate neutrality by 2050. Since its inception, the campus has completed numerous energy initiatives including LED retrofits, retrocommissioning and other projects outlined in Section 1.2.

1.2 PREVIOUS ENERGY STUDIES & PROJECTS

Central has had targeted energy studies in the past focusing on specific campus buildings or programs. As part of a system-wide initiative, Central recieved a facility benchmarking study in 2013. The report provided space profile, capital expenditures and operations comparisons against regional peers. The results indicated a 10% decrease in energy use at Central between the years 2008 and 2012 with an average energy use of approximately 132 kBtu per GSF. The corresponding regional peer average used 117 kBtu of energy per GSF . Central has continued to exemplify a desire to reduce its energy use.

Central's energy projects are also largely driven by their 2009 Climate Action Plan (CAP) goals of achieving climate neutrality by 2050. Their CAP outlines the avenues to achieve their goal. The campus' Phase 2 of the plan (FY 2016 to FY 2025) focuses on reducing greenhouse gases by 50% from 2008 levels, by implementing projects related to energy conservation, renewable energy, thermal conservation and others. This phase aligns with the Central's Energy Master Plan Chapter goals.

Due to Central's commitment to sustainability, and in an effort to save energy and capital, Central has completed significant energy projects in the past described in the following list

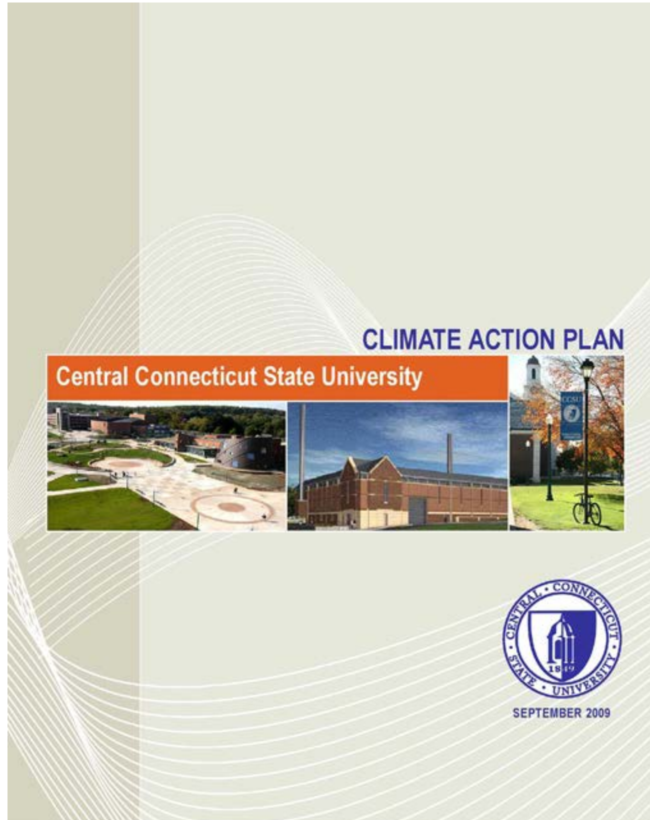


FIGURE 1.4: Central Connecticut State University Climate Action Plan

COGENERATION

Description: Installed 1.4MW fuel cell as part of a CHP system, as well as two Internal Combustion Engines. [1]
Year: 2011, 2004
Associated Building: East Hall and Energy Center

LIGHTING

Description: Installed energy efficient outdoor lighting fixtures, LEDs, and other retrofits as part of the Connecticut Light & Power program. [2]
Year: 2010
Associated Building: Various

Description: Replace existing lighting with energy efficient lighting in any spaces undergoing renovations.
Year: Ongoing
Associated Building: Various

Description: Changed 700 lighting fixtures from 150W High Pressure Sodium bulbs to 100W Metal Halide bulbs. Plans are to upgrade to LEDs in the future.
Year: 2011 / Future
Associated Building: Copernicus Parking Garage

Description: Changed 216 lighting fixtures from 150W High Pressure Sodium bulbs to more efficient fluorescent bulbs. Plans are to upgrade to LEDs in the future.
Year: 2011 / Future
Associated Building: Welte Parking Garage

Description: Installed motion-sensor lighting in classrooms and other campus areas.
Associated Building: Various

Description: Completed lighting projects involving de-lamping, re-lamping and re-ballasting. [3]
Associated Building: Various

ENERGY CONSERVATION

Description: Removed window mounted air conditioning units and replaced with central air. [4]

Description: Installed vending machine misers.

PROCUREMENT

Description: Public access to EV chargers (only location in the state with 24/7 free access/charging). Chargers in conjunction with CT DEEP grants.

LEED

Description: LEED Gold/Silver Certification
Year: In Progress
Associated Building: Mid-Campus Residence Hall

Description: LEED Gold Certification
Year: 2013
Associated Building: Social Sciences Hall

RETRO COMMISSIONING [5]

Phase 1: Energy Conservation Measures (ECMs) to include chilled water pump optimization, rooftop AHU optimization, second floor AHU optimization, and VAV box occupancy control
Year: October 2011
Associated Building: Robert C. Vance Academic Center, Nicolaus Copernicus Hall
Simple Payback with Rebate: 1.5 years

Phase 2: ECMs for the Energy Center thermal side of the plant to include VFDs for all three boiler forced draft fans, VFDs for all three boiler feed water pumps, and optimization of auxiliary ventilation systems to reduce fan motor HP.
Year: December 2012
Associated Building: Energy Center
Simple Payback with Rebate: 1.4 years

Phase 3: ECMs to include converting constant volume to VAV, applying aggressive time clock scheduling, resetting fans to operate on static pressure, optimizing chilled water control, optimizing VAV hot water valves, installing VAVs, and optimizing RTU fan operation.
Year: June 2013
Associated Building: Harrison J. Kaiser Gym, Robert C. Vance Academic Center, Herbert D. Welte Hall
Simple Payback with Rebate: 2 years

[1] Energy Purchase Agreement by and between FuelCell Energy, Inc. ("Seller") and Central Connecticut State University ("Purchaser"), September 2011.
[2] Gagne, Rob. Green Campus Conference at ECSU, April 19, 2012.
[3] Central, Another Milestone Reached in CCSU Sustainability Initiative. Posted Apr. 22, 2010.
[4] Second Nature, Progress Report for Central Connecticut State University. Jan. 14, 2014. http://reporting.secondnature.org/progress/969/
[5] Central, Summary of Retrocommissioning Projects for CCSU. Mar 10, 2015

EXISTING CONDITIONS & RECOMMENDATIONS

Information on Central's existing conditions was captured from campus interviews, energy data and reports provided by the campus. A holistic view of existing practices, material on energy management, energy infrastructure and project implementation processes was reviewed. Analysis of the data and campus walkthroughs helped clarify recommendations with the goal of decreasing energy use, documented after each subheading.

2.1 FACILITY ENERGY BENCHMARKING AND ENERGY CONSUMPTION

The ability to provide building level data was dependent on the availability of submetering at the campus. Multiple assumptions and data sources were used to establish campus and building level data, which is documented in Appendix A. Central utilizes Square D electrical metering in 85 percent of its occupied buildings. In addition, the University also meters thermal usage in 85 percent of its occupied buildings. Table 2.1 provides a summary of Central's available building submetering.

Energy Type [2]	Total Number of Buildings Consuming Energy Type	Number of Accounts	Number of Buildings Submetered or on an individual Account	Percent of Buildings Submetered
Electricity	46	4	39	85%
Natural Gas	30	23 [1]	26	85%
Fuel Oil	1	1	1	100%
Chilled Water	11	Not metered		0%

TABLE 2.1: Central Submetering by Energy

[1] Two of the accounts are allocated to the fuel cell and cogeneration unit, and do not have an associated building
[2] Central has steam metering, the amount of metering is not currently available.

	Central Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 1.55	$ 2.08	$ 2.49	$ 1.67 [1]
Cost per FTE Student	$ 484.00	$ 677	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.13	$ 0.14	$ 0.14	$ 0.15 [2]
Avg. Cost per MMBtu Natural Gas	$ 5.19	$ 7.32	$ 10.06	$ 10.03 [3]
Avg. Cost per Gallon Fuel Oil	Unknown	$ 3.77	$ 3.46	
Total Operating Expenses (2014) [4]	$ 223,005,573 [4]	$ -	$ -	
Total Energy Spending	$ 4,541,967	$ -	$ -	
% of Operating Expenses	2.04%	2.67%	1.95%	

TABLE 2.2: Energy Cost (FY 2014)

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - *http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm*
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - *http://www.eia.gov/electricity/monthly/current_year/june2014.pdf*
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - *http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm*
[4] Connecticut Community Colleges Financial Statement with Supplementary Combining Information June 30, 2014 and 2013

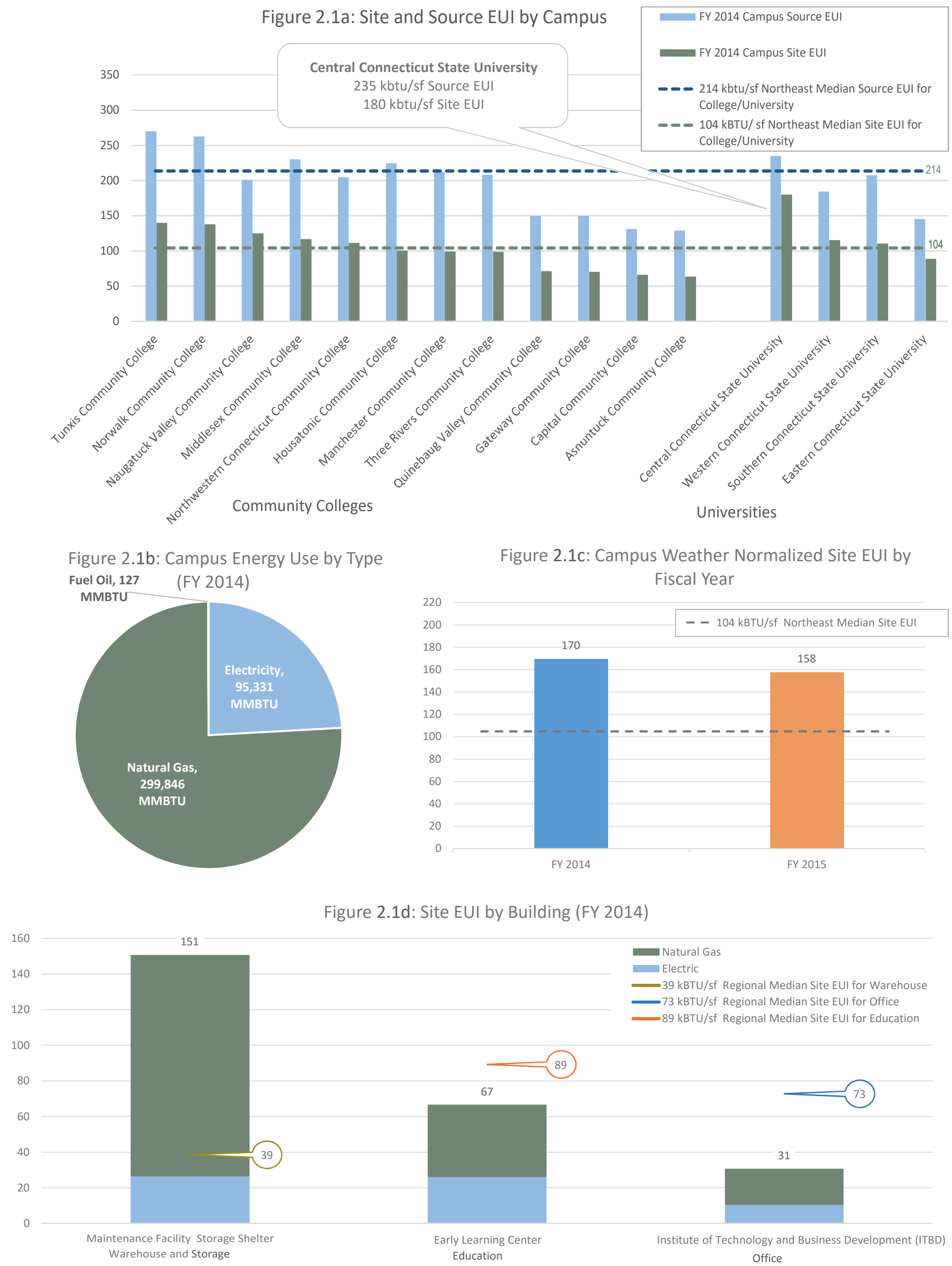


FIGURE 2.1: Central Connecticut State University Energy Dashboard

* Only buildings with both electricity and fuel submetering data are shown

Central is the largest CSCU campus in terms of total energy use, energy use intensity (EUI) and area in gross square feet (GSF). Central realized approximately a 7% decrease in EUI from fiscal year 2014 to 2015, after normalizing for weather variations (Figure 2.1c).

Even so, Central uses over 40% more energy per square foot than the northeast College/University site EUI of 104 kBtu/sf and has the highest EUI of all of the campuses, graphically represented in Figure 2.2.

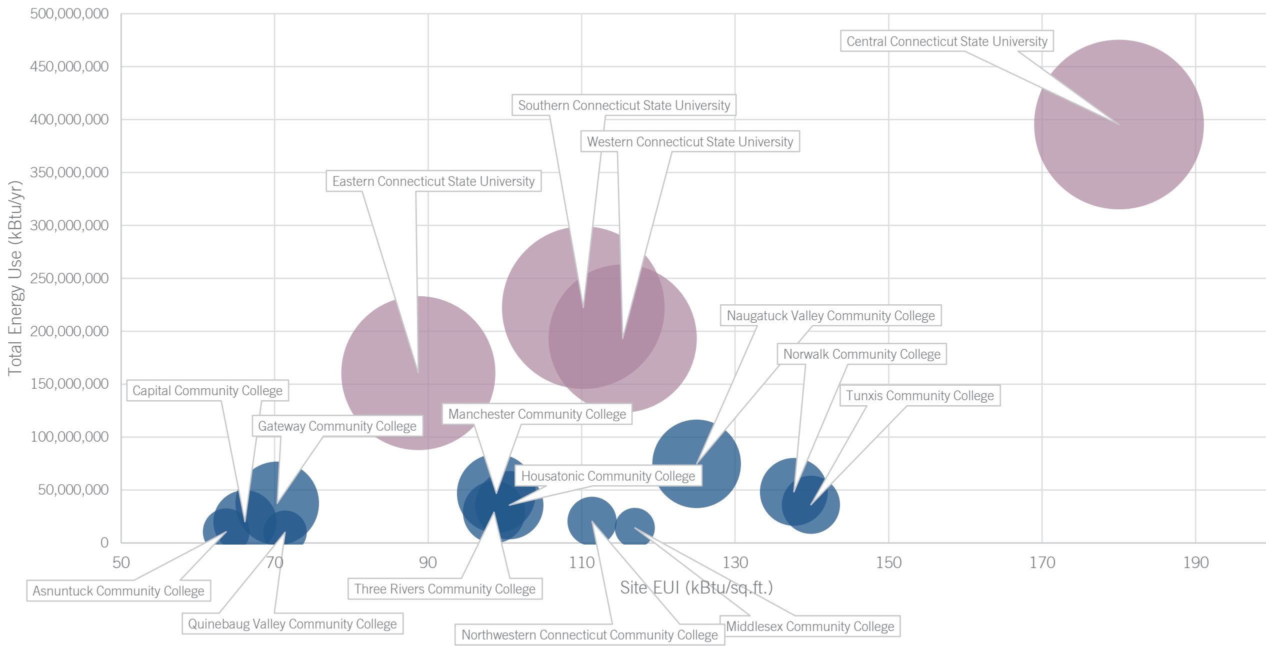


FIGURE 2.2: Campus Energy Metrics Based on GSF; Site EUI

This high site EUI is likely attributed to Central's intensive use of natural gas, which makes up more than 75% of the total energy Central uses (Figure 2.1b).

Natural gas fuels the Energy Center, cogeneration unit, and 1400 kW fuel cell. Since Central produces so much energy on site and not from power plants, the source EUI is not the highest (Figure 2.3)

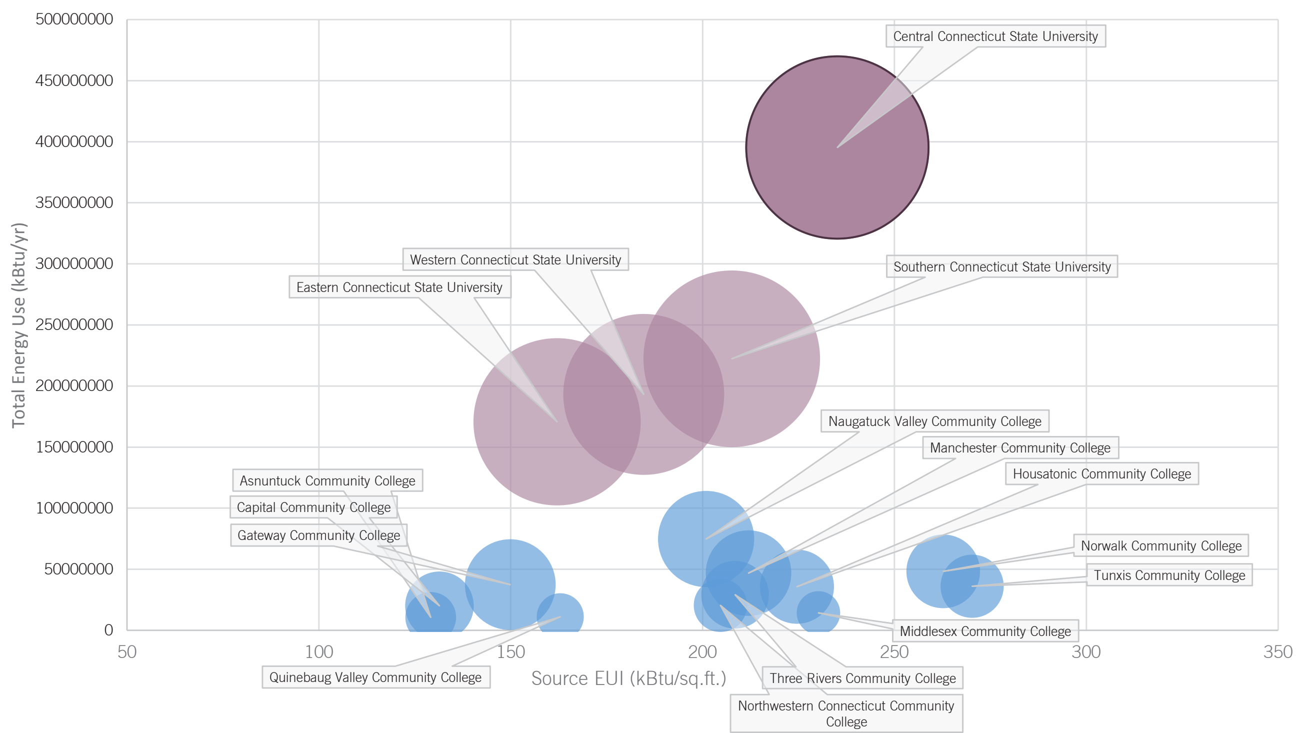


FIGURE 2.3: Campus Energy Metrics Based on GSF; Source EUI

Figure 2.4 provides a breakdown of natural gas by type. The Energy Center boilers use the majority of natural gas followed by the fuel cell.

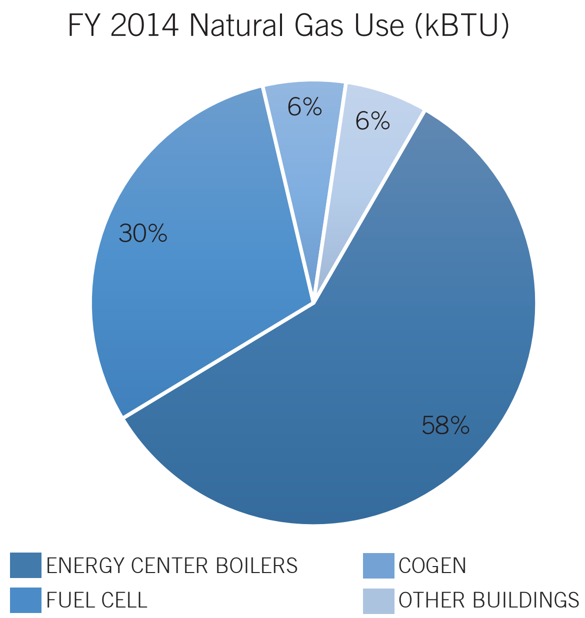


FIGURE 2.4: FY 2014 Natural Gas Use (kBtu)

While Central has over three quarters of occupied buildings submetered, FY 14 data was not available at the time of the analysis. Of the buildings with available data, there are seven buildings that use natural gas and are not on the Central loop (See table below). These buildings have their own natural gas site EUIs which provide an indication of their energy use. Memorial Hall's gas use is for cooking and a back up boiler.

	2014 NATURAL GAS SITE EUI
GROUNDS BUILDING:	272 kBtu/sf
KAISER HALL ANNEX:	156 kBtu/sf
MAINTENANCE FACILITY STORAGE SHELTER:	124 kBtu/sf
CENTRAL POLICE BUILDING:	54 kBtu/sf
EARLY LEARNING CENTER:	41 kBtu/sf
MEMORIAL HALL:	40 kBtu/sf
INSTITUTE OF TECH. AND BUSINESS DEV. (ITBD):	20 kBtu/sf

An obvious high energy user is the grounds building which is heated but most likely attributable to energy loss resulting from personnel frequently entering and exiting the building for supplies, allowing heat to escape. The Maintenance Facility Storage Shelter, Early Learning Center and ITBD are also shown and have their own-building specific total site EUI (Figure 2.1d).

Each building is compared to the Northeast Regional site EUI based on benchmarking building type. The Maintenance Facility Storage Shelter, under the Warehouse and Storage category uses significantly more energy than Northeast median site EUI. The two other buildings under the education and office category use less than the median site EUI. Recommendations for these buildings are documented in Section 2.14. While some accounts had individual gas metering, a majority of the buildings did not have electric metering available for the dates in the analysis. The total EUI for most buildings could not be calculated without historical energy submetering for each building connected to the Central Plant.

Central has an above average campus user density, as described in their 2014 Sightlines report. Of the Connecticut State Universities, Central has the second highest FTE student density. (see Figure 2.5).

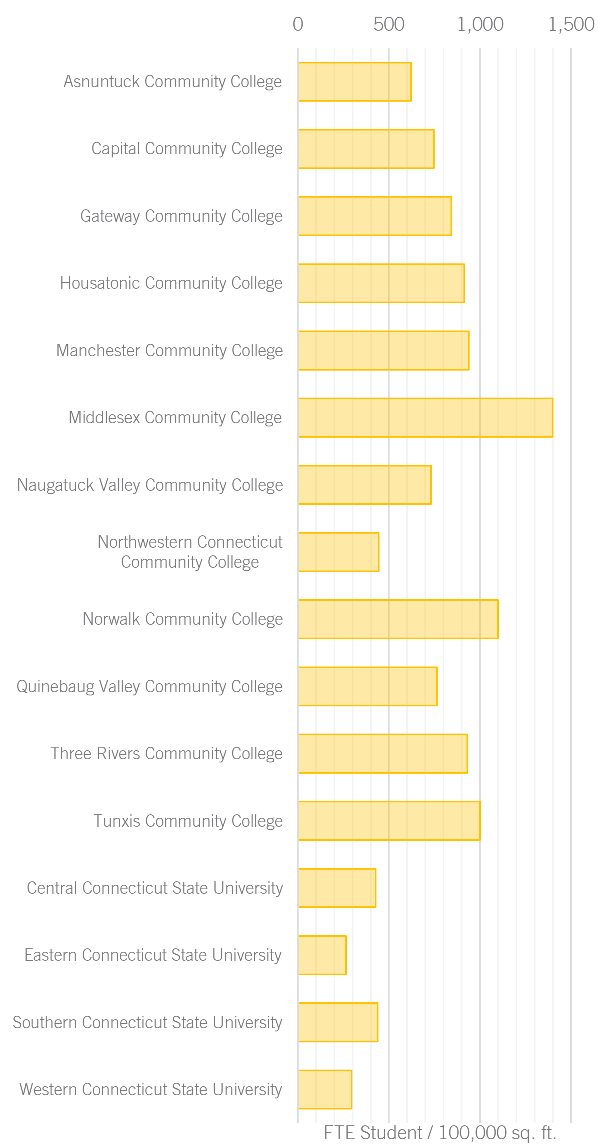


FIGURE 2.5: Sightlines CSCU FTE/100,000 Square Foot Comparison

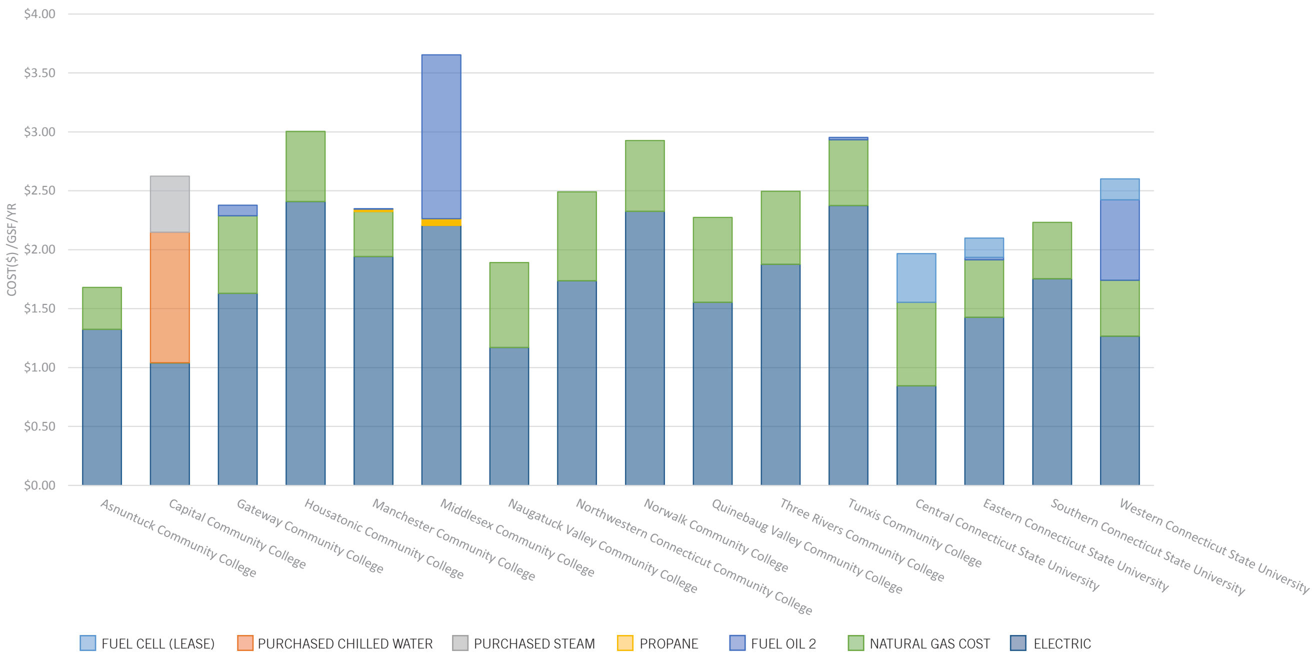


FIGURE 2.6: CSCU FY 14 Energy Cost/GSF

To note: Prices for oil were not provided and therefore not included

While Central has the highest energy use/ GSF it also pays the lowest energy cost of the Universities on a GSF basis (Figure 2.6) partially owing to its large use of natural gas for the fuel cell and cogeneration, instead of electric. Central also has a very low natural gas rate about half of that paid by other campuses. When the campus switched from their old procurement contract with Hess Energy, to the Local Distribution Company, CNG, as their supplier in FY 14, their overall prices fell about three times from their usual cost.[1]

2.2 CAMPUS UTILITIES AND DISTRIBUTION

Central uses mainly electricity and natural gas for energy use, as shown in the energy dashboard. The Energy Center also uses fuel oil for its diesel generators. The following is a list of Central's utility providers:

- Electric: Eversource (formerly Connecticut Light & Power)
- Natural Gas: United Illuminating Holdings (formerly, and also referred to as Connecticut Natural Gas (CNG))
- There is no information to indicate Central uses propane.

Central has some distributed heating, with a heating loop that serves 16 buildings on campus. The campus' Energy Center includes two absorption chillers and one electric chiller providing chilled water to 11 buildings.

[1] Per email from Central dated October 25, 2013.

2.3 ENERGY PROCUREMENT

In FY 2014, Central paid $ 4,541,967 for energy, including the cost of the PPA lease.

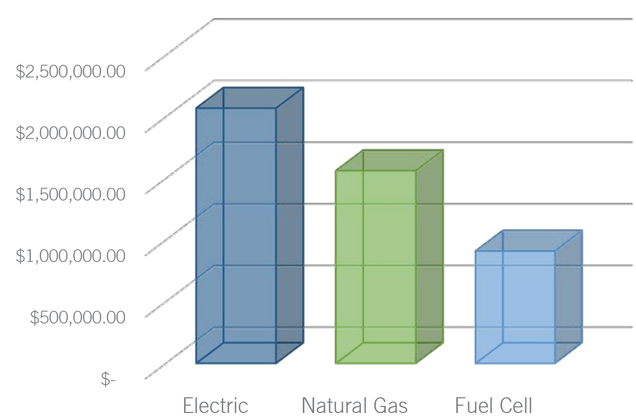


FIGURE 2.7: Central FY 2014 Cost by Commodity

NATURAL GAS PROCUREMENT

Central has changed natural gas suppliers multiple times since 2010. In 2009, Central went out to bid under a Connecticut Department of Administrative Services (DAS) RFP for a natural gas supplier for its Energy Center gas account. The contract was awarded to Hess Energy for a unit commodity price of $5.437 /MMBTU. When the contract expired in 2013, the CSCU completed another reverse auction. The results for a separate supply of natural gas were not lower than the local distribution company CNG's supply prices, so the campus reverted back to CNG.

In FY 13 and FY 14, Central also had eleven accounts with the supplier Direct Energy. Starting in fiscal year 15 all the campus' supplier accounts are with CNG. This has been extremely favorable for the campus. The supply change cut natural gas costs for the accounts with Direct Energy, by more than 50% in some cases. The prices of natural gas/MMBTU in FY 14 and FY 15 is shown for the cogeneration account as an example:

FY 14 Total Natural Gas Cost with Direct Energy ($/MMBTU)	FY 15 Total Natural Gas Cost with CNG ($/MMBTU)	% Change in Cost
$ 9.94	$ 3.84	61.4%

* Note: July 2014 of FY 15 was the last month that Central used Direct Energy prior to switching to CNG. The Direct Energy bill was missing. Without the cost information, the FY 15 Cogeneration price is $3.63/MMBTU. July 2013 $/MMBTU was used to extrapolate the Direct Energy cost of the missing bill.

Also, to note is that the cogeneration account does not have the distributed generation rider. With the utility bill waiver, the price of natural gas for the cogeneration unit might be even lower.

ELECTRIC PROCUREMENT

As stated in the Energy Master Plan, in 2013 the CSCU conducted a reverse auction for an electric supplier for the CSCU campuses. The contract was awarded to Direct Energy (formerly Hess Energy). Central participated in the reverse auctions and its accounts are also part of the electric supply procurement contract with Direct Energy.

FUEL CELL PROCUREMENT

As part of a University system-wide initiative, Central entered into a power purchasing agreement in 2011 with Fuel Cell Energy for a 1400 kW fuel cell. Below is the summary of the terms and prices under the PPA:

Time (Years):	10 years
Monthly Price:	Varies
PPA Price Over Term:	$9,097,200
Minimum Electricity Capacity (kW) Promised Over Term:	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

Extension Terms: The first term extension is over 5 years, promising minimum electricity capacity of 6,207 kW at a price of $4,093,704. The second term is also another 5 years, with a kw capacity also of 6,207 and a reduced price of $3,866,304.

The contract outlines the respective responsibilities of the campus and system owner. Highlighted aspects of the contract are presented below:

- Central is required to supply up to 115,369 MMBtu /yr of natural gas to the fuel cell (if that amount of natural gas is exceeded, the seller will reimburse the cost). Similarly, there is a requirement for the amount of feedwater that should be supplied per year.
- The PPA guarantees a total steam capacity of 16,654 lb/hr of saturated steam over the term.
- If the fuel cell under delivers compared to the minimum electric guarantee, as well as steam guarantee, Central receives a capacity adjustment credit. The credit is applied to the following operation year in three installments.
- Central is responsible for the fuel supply and water supply, if that is the cause of underperformance then no credit is allotted.
- Central can curtail use if needed, but must give 10-day advanced notice
- The seller owns all the meters, and is responsible for maintenance.
- On a monthly basis, the seller will provide a report on operation and performance.

The approximate normalized cost for fuel cell operation at Central based on the terms of the PPA agreement is approximately $0.14/kwh over the life of the contract. This is a conservative estimate as it includes the minimum electricity capacity and maximum fuel input required over the 10-year PPA. The normalized cost is based on the PPA contract and not actual output. If the campus produced more electricity and consumed less fuel, at a lower fuel cost, then the normalized actual cost may drop. 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 issues with the fuel cell. According to campus stakeholders, the fuel cell is not performing as desired and since 2012 has underperformed each year as it can easily go off-line when there are little disturbances. However, with the contract, Central's fee gets reduced due to lack of performance. According to FY 14 data, Central is capturing some savings with the contract, which is documented in the Section 2.9.

2.4 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

2.4.1 CURRENT CONDITIONS

At Central, energy management is a team effort. Facilities and Environmental Health & Safety (EHS) review energy on a monthly basis. While separate departments, facilities and purchasing both get to see energy bills each month.

The Environmental Health & Safety Director focuses on gas usage, while the Facilities Management Operations Coordinator reviews all incoming bills. With the data, Facilities provide EH&S a breakdown of energy at the end of the month to comply with the yearly permit for the state.

Central has an Assistant Chief Administrative Officer who manages energy in several ways:

1. Monitors the energy use at buildings through the Universities Square D Metering (Power Monitoring Expert v8.0),

2. Peak shaves the campus load with intermittent generator shedding to prevent increased demand charges by the utility company,

3. Performs a reconciliation of the utility bills, and

4. Coordinates the planning for energy efficient upgrades as they relate to the entire campus infrastructure.

Specific to the central plant, each morning Facilities documents by hand the fuel use at the Energy Center. They look at fuel oil use, kWh generation and the fuel cell electric generation. Appendix B summarizes a month's worth of tracking data at the Energy Center.

Facilities is responsible for staying apprised of operational improvements and management strategies. Facilities personnel have limited influence over the operations of classrooms. Central does adjust all night setback clocks and temperature control set points to accommodate classroom schedules. The campus operates by block scheduling.

Central's BAS System, SE Building Systems, is programmed to execute setbacks and building shut downs. Not all buildings are fully operational year round, allowing the campus to take advantage of savings when possible. For instance, during the summer Central shuts down Copernicus garage and the associating lighting. Facilities also shuts down residence halls when they are not used in the summer.

Facilities has frequent communications with Residential Life and can influence decisions to help consolidate student placement during the summer and winter breaks. Students' behavioral choices are more difficult to influence. There are frequently open windows in the winter, with no controls in the residence halls to alert specific instances, with the exception of Carol Hall. To combat instances of wasted energy, the custodial staff checks for open windows and lighting.

2.4.2 RECOMMENDATIONS

Central already implements multiple tracking systems for its energy. Along with tracking, benchmarking is essential for an overall view of needed building energy improvements. Central should:

- Monitor data with an eye on energy use per square foot in a monthly reporting spreadsheet along with budget tracking
- Consider using energy use dashboards located in a public area of the building being monitored. Dashboards are a great way to help encourage energy efficient behavior of students, faculty and staff.
- Consider BTU-meters and use for continued benchmarking in all occupied buildings connected to the Central plant to monitor energy use on a recommended 15-minute basis.
- Some of the 16 buildings with individual natural gas meters could also benefit from having BTU-meters on the water side of each boiler.

2.5 EXISTING BUILDING COMMISSIONING

2.5.1 CURRENT CONDITIONS

Appendix C provides a summary of retro commissioning projects completed at Central, dated March 10, 2015. The first three phases have been completed for a combined cost of $753,974 and all resulted in an actual return on investment in under 2 years.

The recommissioning activities also included adding new VAV boxes, controls, and motor VFDs. An additional phase, 2B, is already planned, and waiting for approval. The Phase 2B project is described in the first bullet point of Section 2.5.2.

2.5.2 RECOMMENDATIONS

- Phase 2B is the next phase of retrocommissioning that would tie into Phase 2 of the Energy Center. This phase consists of optimizing the campus wide chilled water loop system to include primary and secondary chilled water pumps, and optimizing the condenser water system. The estimated implementation cost for this project is $240,000 with an estimated return on investment of 0.52 years based on the proposed energy conservation measures to be investigated.
- Re-commission buildings at least every 5 years
- Select Retro/Re-commissioning building candidates with preference towards:
    - **a.** Management support and commitment
    - **b.** A motivated and available building staff
    - **c.** An unjustified, high EUI
    - **d.** An Energy Management Control System
    - **e.** No major system problems
    - **f.** Easily accessible and up-to-date building documentation
    - **g.** Newer equipment (12-years or less)
- Monitoring Based Commissioning (MBCx), use data analytics software in conjunction with the BMS to help continuously commission building energy systems and equipment.

2.6 MECHANICAL SYSTEMS

2.6.1 CURRENT CONDITIONS

Central operates its own central power plant, known as the Energy Center, which supplies hot water, heating, cooling, and some electricity to the campus. Per Central's Climate Action Plan, all new buildings are tied into the Energy Center for heat and chilled water. The Energy Center has two Cummins 1.25 MW natural-gas engines with heat recovery, and three dual-fuel Nebraska boilers. In 2011, Central acquired a 1.4 MW fuel cell housed next to East Hall, where the Department of Facilities Management is located. Central is under a long-term power purchase agreement with FuelCell Energy, the company that maintains the fuel cell. The natural gas fuel cell generates electricity and steam for campus heating and cooling. The fuel cell enables Central to continue power its critical facilities in case of an outage, by disconnecting from the grid.

BOILER SYSTEMS

The Energy Center steam boilers take advantage of economies of scale. The boilers as configured can generate steam at higher efficiencies than small package boilers due to a smaller proportion of radiation losses and the addition of energy saving equipment that is often too expensive to implement on smaller boilers.

The boilers generate approximately 80-85 psig saturated steam for distribution throughout the campus.

The Heat Recovery Steam Generators (HRSG) connected to the CHP units connect to the 80-85 psig steam header and are covered in a subsequent section dedicated to cogeneration. An overview of the equipment and/or energy efficient features noted during the walkthrough assessment are listed below.

- Three (3) dual-fuel Nebraska steam boilers each capable of 65,000 pounds per hour (PPH) of steam
    - **a.** Feature independent control of fuel/air ratio with VFD forced draft fans for O_2 trim
    - **b.** Variable speed feedwater pumps
    - **c.** Feedwater economizers (Blr #2 feedwater ΔT=30°F)

All equipment appeared to be in good working order.

Table 2.3 provides the actual boiler and CHP HRSG operating steam production range for Calendar Year (CY) 2014. Detailed equipment documentation, such as drawings, data sheets, and O&M manuals, were not reviewed for the purposes of this high-level operational review.

Based on this review, the boilers are not operating anywhere near peak capacity and it therefore is reasonable for all new buildings to continue to use the Energy Center for heating and cooling needs.

FIGURE 2.8: Energy Center

Equipment	Steam Production Rating	Minimum Steam Production	Maximum Steam Production	Percent Available Capacity
Boiler 1	65.0	11.4	37.6	42%
Boiler 2	65.0	10.2	34.5	47%
Boiler 3	65.0	6.2	30.3	53%
HRSG 1	2.0	--	0.7	68%
HRSG 2	2.0	--	--	100%
HRSG 3	2.0	1.3	2.3	0%

TABLE 2.3: Summary of CY2014 Equipment Operating Ranges

CHILLER SYSTEMS

Electric Chillers have a Coefficient of Performance (COP) often exceeding 6. Absorption chillers are usually in the COP range of 0.6 to 1.4 and are generally installed where there is a heat source that would otherwise be vented to the environment. At Central, absorption chillers and electric chillers are both used. An overview of the equipment and/or energy efficient features noted during the walkthrough assessment are listed below.

- One (1) 1,500 Ton electric centrifugal chiller
- Two (2) 1,500 Ton steam absorption chillers
- Two (2) cell induced draft cooling tower

All equipment appeared to be in good working order.

BUILDING HVAC SYSTEMS

Steam is used in all of the buildings connected to the Energy Center. Steam is used in steam coils in the building air handling units, in steam radiators, and/or to produce domestic hot water. Similarly, chilled water is used in HVAC equipment coils where buildings are connected to the Energy Center. Where not connected to the Energy Center, smaller direct expansion (DX) units are used.

The walkthrough level assessment did not allow for detailed study of the HVAC systems in each building. However, documentation from previous work on fume hoods was reviewed to reveal the following:

- Fume Hoods, 54 in Copernicus

    a. 41 VAV, 13 constant volume (CV)
    b. All but three fume hoods were in good condition and balanced by a TAB professional in 2009

As fume hoods can be extremely large users of energy, not only in fan energy but more so due to the necessary conditioning of makeup air, it is good practice for Central to continue to periodically recommission fume hood systems.

Many of the buildings still use pneumatically operated HVAC equipment as opposed to Direct Digital Control (DDC). Recent projects have upgraded some of these systems to DDC or have upgraded to VAV systems, which save energy over constant air volume systems.

CENTRAL CURRENT BEST PRACTICES

Central has already applied several of the best practices covered in the Energy Master Plan. The currently applied best practices observed during the campus assessments or while reviewing documentation are broken down into each mechanical system category below.

BOILER BEST PRACTICES

- Installed feedwater pre-heat economizers after the boiler stack breach for boilers 300 HP or greater for a typical savings of 3-10%
- Implemented an internal (conditioning of impurities within the boiler system) and external (softening, deaeration) water treatment program with goals to extend equipment life, reduce maintenance, and increase heat transfer.

CHILLER BEST PRACTICES

- Used correctly sized, water cooled centrifugal chillers when not operating as cogeneration or when a chilled water system exists as they are the most efficient.
- Implemented water temperature reset strategies on both the cooling tower and chilled water loops.

PUMP/FAN BEST PRACTICES

- Triple-duty valves, although useful for balancing a hydronic system without Variable Frequency Drives (VFDs), were fully opened once VFDs were used.
- Opened dampers for fan flow control completely when coupled with VFDs.
- Replaced older inefficient motors (typically less than 90%) with premium efficiency inverter duty motors.

2.6.2 RECOMMENDATIONS

BOILER SYSTEMS

- Implement a steam trap maintenance program.

    a. Consult with Eversource for arranging a steam trap audit.
    b. 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.
    c. Consider investing in automatic steam trap survey equipment which connects to the BMS.

- Investigate whether steam pressure can be reduced to save energy by reducing thermal losses.
- Investigate if a back pressure steam turbine is cost effective to generate electricity while reducing the steam distribution pressure.
- Include boilers in recommissioning activities.

CHILLER SYSTEMS

- Coordinate the chilled water temperature set point with the discharge air temperature set point of the air handlers.
- Monitor supply air humidity when using a chilled water reset strategy because an increase in supply water temperature may prevent proper dehumidification. This strategy has the best savings potential when applied to variable speed centrifugal chillers versus constant speed chillers.
- Take advantage of free cooling or economizer modes whenever possible by installing a heat exchanger and pumps or modifying the electric chiller controls to accommodate (consult with manufacturer to verify).
- Use absorption chillers when waste heat is available
- Include the chiller system in recommissioning activities

HEATING, VENTILATION AND AIR CONDITIONING (HVAC)

- Implement a fume hood sash management training program.
- Convert seven (7) of the fume hood controllers currently set up for CV and reconfigure for VAV, or try to consolidate use to only the most efficient fume hoods.
- Continue to install DDC where pneumatic controls currently exist.
- Continue to upgrade Constant Air Volume (CAV) to Variable Air Volume (VAV) HVAC.
- Expand use of occupancy controls and DCV with CO2 sensors with makeup air units (MAU).
- Install individual thermostats on steam radiators.
- Include HVAC in recommissioning activities.

FIGURE 2.9: Lab and Fume Hoods

2.7 LIGHTING

2.7.1 CURRENT CONDITIONS

Central's campus lighting is comprised of predominantly T-8s as well as LEDs in outdoor lamps from Central's LED Replacement Project. Using utility incentives, Central completed several projects in the early 2000s involving de-lamping, re-lamping and re-ballasting for the Sam May Building, School of Business, football stadium, student center and others . Additionally, the campus is also continuing to explore LED lighting upgrade projects, as proposed by Eversource. Four proposals were provided for upgrades from CFLs and T8s to LED wall packs for Welte Garage, Copernicus Garage, the Student Parking Lot and Vance Garage. The projects propose a payback of less than two years for each location, factoring in the utility's anticipated rebate.

The following is a savings example for the lighting upgrade at Vance Garage, assuming an electric cost of $0.11/kWh:

Materials and Labor:	$ 34,960
Lamp and Ballast Disposal:	$ 772
Sales Tax:	$ 0
Total Projected Cost:	**$ 35,732**
Anticipated Utility Rebate:	$ 22,351
Net Projected Cost	$13,381
Estimated Annual Electric Savings:	$10,257
Simple Payback:	**1.3 years**

2.7.2 RECOMMENDATIONS

- Work with Eversource to implement the four lighting upgrade projects.
- Install lighting controls or ensure existing controls work based on the BAS and/or photo sensor, especially for areas with potential for natural sunlight.
- Adjust lighting levels based on current use of space
- Replace all T12 magnetic systems with LED and evaluate replacing all other non-LED luminaires.
- Include lighting upgrades in recommissioning activities.

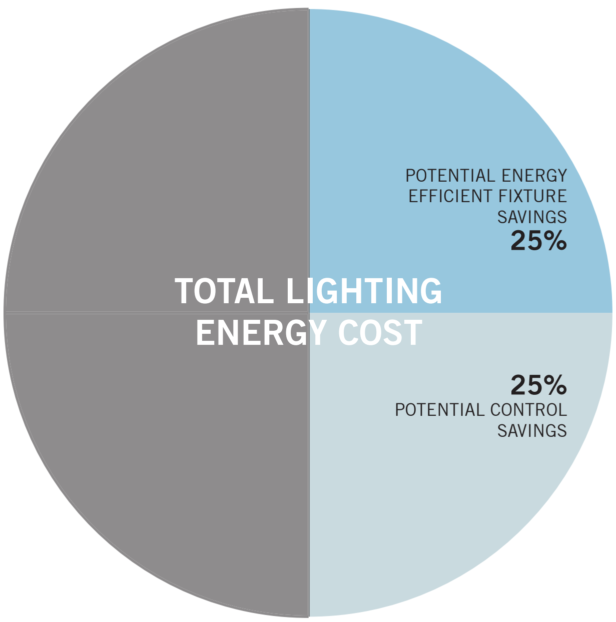


FIGURE 2.10: Lighting Energy Conservation/Efficiency

2.8 BUILDING ENVELOPE

2.8.1 CURRENT CONDITIONS

Much of Central's campus is comprised of a mix of older and newer buildings. More than half, twenty-two, of Central's buildings were constructed prior to 1981. In 1979, Connecticut legislated its first energy-related state wide standards for buildings, with 1981 as their implementation year. Therefore, for buildings constructed prior to 1981, it is assumed there is limited insulation, air sealing and other energy-related building envelope features that are now standard practice.

2.8.2 RECOMMENDATIONS

The following sections provide best practices for building envelopes that can be considered by Central, particularly for the buildings constructed prior to 1981.

- Review and ensure ventilation set points are not excessive per the latest edition of ASHRAE 90.1
- Address air infiltration issues by sealing doors and windows
- Insulate heated garage spaces
- Conduct a thermography study using ASTM C1060 or ISO 6781 of buildings built prior to 1980 to identify where there are defects or a lack of insulation.
- Hire a certified consultant to commission the building envelope, for new construction using the National Institute of Building Sciences (NIBS) Guideline 3-2012 to include:
    - **a.** Design & construction document review
    - **b.** Laboratory and/or on site performance verification tests
    - **c.** Construction visual QA/QC Inspections
        - **1.** Air, water, water vapor, and thermal barriers
- Include building envelop in recommissioning activities.

2.9 DISTRICT ENERGY / COGENERATION

2.9.1 CURRENT CONDITIONS

The Energy Center has three CHP units three dual-fuel Nebraska boilers, one 1,500 Ton electric centrifugal chiller, and one 1,500 Ton steam absorption chiller. The boilers generate approximately 85 psig saturated steam for distribution throughout the campus. The HRSG connected to the CHP units connect to the 80-85 psig steam header. Specifics consist of the following:

Two (2) 1.25 MW Cummins natural-gas IC engines
- **a.** Heat recovery on jacket water, lube oil, and exhaust

- One (1) 1.4 MW fuel cell with heat recovery

FIGURE 2.11: IC Cogen

FIGURE 2.12: Central's Fuel Cell System

The total combined capacity of the CHP systems is near 5,000 pounds per hour (PPH) and could provide for all of the campus' steam needs roughly 70% percent of the year. At the time of the Energy Master Plan study phase, FY14 data was analyzed. In FY 14 only a small percentage of the thermal energy as a byproduct of the electrical generation was utilized as shown in Table 2.4 and about one third of the electrical capacity from the CHP systems is realized as shown in Table 2.5. Cogen-1 and Cogen-2 are the two IC engines.

	Electrical Efficiency	Thermal Utilization	Overall Efficiency
Cogen-1	33.6%	0.5%	34.1%
Cogen-2	35.8%	0.0%	35.8%
Fuel Cell	37.8%	10.5%	48.3%

TABLE 2.4: Summary of CY2014 Cogeneration Equipment Efficiency

Unit ID	2014 Generation [MWh]	Potential [MWh]	Utilization Factor
Fuel Cell	9,624.3	11,068.3	87.0%
Cogen-1	364.5	9,882.4	3.7%
Cogen-2	401.4	9,882.4	4.1%
Total	10,390.2	30,833.1	33.7%

TABLE 2.5: Summary of CY2014 Fuel Cell and Cogeneration Electrical Energy Generation

The two Cummins IC CHP engines were primarily not operated due to high anticipated O&M costs that are expected to outweigh the benefits. Over the course of 2014, it is estimated operation of the IC engines has provided savings near $32,000 with gas purchased at $9.94 per MMBtu.

In 2016, Facilities altered operation of the engines to accommodate the addition of the 218,776 GSF Midcampus Residence Hall (constructed in 2015). In response to the increased electrical and thermal demand, Central has been utilizing a variable rotation of the generators, so that one unit is always base loaded. The utilization of one generator running close to full capacity allows for the offset of electrical costs incurred within the new building.

The rotating standby generator allows for generator maintenance and is used to help protect the University in the event of high demand peak shaving to prevent higher utility demand charges. These increased demand charges can equate to over six figures for the entire year, according to the campus.

FUEL CELL

Central is one of three CSCU universities with a fuel cell. In 2011, the campus acquired the 1.4 MW fuel cell under a long-term power purchase agreement with Fuel Cell Energy. The natural gas fuel cell is housed next to East Hall, where the Department of Facilities is located and generates electricity and steam for campus heating and cooling. When it is operating, the fuel cell enables Central to continue power to critical facilities in case of an outage, by disconnecting from the grid and independently supplying the campus power. Since its inception, the fuel cell was projected to save an average of $100,000 a year*. As outlined in the procurement section of the plan, the campus pays a standard $75,000 a month under the contract, with a reduced fee if there is a lack of production. The campus does not hold the related renewable energy credits generated by the fuel cell.

To date, the fuel cell is not always able to handle small disturbances. Due to downtime, the unit is believed by the campus to cost more than it is saving. When the fuel cell experiences downtime, the second IC engine is used as backup for redundancy. Despite perceived unreliable results thus far, the campus is tentatively interested in future fuel cells. Using the fuel cell's actual performance data in FY 2014, including the campus' fuel price, electric price, and lease payment (see Appendix D), the total savings for the year was established. According to FY 14 data, the campus is capturing approximately $262,000 in savings at a normalized cost of $0.10/kwh.

* Granata, Kassondra. New Fuel Cell for CCSU. http://www.ccsu.edu/about/sustainability/fuelCell.html

The FY 14 operation of the fuel cell demonstrated increased thermal recovery and electric efficiency, providing a lower normalized cost than the projected outputs based on the PPA contract terms. Another factor for the increased savings may be attributable to the fuel cell natural gas rate, estimated at $3.82 per MMBtu. A high-level analysis of the fuel cell and CHP's current operating conditions and potential operating conditions which led to the following recommendations is contained in Appendix E.

2.9.2 RECOMMENDATIONS

Central may realize additional savings if it modifies the sequencing of boilers and CHP units in order to maximize the runtime and use of the IC CHP engines. A detailed 8,760-hour model of the CHP operations should be considered to fairly consider all variables. Variables that should be considered include:

- New natural gas and electricity prices from the results of the CSCU new procurement bids.
- Potential for load following with the cogeneration units, as the 2.5 MW capacity from cogeneration often exceeds building demands in unoccupied times.
- Potential modification to allow for net metering from the fuel cell or cogeneration units, if economical.
- Actual quoted maintenance/ overhaul costs (the current model uses an assumed maintenance cost of $0.012/ kWh).
- Redundancy considerations. The generators are currently used for load shedding, and if a generator experiences downtime, back up load shedding is not likely.
- The ability to maintain redundancy and increase generation in the event of fuel cell downtime. As currently one of the generators is used as backup.

The economic benefit for increasing the use of cogeneration can be seen on normalized $/kWh basis. By adjusting the percent of useful recovered thermal of the CHP, through increased running and optimization, normalized electrical cost drops. Table 2.6 illustrates this based on Central's FY 2014 fuel and electric costs ($0.13/kwh and $9.94/MMBTU), non-fuel O&M cost of approximately $236,000 a year, and by adjusting useful recovered thermal. Even if there is a low thermal recovery of 25%, the costs of electric is still lower than the $0.13/kwh that Central pays for electricity, and much lower if RECs are considered.

Percent Useful Recovered Thermal (based on Central's Cogeneration)	Normalized Average $/kWh Electrical Cost/Year without RECs	Normalized Average $/kWh Electrical Cost/Year with RECs
0%	$ 0.12	$ 0.099
25%	$ 0.11	$ 0.091
50%	$ 0.10	$ 0.082
75%	$ 0.095	$ 0.074
100%	$ 0.087	$ 0.066

TABLE 2.6: Central kWh pricing based on useful percent of useful recovered heat

CLASS III RENEWABLE ENERGY CREDITS

RECs, when awarded per every MWh of electric output, can provide significant financial benefits for the campus.

In order to receive RECs, the cogeneration system 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)

Central pursued this option in the past. The University was included in the State Docket (#07-05-02) for consideration to be recognized as a cogeneration plant, which would allow the University entitlement to various incentives. The findings outlined that: *Since the Energy Independent Act was initiated in July of 2005 and since Central Connecticut State University built their cogeneration plant prior to the Act*, Central Connecticut State University was not entitled to incentives such as RECs. Central's cogeneration became operational in 2004, and by the original rules was not be eligible. However, since the rejection of the application, there is recently an avenue for CHP systems installed prior to 2007 to capture RECs. Per Docket 15-03-52, the entity must demonstrate to the Department of Energy & Environmental Protection (DEEP) that a significant modification has been made to the system creating incremental output gains . It is likely that Central may be able to make an appeal by arguing for RECs as a result of a modification to the plant. Future changes, such as controls updates to the system installed before the said date, can retroactively be considered for RECs when recommissioned.

The incremental savings, including estimated operations and maintenance costs of $0.012 per kWh, by updating the control strategy of the CHP engines were estimated using 2014 operational data.

* As mandated in Section 16 243q of the General Statutes of Connecticut (Conn. Gen. Stat.), along with 2008 Decision in Docket No. 05 07 19, DPUC Proceeding to Develop a New Distributed Resources Portfolio Standard (Class III).
** Docket No. 15-03-52 Application Of Norwalk Hospital For Qualification Of Norwalk Hospital Cogeneration Plant As A Class Iii Renewable Energy Source. July 22, 2015.

Based on operating strategies in FY14, the potential savings that could be achieved are outlined below. Original cost savings calculated using FY14 data and operational practices have been reduced by 50% since the FY16 and forward operational practices have changed to have one unit base loaded continuously.

- Operate both Engines to furthest extent possible:
  $222,500 per year without RECs
- Change control logic from demand response to continuously running
  $193,500 additional savings from REC's will likely cover all programming and logic changes necessary for a less than one-year payback.

The savings above are based on the FY14 cost of natural gas for the CHP engines and boilers at $9.94 and $4.85 per MMBtu respectively.

However, total CHP operational savings without RECs may be greater, assuming the new and lower natural gas rates in FY 15 of $3.84 for the CHP engine and $4.31 for the boilers, and keeping all other assumptions the same, including assuming demand response payments are not lost and new peak demand charges are not imposed. Actual additional savings achievable are dependent on further study and review. to fully account for additional operating costs that may offset some of the projected savings.

Note: As stated prior, original savings were based on the FY14 data analysis when both units were not run frequently. However, given new operations with one unit running at baseload, Central is likely capturing half of the originally projected savings of $222,500 per year without RECs.

The normalized cost of generating electricity from the fuel cell and IC engine including normal O&M costs is below the cost of purchased electricity as detailed in Appendix E.

COGENERATION OPERATIONS AND DEMAND RESPONSE

As presented in the next section, the campus partakes in demand response, or energy reduction efforts in peak times to reduce demand charges on electric bills. Specifically, the campus will run one of the cogeneration units to produce electricity, avoiding the need to access more energy from the grid in peak times. A campus concern with changing cogeneration operations is not being able to partake in demand response.

Given the intermittency of the fuel cell operations, if the two cogeneration units are base loaded, and the fuel cell's operations are interrupted in peak times, Central could see demand charges. At this point, the campus is not compensated for demand response through ISO-New England, but instead uses demand response as a savings measure.

ELECTRIC GRID PEAK DEMAND ICAP TAG

The most important days to ensure the units are running are generally during hot days when peak demand of the electric grid may occur.

Each end-user has an Installed Capacity (ICAP) tag, which represents the end-user's share of New England's requirement for generation capacity. The ICAP tag determines a portion of a customer's electric supply costs for the following year and it is set by the customer's load in the peak hour during the regional electric grid's highest usage.

Preliminary load data from ISO-NE suggests the peak load day in 2016 was on August 12th. Based on ISO-NE reports, in the past 15 years, peak load has occurred in July and August each year, with 2008 as an exception with peak load in June. In general, Central's cogeneration operators should ensure the fuel cell and cogeneration units are running during possible peak days, and defer scheduled maintenance to times outside of possible peak days.

Ultimately, further detailed study of increased cogeneration operations is needed to accurately model savings and potential impacts.

BEST PRACTICES

- Maintain at least a 50% total operating efficiency throughout the year and at least 20% for thermal or electrical efficiency at any given time to achieve RECs

The following actions are recommended:

- Continue operating the fuel cell at the highest electrical output relative to the nameplate rating;
- Continue monitoring electrical power demand penalties;
- Refine system operational review through detailed operational data evaluation and determine the ability to meet REC program requirements with existing equipment;
- Evaluate capacity payment opportunities
- Identify opportunities to modify system operating set points and determine additional programmable logic necessary to realize the full financial benefit from the systems; and
- Develop a decision tree as an operators' guide to onsite generation optimization.

Operating the central plant in the continuous HRSG and trimming boiler mode provides an opportunity for increased electrical generation. Suggestions for target steam loads associated with equipment operation consist of the following:

- Up to 2,100 PPH - Load follow with Fuel Cell + HRSG, dump unused steam energy
- Approximately 2,100 PPH to 3,500 PPH - baseload fuel cell and load follow thermal needs with one Engine Generator + HRSGs, dump unused steam energy
- Approximately 3,500 PPH to 5,000 PPH - Baseload fuel cell and load follow with two Engine/Generators + HRSGs
- Greater than 5,000 PPH - baseload fuel cell and two Engine/ Generators + HRSGs, trim steam demand with lead boiler

2.10 DEMAND RESPONSE

2.10.1 CURRENT CONDITIONS

An energy management strategy used by the campus is demand response. During peak air conditioning loads, the Energy Center utilizes the 1500-ton steam absorption chiller to further reduce the overall campus electrical load by 500 to 600 KW, according to campus stakeholders.

2.10.2 RECOMMENDATIONS

It is recommended that the campus uses its absorption chiller primarily to maximize output from the cogeneration systems through the cooling months. The campus should continue to monitor high peak days and apply demand response strategies to decrease load during the high cost periods. This is most important on the electric grid's peak day. These recommendations should be reevaluated at least annually or whenever electric billing structures and rates change, including natural gas rates. Additional study is needed to look at hourly load data to better understand the balance of CHP operations needed for demand response.

2.11 RENEWABLE ENERGY

Renewable energy provides an opportunity for the CSCU campuses to generate local energy while reducing their greenhouse gas emissions. The advantages and disadvantages for varying renewable energy technologies are provided in the Energy Master Plan.

2.11.1 CURRENT CONDITIONS

Central currently does not have any renewable energy projects on campus. However, the campus is committed to achieving its Climate Action Plan (CAP) goals, and would like to have the benefits of solar on campus. A number of faculty on campus have shown interest in exploring solar on the new engineering building. Steps toward a project have yet to be taken.

Facilities Management is very interested in having the entire library powered by solar as a show of commitment to the CAP. A PPA with maintenance costs included is important to Facilities to ensure maintenance costs are allocated within an O&M budget.

Stakeholders also expressed an interest in a solar battery project, but are aware of the current high market price of batteries. Aside from capital investment, a barrier to solar on campus in the past has related to insurance risks. The State of Connecticut's building insurance company, FM Global, according to stakeholders, has stringent recommendations related to solar panels on buildings, particularly existing buildings. These recommendations are further documented in the Energy Master Plan. For instance, FM Global recommends solar with an adjoining maintenance program.

Central owns a large tract of land east of the main campus on the opposite side of Route 9. There are future plans to develop this area into an "East Campus" as illustrated in Figure 2.14. The site could provide a large area for ground mounted PV. PV plans would have be built in part around a newly constructed regional busway on the tract of land.

Additionally, Central has Investigated geothermal; a consensus on the viability of a project was not reached as they still need to factor in operational costs.

2.11.2 RECOMMENDATIONS

Central's existing building infrastructure was reviewed for solar potential. Roof area clear of obstructions, shading and roof installation date were all used to preliminarily assess solar potential. Table 2.7 provides an overview of the buildings that may be considered for solar PV in the future. Following the table are images of each of the sites.

FIGURE 2.13: Central Potential Areas for Solar PV

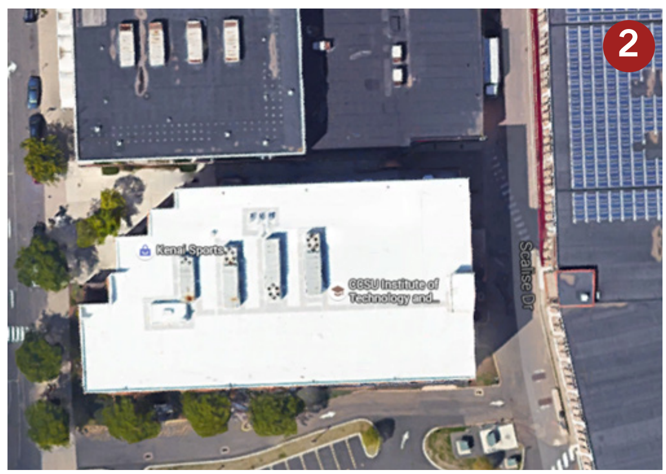
Building Name	GSF [FY 2015]	Building Roof sq. ft.	Roof Install/ Replacement Date	Roof Type	Array Size Potential (kW DC)[1]	Annual Generation Potential (MWh)[2]	Solar Suitability Comments
HIGH PRIORITY PROJECTS							
East Hall	46,777	15,592	1998	Built up	57-75	75-96	
Energy Center	33,705	11,235	2004	Built up	41-54	54-69	Roof will be replaced soon
Institute of Technology and Business Development (ITBD)	109,558	21,912	2014	PVC Membrane	81-105	105-135	
James J. Maloney Hall	57,208	19,069	2009	PVC Membrane	70-92	92-117	
Student Center	98,016	49,008	1994	Built up	120-157	157-201	With setback
Subtotal	345,264	116,816			369-483	483-618	
LOW PRIORITY PROJECTS							
Elihu Burritt Library	140,951	28,190	2000	Built up	104-135	135-174	Needs replacement
Vance Parking Garage	150,882	37,712	N/A	N/A	139-181	181-232	It's a new garage
Subtotal	291,833	65,902			243-316	316-406	
Total	637,097	182,718			612-799	799-1024	

TABLE 2.7: Central Potential Areas for Solar PV

[1] Assumes that 80% of roof area is available for solar PV and that each sf of panels can generate between 4.6 and 6 Watts DC (about a third of the PVWatt Output Assumptions). Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Actual generation values would be calculated if a solar PV study was performed.
[2] Assumes that 80% of roof area is available for solar PV and that each sf of panels can generate between 6 and 7.7 kWh annually (about a third of the PVWatt Output Assumptions). Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Actual generation values would be calculated if a solar PV study was performed.

EAST HALL AND ENERGY CENTER

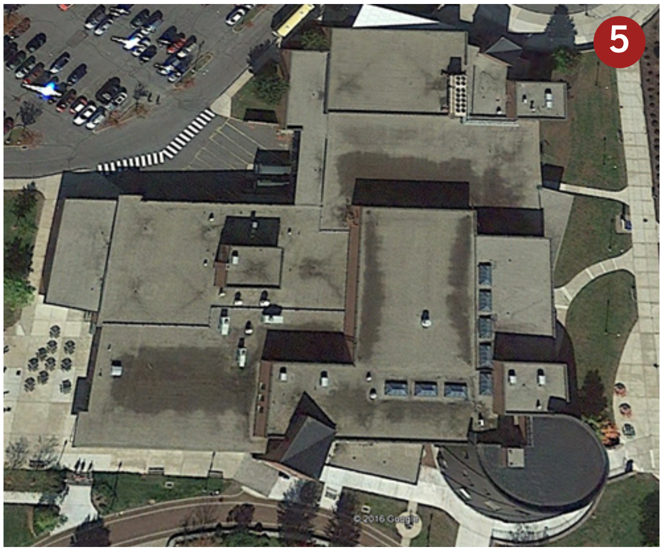
INSTITUTE OF TECHNOLOGY AND BUSINESS DEVELOPMENT



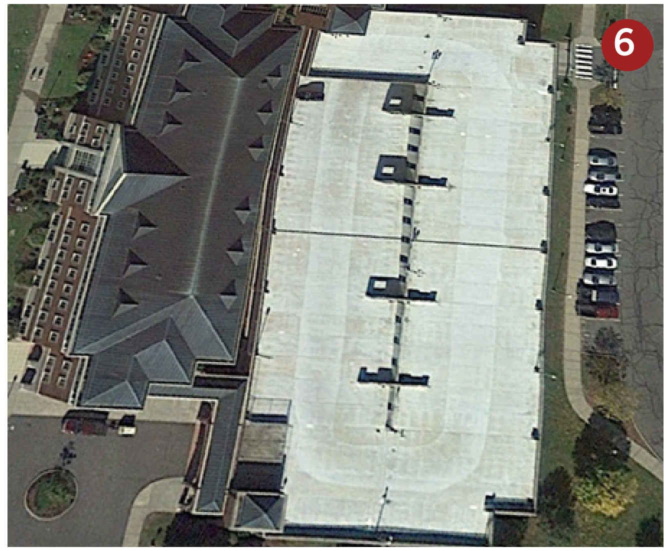
ELIHU BURRITT LIBRARY

MALONEY HALL

STUDENT CENTER



VANCE PARKING GARAGE



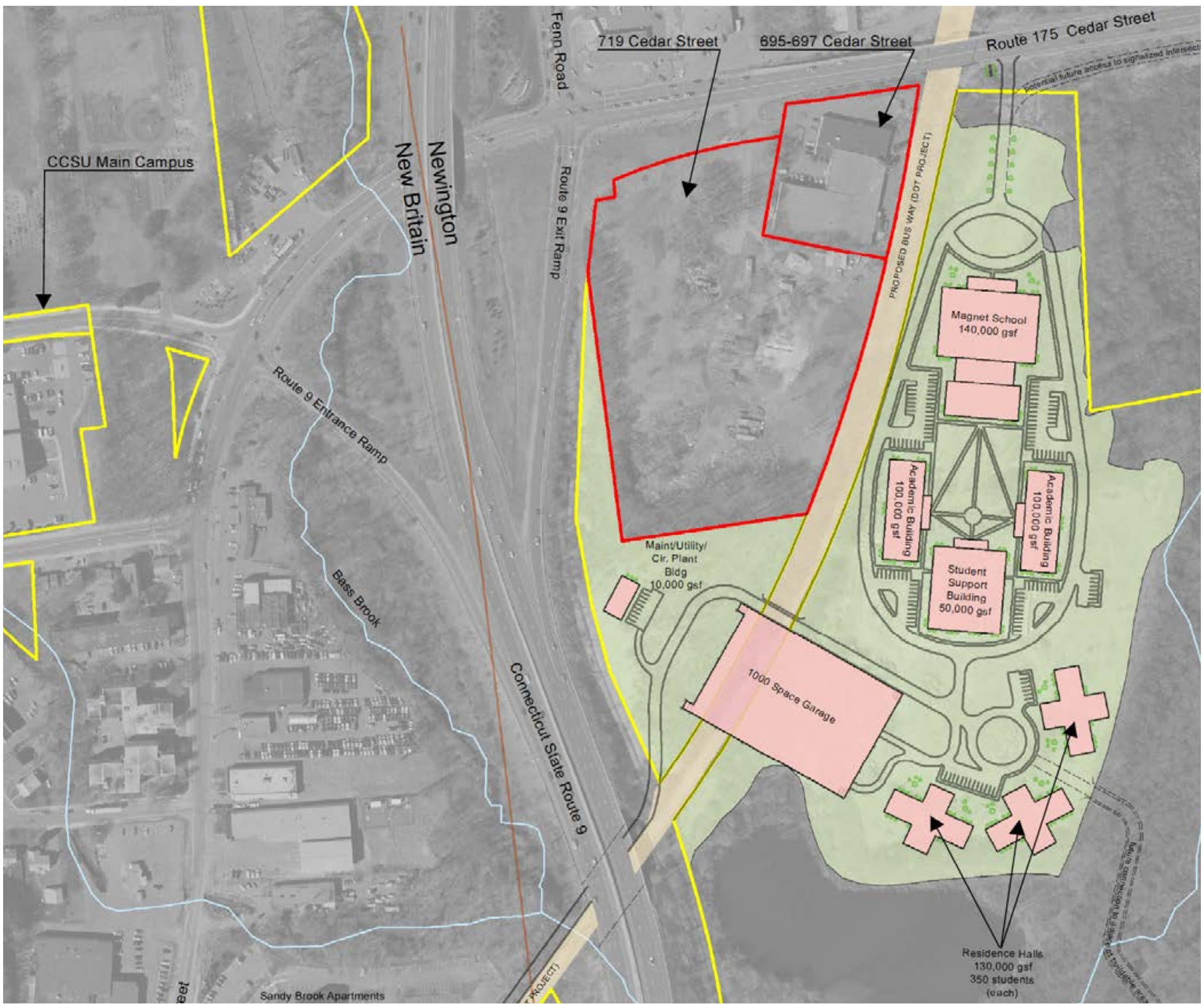


FIGURE 2.14: A Conceptual Option for Development an "East Campus" at Central

Along with the building infrastructure, a large opportunity exists off campus. Central owns an undeveloped parcel of land on the opposite side of a nearby highway. This may present a large area for a major solar array. It is recommended that the campus review the following conditions:

- Wetlands
- Placement of PV panels in relation to the new regional busway that runs diagonally through the site
- Implementation timeline: Consider the feasibility of installing PV until the East Campus is developed

Additionally, while there are currently no solar and battery programs offered in Connecticut, Central should stay apprised of opportunities for solar and battery pairing. As prices of batteries fall, it will be an advantage for storage of solar power in times of emergency situations.

2.12 CAPITAL PLANNING

2.12.1 CURRENT CONDITIONS

Central's Facilities Management Department is responsible for the capital planning process from design to construction and operations. Central follows the State of Connecticut's High Performance (Green) Building Standards, enacted in 2009, which specifies energy efficiency requirements for capital projects. Additionally, based on Connecticut's Department of Administrative Services (DAS) Guidelines, state-funded new buildings, additions and renovations should also have an associated Life Cycle Cost Analysis. Currently, lifecycle costing is not implemented consistently across campus.

The campus uses its internal operating budget and CSUS 2020 money that must be approved by the System Office. A barrier to completing projects is the difficulty in attaining upfront money for projects, as well as contracting complications. Additionally, when capital is provided for a new building, the campus has less resources to devote to other buildings, deferring maintenance further.

2.12.2 RECOMMENDATIONS

- Engage the System Office by providing lifecycle cost analysis for needed building upgrades, per DAS guidelines

2.13 COLLABORATION / PARTNERSHIPS

2.13.1 CURRENT CONDITIONS

Central has a strong collaborative relationship with Eversource. Both entities meet regularly to discuss potential energy conservation measures and retrocommissioning projects.The campus uses its internal operating budget and CSUS 2020 money This kind of partnership has led to over $535,000 in incentives since 1998. The four garage and outdoor lighting projects alone have incentives offered of $441,708*. The collaboration helps Central stay apprised of potential new initiatives or funding programs that may benefit both parties. For instance, Eversource is in the process of developing a green labs initiative, which was available to Massachusetts customers and will now be offered to Connecticut customers.

Central has a purchase agreement in place with Eversource for identification and implementation of retrocommissioning projects. As described in the lighting section, Eversource recently provided four proposals for lighting upgrades on campus.

As a state entity, Central is required to contract with state approved contractors through the Department of Administrative Services, as described in Section 2.5 of the Energy Master Plan. Oftentimes the contractors available through Eversource do not overlap with the DAS. However, the campus is not restricted to Eversource's contractors and the campus can choose any contractor from the DAS list, other available state contracts or go through a public bid process.

2.13.2 RECOMMENDATIONS

Central should continue to grow the partnership with Eversource and engage the team with the recommendations listed in this Energy Master Plan.

2.14 SUMMARY OF RECOMMENDED ENERGY EFFICIENCY MEASURES (EEMs)

As a result of the campus visits, walk through energy assessment, and interviews with campus staff, a list of recommended potential Energy Efficiency Measures (EEMs) is presented in Table 2.8.

These projects represent both low cost, immediate action measures, as well as projects that may require larger capital and therefore be longer-term. The simple payback in most cases cannot be reasonably estimated without detailed building models and/or more operating data. The payback periods provided are based upon the performance of past similar projects and are not from previous studies or are based upon necessarily indicative of future results.

* Per Eversource provided project list: "\\wc\shared\projects\228934 Perkins+Will - CSCU Energy Master Plan\wip\CSCU info\Central\Campus Audit Information\CCSU_past_EE_projects- filed past projects.xlsx"

Opportunity ID	Energy Efficiency Opportunity	Associated Building if Applicable	Cost	Payback w/rebate (Years)	Priority
CCSU-1	Consult with CNG (UIL) to incorporate Steam Trap Audit and Maintenance Program.	N/A	Varies	<1 - 2	1
CCSU-2	Establish hood management program and renovate fume hoods with energy efficient designs. At time of visit Fume Hood system venting consisted of approximately 45,000 CFM of conditioned air. Eversource Green Labs Initiative may be a resource if variable speed drives are added.	Nicolaus Copernicus Hall	Varies	Varies	1
CCSU-3	Review ventilation set points and controls for both air quality and efficiency. Engage with Eversource Green Lab Initiative for possible funding.	Nicolaus Copernicus Hall	Varies	Varies	1
CCSU-4	Complete Phase 2 retrocommissioning of the Energy Center. This phase consists of optimizing the campus wide chilled water loop system to include primary and secondary chilled water pumps and optimizing condenser water.	Energy Center (CCSU)	240,000	<1	1
CCSU-5	Work with the utility CNG to have the distributed generation rider added to the cogeneration account.	N/A	N/A	Varies	1
CCSU-6	Review utility rate demand and usage charges and compare with demand response credits and fuel costs to determine best operating strategy for on-site generators.	N/A	Varies	Varies	1
CCSU-7	Upgrade to LED lighting. Consult with Eversource on energy saving lighting upgrades.	Copernicus Parking Garage	$384,609	2.5	1
CCSU-8	Upgrade to LED lighting. Consult with Eversource on energy saving lighting upgrades.	Welte Parking Garage	$171,930	1.2	1
CCSU-9	Upgrade to LED lighting. Consult with Eversource on energy saving lighting upgrades.	Vance Parking Garage	$34,960	1.3	1
CCSU-10	Upgrade to LED lighting. Consult with Eversource on energy saving lighting upgrades.	Student Center Parking Garage	$178,598	1.8	1
CCSU-11	Upgrade lighting in residence hall to LED	Midcampus Residence Hall	Varies	2-6	1
CCSU-12	LED lighting upgrades and/or study. Consult with Eversource on energy saving lighting upgrades.	General Information (CCSU)	Varies	2-6	1

CCSU-13	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations. Also investigate solar PV on East Campus, dependent on future development plans	N/A	Varies	10-20	1
CCSU-14	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops, garages, or any other space where air is prone to stratification with ceilings >15' tall.	Grounds Building	Varies	3-6	2
CCSU-15	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops, garages, or any other space where air is prone to stratification with ceilings >15' tall.	Maintenance Facility Storage Shelter	Varies	3-6	2
CCSU-16	Add VFDs to cooling water pumps, ensure minimum flow requirement to chillers are met and use when "free cooling" after study.	Energy Center (CCSU)	$365,900	Varies	2
CCSU-17	Add cooling tower water side heat exchanger and pumps for free cooling after study.	Energy Center (CCSU)	$2,181,000	Varies	2
CCSU-18	Install CO2 occupancy controls on fans in residence halls.	Midcampus Residence Hall	Varies	Varies	2
CCSU-19	Install CO2 occupancy controls on fans in residence halls.	Catherine Beecher Hall	Varies	Varies	2
CCSU-20	Install CO2 occupancy controls on fans in residence halls.	Clarence Carroll Hall	Varies	Varies	2
CCSU-21	Install CO2 occupancy controls on fans in residence halls.	F. Don James Hall	Varies	Varies	2
CCSU-22	Install CO2 occupancy controls on fans in residence halls.	Mildred Barrows Hall	Varies	Varies	2
CCSU-23	Install CO2 occupancy controls on fans in residence halls.	Robert E. Sheridan Hall	Varies	Varies	2
CCSU-24	Install CO2 occupancy controls on fans in residence halls.	Robert Vance Hall	Varies	Varies	2
CCSU-25	Install CO2 occupancy controls on fans in residence halls.	Samuel J. May Hall	Varies	Varies	2
CCSU-26	Install CO2 occupancy controls on fans in residence halls.	Seth North Hall	Varies	Varies	2
CCSU-27	Install CO2 occupancy controls on fans in residence halls.	Thomas A. Gallaudet Hall	Varies	Varies	2
CCSU-28	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Midcampus Residence Hall	$160 - $315 per thermostat	1-5	2
CCSU-29	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Catherine Beecher Hall	$160 - $315 per thermostat	1-5	2

CCSU-30	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Clarence Carroll Hall	$160 - $315 per thermostat	1-5	2
CCSU-31	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	F. Don James Hall	$160 - $315 per thermostat	1-5	2
CCSU-32	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Mildred Barrows Hall	$160 - $315 per thermostat	1-5	2
CCSU-33	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Robert E. Sheridan Hall	$160 - $315 per thermostat	1-5	2
CCSU-34	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Robert Vance Hall	$160 - $315 per thermostat	1-5	2
CCSU-35	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Samuel J. May Hall	$160 - $315 per thermostat	1-5	2
CCSU-36	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Seth North Hall	$160 - $315 per thermostat	1-5	2
CCSU-37	Review heating zones in residence halls and rebalance and/or install independent controls. Steam systems can use individual radiator thermostats.	Thomas A. Gallaudet Hall	$160 - $315 per thermostat	1-5	2
CCSU-38	Install occupancy sensors for lighting and/or ventilation. May be needed for up to 90% of campus.	All (CCSU)	Varies	3-7	2
CCSU-39	Convert pneumatic controlled HVAC systems to DDC with VAV.	East Hall	$228,000 - $520,700	Varies	2
CCSU-40	Convert pneumatic controlled HVAC systems to DDC with VAV.	Nicolaus Copernicus Hall	$908,600 - $2,075,100	Varies	2
CCSU-41	Convert pneumatic controlled HVAC systems to DDC with VAV.	Harrison J. Kaiser Gym	$825,300 - $1,884,800	Varies	2
CCSU-42	Convert pneumatic controlled HVAC systems to DDC with VAV.	Henry Barnard Hall	$393,800 - $899,300	Varies	2
CCSU-43	Convert pneumatic controlled HVAC systems to DDC with VAV.	Elihu Burritt Library	$686,900 - $1,568,800	Varies	2

CCSU-44	Explore solar PV coupled with a battery storage system to reduce electrical costs in partnership with the utility.	N/A	Varies	Varies	2
CCSU-45	Investigate campus microgrid to leverage higher central generation efficiency and resiliency.	N/A	Varies	N/A	3
CCSU-46	Investigate additional fuel cells or other CHP opportunities where waste heat can be utilized.	N/A	Varies	5-15	3

TABLE 2.8: Central Recommended Energy Efficiency Measures

The list below presents recommendations for improving the energy reliability and resiliency of the campus.

SCHOOL OF ENGINEERING

- Evaluate and implement redundant power for the School of Engineering.

CAMPUS-WIDE

- Add increased backup generation capacity.
- Add a load leveler to the fuel cell to allow for redundant power generation ability.
- Upgrade diesel generators to natural gas.

ENERGY CENTER

- Upgrade infrastructure in energy center; upgrade switch gear.
- Increase chiller capacity to support campus functions in an emergency

ALL

- Improve building envelope
- Bury power lines to provide uninterrupted power after severe winds

ENERGY NEEDS

3.1 FUTURE DEVELOPMENT

As Central's campus grows it is important to factor the new buildings' impact on campus energy use. Central has been in the midst of completing a number of campus improvements, and has plans for campus expansions to accommodate higher student enrollment. Central's growth is driven in part by its Campus Master Plan (1998-1999) and 2012 Update, which address projected enrollment and potential space constraints. The CSCU strategic initiative, Transform CSCU, also provides impetus for campus growth with goals to incorporate high-tech smart classrooms, system wide facilities plans, and uniting the campuses as interdependent parts in one system.

Central's most recent completed project was the construction of its new Hilltop Cafe. The project provided a needed second residential dining center, with serving and food preparation areas situated near existing housing on the northeast quad. The approximately 18,000 square foot building is designed to hold 1,000 students during one meal, and seat approximately 500. The project was completed in March of 2016.

FIGURE 3.1: Hilltop Cafe

Due to campus growth, substantial energy adjustments have been necessary. A new chiller had to be installed at the Energy Center to accommodate the cooling loads from the new campus expansions. Chilled water piping was also extended into Kaiser Hall, Willard Hall and DiLoreto Hall .

Several large campus projects slated for completion in the short-term include:

- **Engineering Building**: Central recently created its School of Engineering, Science and Technology. To house office, classroom, and laboratory facilities required to meet those needs, Central plans to construct a 100,000 square foot building. The building will be located on the main campus adjacent to Burritt Library. The building's distribution system will be added to the Energy Center.
- **Addition at Kaiser Hall:** At the recreation center, the existing Kaiser Annex or "bubble" will be taken down. 70,000 square feet of new building will be added to the Recreation Center to plan for athletics/ recreation program goals. Kaiser Hall is supplied by the Energy Center and there are plans to keep it on the central plant. The project is still in the design phase. According to campus staff, the Recreation Center is in need of a new generator.
- **Willard Hall and DiLoreto Hall Renovations**: Central's Willard Hall houses the campus' English Department and several administrative departments. The adjacent DiLoreto Hall functions as a joint academic and administrative building. Renovations will include a four-story "in-fill" connecting the two buildings. At completion, there will be an added 43,000 GSF to support the existing academic and administrative departments.

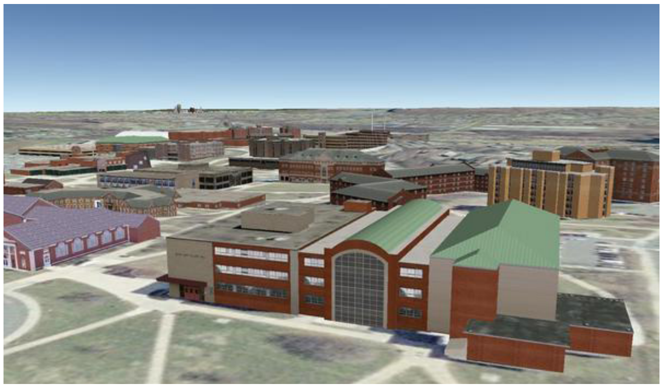


FIGURE 3.2: Willard Hall and DiLoreto Hall Renovation Rendering

- **Elihu Burritt Library Addition/Expansion:** The planned addition to the Burritt library will almost double the existing 165,059 gross feet to 327,059 square feet to meet the current space needs. Additional space includes rooms serving media, library, and computer functions. Services that do not directly support the library's needs will be relocated to surrounding buildings.

FIGURE 3.3: Elihu Burritt Library Addition/Expansion Rendering

Other projects proposed in the Master Plan for the future include, but are not limited to:

- A 500-car parking garage to go with new residence Hall
- 60,000 sq ft addition onto the Student Center
- Addition onto Welte Hall – windows have been completed
- Renovation of Memorial Hall
- 20,000 sq. ft. addition and renovation to Barnard Hall
- A 600-space parking garage

Ensuring a reliable supply of energy to maintain campus operations is important as the campus expands. The Energy Center and campus utility tunnel are essential utilities providing campus with heating, cooling, and electricity. Most of Central's buildings and food service areas have emergency generator backup capacity. However, there remain portions of campus, such as the new dining hall, where capacity needs to be added or increased in order for the entire campus to have full backup generator capacity.

The campus has two electric feeders to the campus, which does provide power supply redundancy.

As Central continues to experience significant expansion an energy infrastructure evaluation should be completed to be able to support the new buildings. The campus may need additional back-up power generation, as identified in Section 2.14

CONCLUSION / NEXT STEPS

Central has interspersed energy management and reduction actions into its campus framework. The campus does well with various aspects of energy management. Facilities looks at invoices and uses its BMS where possible to complete shut downs and setbacks. Despite the campus having high natural gas use, Central has a very favorable and low gas rate. The campus continues to be motivated to reduce energy use through its Climate Action Plan. Collaborations with Eversource have led the campus to low-cost energy savings measures such as retrocommissioning and lighting upgrades.

There are many viable energy savings and improvement opportunities, considering Central has the largest site EUI due to its high natural gas use. In order to meet Central's Climate Action Plan Phase 2 goal of 50% greenhouse gas emissions reductions by 2025, Central should focus on renewable energy implementation and other low energy intensity projects, described in this plan. To solidify a comprehensive energy program for the campus, top priority iniatives include:

- Continue to monitor energy use and costs in relation to budget goals each month.
- Modify the operation of the existing cogeneration system, investigate capacity and demand response payments, and pursue Renewable Energy Credits through DEEP to capture optimal energy savings.
- Evaluate and pursue roof-top solar power purchase agreements on campus, and ground-mount PPAs for "East" Campus
- Implement projects with a payback less than one year.

A summary of further projects and priorities for the campus are listed in Section 2.14. Central has an opportunity to capture savings, decrease energy use and increase energy reliability and sustainability by continuing to strengthen its existing energy efforts and continuing to focus on operations at the cogeneration facility.

4.1 CONTACT INFORMATION FOR KEY STAKEHOLDERS

Collecting all the necessary information for this planning effort required a collaborative effort. Stakeholders that were active in providing their expertise Central's campus current conditions and future needs, and energy related decisions.

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APPENDIX A: CENTRAL DATA, METHODOLOGY, ASSUMPTIONS AND NOTES

The following are the data methodology and assumptions that were used when analyzing and benchmarking data for Central:

Electricity: Eversource Utility bills (FY13,14,15) and Energy Center fuel usage reports (FY14,15)

- Eversource also had 5 small lighting accounts which were not included in benchmarking EUI.
- Parking lighting energy consumption was subtracted and estimated based on a power density of 0.19 W/ft2 applied to 75% of the garage GSF. The estimated consumptions were then subtracted from the campus total to compensate for the exclusion of unconditioned GSF in the EUI.
- The fuel cell and Cogen electrical productions are from Energy Center fuel usage report scans.
- The cost per kWh was taken from the utility bills for FY14. It does not include the cogen-produced electricity and is therefore just for the grid purchased electricity. Supply and demand costs are blended.

Natural Gas: CNG Utility Bills (FY14,15)

- 21 buildings as part of the study had natural gas accounts with CNG. There were 2 additional accounts for the fuel cell and the two cogeneration units. The consumptions of these 23 accounts are what make up the campus total.
- At the time of the analysis, there was no BTU submetering available for the individual buildings that received steam from the energy center's boilers, cogeneration units, and fuel cell. However, condensate return meters are in place.
- The football field and Copernicus Parking Garage had natural gas consumptions that were not summed into the campus totals.
- The following buildings are on the central heating loop:
    1. Beecher Hall
    2. Burritt Library
    3. Energy Center
    4. Welte Hall
    5. Davidson Hall
    6. White Hall and Annex
    7. Memorial Hall
    8. Midcampus Residence Hall
    9. Copernicus Hall
    10. Vance academic Center
    11. Sheridan Hall
    12. May Hall
    13. North Hall
    14. Social Sciences Hall
    15. Student Center
    16. Carroll Hall
    17. James Hall
    18. Barrows Hall
    19. Kaiser Hall
    20. Vance Hall
    21. East Hall
    22. Maloney Hall
    23. Willard Hall
    24. Diloretto Hall
    25. Barnard Hall
    26. Old Power House
- Of those buildings on the central heating loop the following also have their own natural gas accounts. Natural gas in these buildings are used for back up heat and dining; consumption from the utility accounts alone is not an accurate depiction of building level EUI, without BTU submetering.
    1. Beecher Hall
    2. Energy Center
    3. White Hall and Annex
    4. Copernicus Hall
    5. May Hall
    6. North Hall
    7. Student Center
    8.Gallaudet Hall
- The following buildings are not on the central heating loop. The ones with stars can have a fuel EUI calculated because the data is complete. The ones with triple stars can have a total EUI calculated because electrical submetering was also available.
    1. Bichum Engineering Laboratory
    2. Police Building*
    3. Early Learning Center***
    4. Grounds Building*
    5. ITBD
    6. Kaiser Hall Annex
    7. Maintenance Storage Shelter

Chilled Water: No submetering information available

- The following buildings are on the chilled water loop, which comes from the Energy Center's two (2) absorption chillers and 1 electric chiller. No submetering is available but the electric chiller was already captured in the main campus electric account, and the adsorption chiller was already captured by the energy center natural gas use.
  1. Energy Center
  2. Burritt Library
  3. Willard Hall
  4. Welte Hall
  5. Davidson Hall
  6. White Hall and Annex
  7. Copernicus Hall
  8. Vance Academic Center
  9. Sheridan Hall
  10. May Hall
  11. Student Center
  12. Social Sciences Hall

Fuel Oil: Energy Center fuel usage reports (FY14,15)

- The only fuel oil consumption on campus is at the Energy Center.

APPENDIX B: MONTHLY DATA TRACKING EXAMPLE AT CENTRAL'S ENERGY CENTER

CCSU Energy Center fuel usage report December 2015

Net Gas 23,491 - MCF

Net Oil 730 GALLONS

Energy Center info for December 2015

Natural Gas : **Oil:**

Non-Interruptible Gas Used = 7,897 - MCF
Main- Interruptible Gas Used = 15,594 -MCF
Total Net Gas Used = 23,491 -MCF

Boiler #1 Net Gas Used = 6,779 -CFH-X-1000
Net Oil Used = 0 Gallons
Run Hours = 329
Total Run Hours = 31,426

Boiler #2 Net Gas Used = 4,750-CFH-X-1000
Net Oil Used = 0 -Gallons
Run Hours = 224
Total Run Hours = 31,863

Boiler #3 Net Gas Used = 3,770 -CFH-X-1000
Net Oil Used = 730-Gallons
Run Hours =178
Total Run Hours= 31,479

Water:
Meter #1 = 26,260 -Cubic Ft.
Meter #2 = 30,733 -Cubic Ft.

Total Water used = 56,993 -Cubic Ft.

Cooling Tower Basin Make-Up = 166,498 -Gallons

Electricity:

52-M1 =1,028,772 -KWH
51-M2 = 0 -KWH
Fuel Cell Revenue Meter = 629,772 -KWH
Total Electricity Used = 1,658,544 -KWH
Difference 99,000-KWH more from 52-M1

Fuel Cell Energy Steam = 820.2 - MBTU

Generator #1-KWH Generated = 661,790 -KWH
Corrected Gas Used = 63,729 -CF-X1
Run Hours = 609 -Hours
Total Hours = 9,516-Hours

Generator #2- KWH Generated = 115,087-KWH
Corrected Gas Used = 11,917-CF-X1
Run Hours = 109-Hours
Total Hours = 9,370 -Hours

Chiller #1-Electricity Used = 0 -KW
Cooling Tons Produced = 0 -Tons

Chiller #2- Steam Used (estimated) =0–Klb
Cooling Tons Produced =0 - Tons

Chiller #3 Electricity used = 0 - KWH
Cooling Tons Produced =0 – Tons

REZERO EVERY JAN. 01
Non-Interruptible Gas YTD = 64,093 -MCF
Gen #1-Elect. Generated YTD = 2,882,476 -KWH
Gen #1 Gas YTD = 254,914 - CF-X1
Gen #2-Elect. Generated YTD = 2,307,623 -KWH
Gen #2 Gas YDT = 238,386 -CF-X1

JFM

APPENDIX C: EXECUTIVE SUMMARY OF RETROCOMMISSIONING PROJECTS

March 10, 2015

Summary of Retro commissioning Projects for CCSU

Phase 1 Executive Summary Dated (10/10/2011)

Phase 1 consisted of Energy Conservation Measures for Vance Academic Center, and Copernicus Hall to include Chilled water pump optimization, rooftop AHU optimization, second floor AHU optimization, and VAV box occupancy control. The implementation cost for the project was $164,166 with an actual return on investment of 1.5 years.

Phase 2 Executive Summary Dated (12/6/2012)

Phase 2 consisted of Energy Conservation Measures for the Energy Center thermal side of the plant to include, VFD's for all three boilers forced draft fans, VFD's for all three boiler feed water pumps, and optimization of auxiliary ventilation systems to reduce fan motor HP. The implementation cost for the project was $270,671.00 with an actual return on investment of 1.4 years.

Phase 3 Executive Summary Dated (6/13/2013)

Phase 3 consisted of Energy Conservation Measures for Kaiser Hall, Student Center, and Welte Hall to include converting constant volume, to variable, applying aggressive time clock scheduling, resetting fans to operate on static pressure, optimizing chilled water control, optimizing VAV hot water valves, installing VAV's, and optimizing RTU fan operation. The implementation cost was $319,137.00 with an actual return on investment of 2.0 years.

Phase 2B Next RCx project in the hopper FUNDING NEEDS APPROVAL

Phase 2B is the next phase of Retro commissioning that would tie into Phase 2 of the Energy Center. This phase consists of optimizing the campus wide chilled water loop system to include primary, and secondary chilled water pumps, and optimizing condenser water system. The estimated implementation cost for this project is $240,000.00 with an estimated return on investment of 0.52 years based on the proposed energy conservation measures to be investigated.

APPENDIX D: CENTRAL FY14 FUEL CELL SCENARIO WITH LEASE COSTS

Inputs based on Central FY 2014 Data

CHP Assumption	Amount	Units
System Size	0	kW
Heat Rate (HHV)	10200	Btu/kWh
Fuel Price	$ 3.82	$/MMBtu
Electric Price	$ 0.13	$/kwh
AEC	$ -	$/REC
Client %	$ 0.85	%
Client Sales Price	$ -	$/REC
Electrical Efficiency	33%	%
Thermal Efficiency	30%	%
Average Availability	90%	%
Default Electrical Efficiency	33%	%
Default Thermal Efficiency	80%	%
Non Fuel O&M Costs (Lease Payment)	$ 909,720.00	$/year
Parasitic Load > 25kW?	No	Yes or No
Parasitic Load (kW)	0	kW
Fuel Type	Natural Gas	

FY 14 Central 1.4 MW Fuel Cell Calculator

Fuel Cell- Annual Summary

	Input 1	A_FC	A_CG	B	C=A-B	C/Input 1	D	E_FC	E_CG	F_CG		F/D			
Month	Facility Electrical Requirement (MWhs)	Fuel Cell Gross Electrical Output (MWhs)	Gross Electrical Output (MWhs)	Parasitic Electrical Load (MWhs)	Net Electrical Output for REC (MWhs)	Percent of Facility Electric Load Served by CHP (%)	Total Facility Thermal Load (MMBtu)	Fuel Cell Fuel Input for CHP (MMBtu)	Fuel Input for CHP (MMBtu)	Fuel Cell Thermal Output (MMBTU)	Percent Facility Thermal Output Utilized (%)	Percent of Facility Thermal Load Served by CHP (%)	REC Production	Fuel Cell CHP Efficiency (%)	Quarterly Efficiency (%)
Jul-13	2,127.4	768.6	0.0	0.0	768.6	36.1%	19,494.6	6,844	0.0	1,066	100%	5.5%	768.6	54%	
Aug-13	1,399.6	524.1	0.0	0.0	524.1	37.4%	16,612.7	5,585	0.0	995	100%	6.0%	524.1	50%	
Sep-13	2,469.9	922.4	0.0	0.0	922.4	37.3%	15,049.1	7,632	0.0	1,551	100%	10.3%	922.4	62%	56%
Oct-13	2,495.8	1004.0	0.0	0.0	1,004.0	40.2%	17,216.0	8,882	0.0	1,721	100%	10.0%	1,004.0	58%	
Nov-13	2,469.9	922.4	0.0	0.0	922.4	37.3%	20,413.7	7,992	0.0	1,551	100%	7.6%	922.4	59%	
Dec-13	2,197.4	917.0	0.0	0.0	917.0	41.7%	24,573.6	7,902	0.0	1,684	100%	6.9%	917.0	61%	59%
Jan-14	2,236.7	995.4	0.0	0.0	995.4	44.5%	28,262.2	8,788	0.0	1,574	100%	5.6%	995.4	57%	
Feb-14	2,121.6	906.0	0.0	0.0	906.0	42.7%	24,903.7	7,671	0.0	1,465	100%	5.9%	906.0	59%	
Mar-14	2,260.6	906.0	0.0	0.0	906.0	40.1%	21,660.5	7,359	0.0	1,464	100%	6.8%	906.0	62%	59%
Apr-14	2,967.9	1556.9	0.0	0.0	1,556.9	52.5%	17,238.8	8,266	0.0	2,625	100%	15.2%	1,556.9	96%	
May-14	2,311.6	994.9	0.0	0.0	994.9	43.0%	13,961.4	8,815	0.0	1,022	100%	7.3%	994.9	50%	
Jun-14	2,684.5	1285.7	0.0	0.0	1,285.7	47.9%	15,204.4	7,468	0.0	-	100%	0.0%	1,285.7	59%	68%
Total	27,742.9	11,703	0	0	11,703	42.2%	234,591	93,204	0	16,719		7.1%	11,703.4		

Credit	Cost	Cost	Cost	Credit	Credit
Avoided Electrical Utility Supply Cost ($/mo)	Gas Thermal Cost ($/mo)	O&M Costs ($/mo)	REC Value ($/mo)	Thermal Savings Offset from Boiler Plant ($)	Savings Per Month ($/mo)
$ 99,919	$ (26,142)	$ (75,810.00)	$ -	$ -	**$ (2,034)**
$ 68,138	$ (21,333)	$ (75,810.00)	$ -	$ -	**$ (29,004)**
$ 119,910	$ (29,153)	$ (75,810.00)	$ -	$ -	**$ 14,948**
$ 130,514	$ (33,930)	$ (75,810.00)	$ -	$ -	**$ 20,774**
$ 119,910	$ (30,528)	$ (75,810.00)	$ -	$ -	**$ 13,572**
$ 119,206	$ (30,185)	$ (75,810.00)	$ -	$ -	**$ 13,210**
$ 129,398	$ (33,571)	$ (75,810.00)	$ -	$ -	**$ 20,016**
$ 117,783	$ (29,305)	$ (75,810.00)	$ -	$ -	**$ 12,668**
$ 117,783	$ (28,113)	$ (75,810.00)	$ -	$ -	**$ 13,860**
$ 202,400	$ (31,576)	$ (75,810.00)	$ -	$ -	**$ 95,013**
$ 129,334	$ (33,673)	$ (75,810)	$ -	$ -	**$ 19,851**
$ 167,142	$ (28,528)	$ (75,810)	$ -	$ -	**$ 62,804**
$ 1,521,437	$ (356,037)	$ (909,720)	$ -	$ -	**$ 255,680**

APPENDIX E: CENTRAL COGENERATION OPTIMIZATION

1. CENTRAL CONNECTICUT STATE UNIVERSITY (CENTRAL) COGENERATION OPTIMIZATION

This analysis was based on FY 14 data. Operations of the cogeneration units have since changed, which would alter the economics. Central is recommended to conduct a detailed study incorporating new operations and new data.

1.1 INTRODUCTION

The intent of this assessment is to provide a high-level review of the boiler plant, cogeneration plant, and chiller equipment located at Central Connecticut State University (Central). The resulting conclusions are based on data review and discussion with campus plant personnel. The existing CHP systems are adequate since the total combined capacity of the CHP systems totals approximately 5,000 pounds per hour (PPH) and roughly 70% percent of the year the CHP systems can be run at 100 percent while using the boilers to trim. Follow–up recommendations are presented as next steps to achieving the optimal balance of central plant and cogeneration systems efficiency and financial benefits. Based on FY 2014 pricing, the estimated annual savings of the current cogeneration (excluding the fuel cell) is $32,000. The estimated range of annual savings beyond current cogeneration savings is between $477,000 (without REC Value) and $864,000 when REC value is considered as a source of project revenue, assuming FY 2014 pricing. It is expected 2016 pricing will drastically increase the savings due to lower natural gas pricing for the cogeneration engines.

Woodard & Curran recommends the following actions be taken:

- Continue operating the fuel cell at the highest electrical output relative to the nameplate rating;
- Continue monitoring electrical power demand penalties;
- Refine system operational review through detailed operational data evaluation and determine the ability to meet REC program requirements with existing equipment;
- Review equipment data sheets to determine operation limitations;
- Identify opportunities to modify system operating set points and determine additional programmable logic necessary to realize the full financial benefit from the systems; and
- Develop a decision tree as an operators guide to onsite generation optimization.

Operating the central plant in the continuous HRSG and trimming boiler mode provides an opportunity for increased electrical generation. Suggestions for target steam loads associated with equipment operation consist of the following:

- Up to 2,100 PPH - Load follow with Fuel Cell + HRSG, dump unused steam energy
- Approximately 2,100 PPH to 3,500 PPH - baseload Fuel Cell and load follow thermal needs with one Engine Generator + HRSGs, dump unused steam energy
- Approximately 3,500 PPH to 5,000 PPH - Baseload fuel cell and load follow with two Engine/Generators + HRSGs
- Greater than 5,000 PPH - baseload fuel cell and two Engine/ Generators + HRSGs, trim steam demand with lead boiler.

1.2 EXISTING INFRASTRUCTURE AND CONSUMPTION

Central operates its own central plant which supplies hot water, heating, cooling, and some electricity to the campus. The central plant has three CHP units (one 1.2 MW natural gas fuel cell, two 1.25 MW natural-gas engines with heat recovery), three dual-fuel Nebraska boilers, one 1,500 Ton electric centrifugal chiller, and two 1,500 Ton steam absorption chiller. The boilers generate saturated steam for distribution throughout the campus. The Heat Recovery Steam Generators (HRSG) connected to the CHP units connect to the 80-85 psig steam header. Central's internal combustion (IC) cogeneration units are referred to herein as Cogen 1 and Cogen 2. The natural gas fuel cell heat is recovered in HRSG 3.

1.2.1 EXISTING INFRASTRUCTURE AND CONSUMPTION

TVC Systems, the central plant system integration contractor, provided the following historical operating data for the central boiler plant:

- January 1, 2013 through December 31, 2014 Central Plant Total Daily operating logs,
- January 1, 2013 through June 30, 2014 Central Plant 15 minute interval operating logs, and
- Fiscal Year 2013 Central Plant Monthly Operating Reports

1.2.2 THERMAL

Total daily steam production for calendar year 2014 was reviewed for comparison of equipment operating ranges. The total campus daily steam load profile is provided in Figure 1.1. For approximately 8,400 hours per year the campus appears to demand between 0 KLBS and 607 KLBS per day for a relatively equal amount of time. The remaining annual 370 hours has campus loads between 607 KLBS and 828 KLBS.

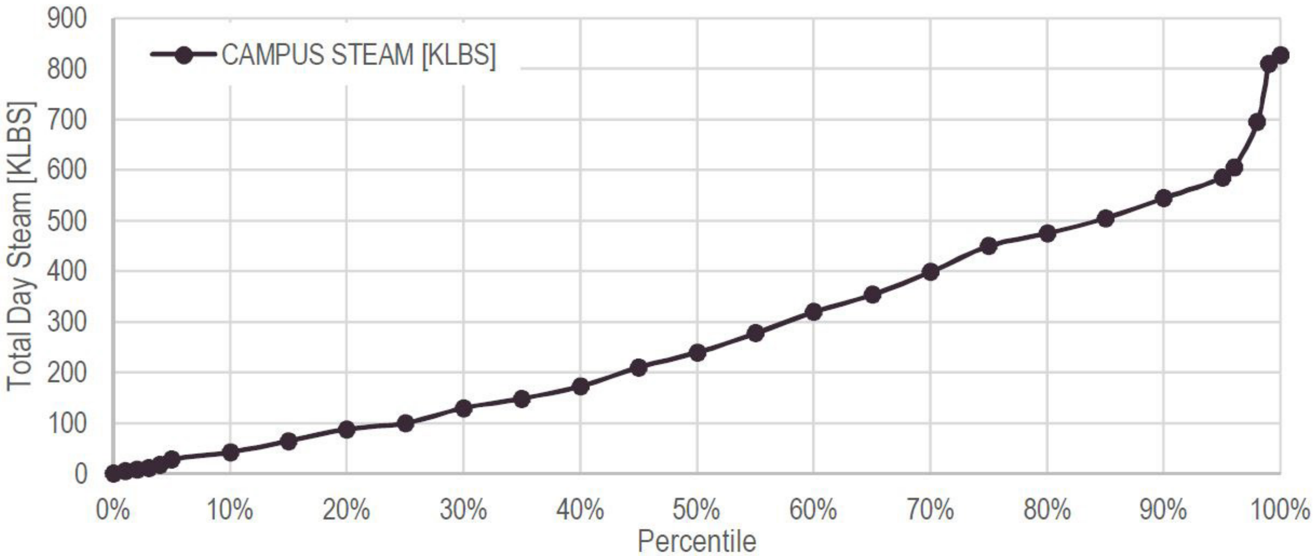

FIGURE: Summary of CY2014 Total Day Campus Steam Use Load Profile

1.2.3 ELECTRICAL

Campus electrical power and energy are supplied by the following:

- Electric utility supply,
- 1,400 kW continuously operated Fuel Cell
- Two 1,250 kW intermittently operated reciprocating engine generators

Calendar year electrical energy generation by unit is provided in Table 1-1. In addition, the potential production, based on 95% runtime at 95% rated capacity, is provided as information for comparison.

Unit D	2014 Generation [MWh]	Potential [MWh]	Utilization Factor
Fuel Cell	9,624.3	11,068.3	87%
Cogen-1	364.5	9,882.4	3.7%
Cogen-2	401.4	9,882.4	4.1%
Total	10,390.2	30,833.1	33.7%

TABLE: Summary of CY2014 Fuel Cell and Cogeneration Electrical Energy Generation

6.14

EASTERN CONNECTICUT STATE UNIVERSITY

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EXECUTIVE SUMMARY

Eastern Connecticut State University (Eastern)'s Energy Master Plan aims to identify ways Eastern can improve energy use on campus, and be an active participant in Connecticut State Colleges & Universities (CSCU)'s energy management, reduction and conservation efforts. Eastern has performed a number of energy-related upgrades to date through a large retrocommissioning effort and by utilizing its building automation system. The utility data received indicates Eastern is the best performing University of the CSCU Universities from an energy perspective (see Figure 1 Eastern Energy Dashboard). The energy use intensity (EUI) method is used for benchmarking and comparison purposes.

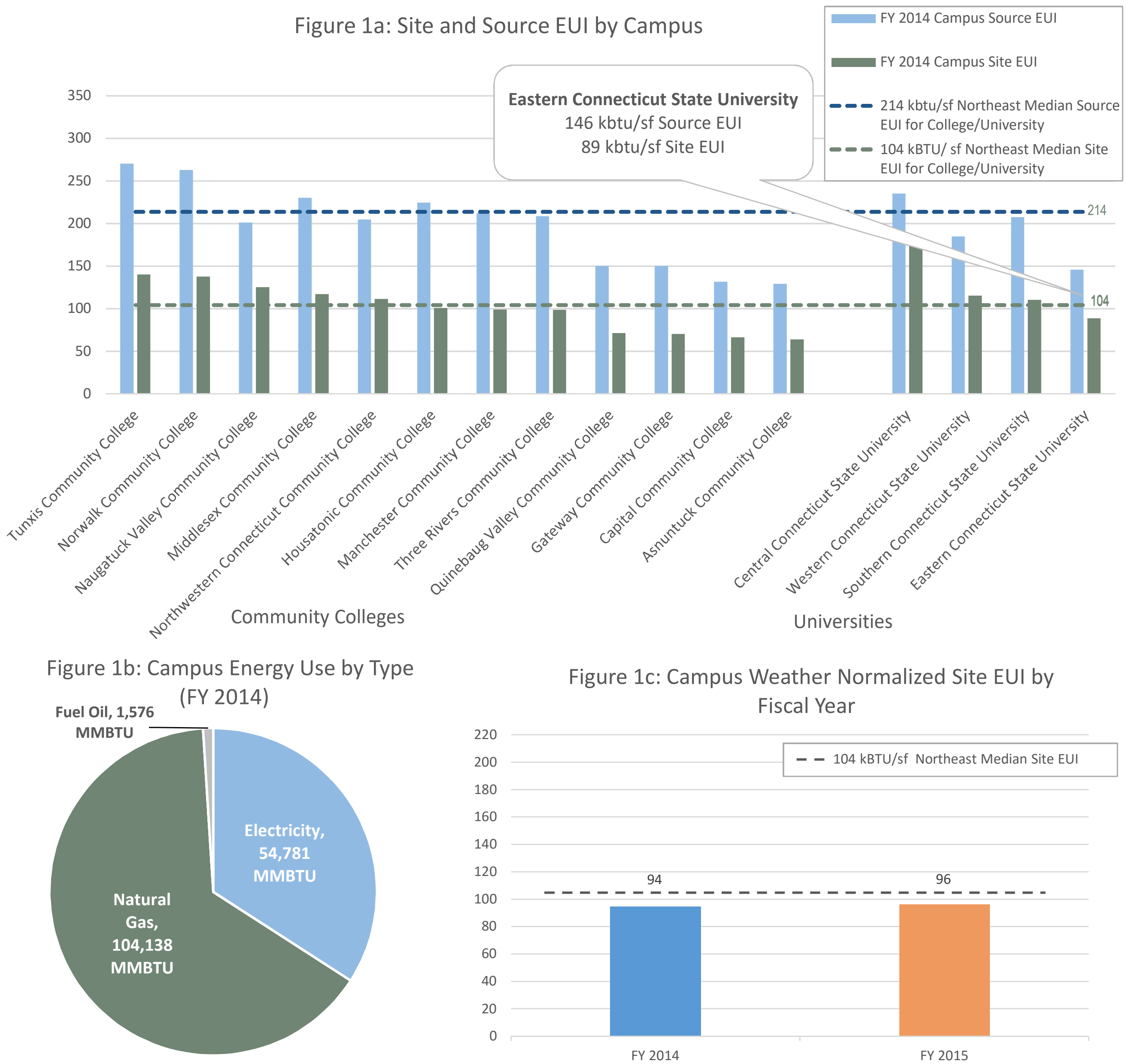


FIGURE 1: Eastern Connecticut State University Energy Dashboard

Some contributors to Eastern's overall low energy use include:

- Numerous recommissioning initiatives,
- Numerous LED lighting upgrades,
- Many relatively new or remodeled buildings,
- HVAC and lighting controls including occupancy and daylight harvesting, and;
- Large geothermal heat pump system

Energy Spending

Table 1 provides a comparison of energy spending to the average of CSCU campuses and the Northeast Region Commercial Sector.

	Eastern Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 1.93	$ 2.08	$ 2.49	$ 1.67 [1]
Cost per FTE Student	$ 804	$ 677.00	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.14	$ 0.14	$ 0.14	$ 0.15 [2]
Avg. Cost per MMBtu Natural Gas	$ 8.46	$ 7.32	$ 10.06	$ 10.03 [3]
Avg. Cost per Gallon Propane	$ 2.07	$ 3.77	$ 3.46	
Total Operating Expenses	$ 127,946,490	$ -	$ -	
Total Energy Spending	$ 3,839,259	$ -	$ -	
% of Operating Expenses	3.00%	2.67%	1.95%	

TABLE 1: Energy Cost Comparison (FY 2014)

Eastern's energy cost per square foot is below the CSCU Universities average, while percent of operating expenses attribute to energy spending is higher than the average. The average cost per kWh does not account for the adjusted cost of electrical generation from Eastern's 400 kW fuel cell.

Utility Incentives/ Develop Plan for Energy Efficiency Measures (EEMs)

Both of Eastern's utilities are through Eversource. This places the campus in a prime position to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project."

Since incentives are based on incremental energy savings, further analysis and collaboration with Eversource is required to determine rebate amounts for each opportunity. Table 2 demonstrates a summary of the EEMs recommended for Eastern to pursue.

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - *http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm*
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - *http://www.eia.gov/electricity/monthly/current_year/june2014.pdf*
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - *http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm*

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
ECSU-1	Optimize fuel cell operations and ensure RECs are received (in progress, with a new contract for a 440kW fuel cell. RECs are included for Eastern in the contract).	Fuel Cell	NA	Varies	1
ECSU-2	Work with Eversource to have the distributed generation rider added to the fuel account	Fuel Cell	NA	Instant	1
ECSU-3	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations, and/or ground mounted arrays through PPA (Eastern is evaluating Burnap Hall and Crandal Hall).	Campus	Varies	Instant - 20	1
ECSU-4	Conduct existing building commissioning (EBCx) for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Burr Hall	Varies	Varies	1
ECSU-5	Insulate all valves and fittings of steam and condensate piping, including condensate receivers (in progress).	Heat Plant (South)	Varies	<1 - 2	1
ECSU-6	Consult with Eversource on steam trap maintenance program.	Campus	Varies	<1 - 2	1
ECSU-7	Install new LED lighting and controls.	Wood Support Services Center	$ 54,394	2 - 6	1
ECSU-8	Install new LED lighting.	Eugene Smith Library	$ 24,984	2 - 6	1
ECSU-9	Replace T8 Lighting throughout the garage with LED.*	Cervantes Garage, Shakespeare Garage	$ 119,253	2 - 6	1
ECSU-10	Evaluate building envelope opportunities, including insulation and removing wall AC units.	Knight House	Varies	Varies	2
ECSU-11	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.2 standard.	Grant House	Varies	Varies	2
ECSU-12	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	182 High Street Counseling Services	Varies	Varies	2
ECSU-13	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Institute for Sustainable Energy	Varies	Varies	2
ECSU-14	Install parallel positioning controls on boilers with O2 trim.	South Heat Plant	$12,000 - 16,000 each	3 - 4	2
ECSU-15	Ensure EBCx testing and balancing (TAB) is performed after renovations and all control points are clearly named for continuous monitoring.	Communi-cation Building	$20,000 - $130,000	1 - 5	2
ECSU-16	Ensure EBCx testing and balancing (TAB) is performed after renovations and all control points are clearly named for continuous monitoring.	Goddard Hall	$20,000 - $130,000	1 - 5	2

** The production of this report was a year long process. This recommendation was made at the beginning of the project and the campus has already successfully implemented the project since.*

ECSU-17	EBCx HVAC controls, reduce outside air as much as possible to maintain indoor a quality while taking advantage of economizer modes when outside air conditions permit.	Mansfield Campus Athletic Support Center	Varies	Varies	2
ECSU-18	EBCx every 3-5 years.	Fine Arts Instructional Center	$1.00 - $3.50/sf	Varies	2
ECSU-19	Conversion from pneumatic to direct digital control (DDC) system. Upgrade to VAV AHUs if possible.	Sports Center	$419400 - $957900	Varies	2
ECSU-20	Conversion from pneumatic to direct digital control (DDC) system.	Wood Support Services Center	$ 222,500	Varies	2
ECSU-21	With building renovations install high efficiency chiller system. Consider using water cooled electric chiller possibly with heat recovery such as a YORK YK.	Communication Building	Varies		2
ECSU-22	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Honors House (ECSU)	Varies	Varies	2
ECSU-23	Upgrade lighting and controls to take advantage of natural sunlight.	Wood Support Services Center	$ 45,652	3 - 6	2
ECSU-24	Install new Controls with lighting upgrades.	Webb Hall	74514	3 - 6	2
ECSU-25	Revaluate energy systems after space use change. Consider downsizing oversized equipment.	Shafer Hall	Varies	Varies	3
ECSU-26	Upgrade kitchen equipment with EnergyStar certified equipment, especially water heaters and dishwashers.	Hurley Hall	Varies	Varies	3
ECSU-27	Install new energy efficient windows complying with ASHRAE 90.1, the 2012 International Energy Conservation Code (IECC), or ENERGY STAR. Windows should be replaced with low emissivity, double paned, high performance windows with thermally broken frames.	Crandall Hall, Burnap Hall	$100/sf	20 - 50	3
ECSU-28	Investigate other CHP opportunities. Options include natural gas driven heat pumps to replace aging geothermal system.	High Rise Apartments	Varies	Varies	3

TABLE 2: Eastern Energy Efficiency Measures

In addition to the priority projects, next steps for Eastern are below:

Next Steps

Management

Eastern should continue to review energy use, including tracking energy use and comparing energy spend to available budgets. Energy metering is in place for nearly all buildings. However, historical logging needs to be setup for complete energy benchmarking, specifically for buildings connected to the North Heat Plant. Eastern should focus on reducing energy in buildings with both high EUIs and overall energy use to result in the most savings. For instance, based on electrical EUIs, Hurley Hall and the Science Building qualify as a target for energy reductions.

Alternative Energy

Explore Power Purchase Agreements (PPAs) for rooftop solar and/or ground mounted arrays. Eastern should work with CSCU to explore photovoltaic (PV) options. CSCU has received favorable pricing for PPA projects with possible discounts of 20%- 50% of purchased power costs. Eastern should also consider exploring off site solar, where possible.

LDC Natural Gas Waiver

Connecticut's natural gas local distribution companies (LDCs) offer a distributed generation rider. Eastern should work with Eversource to make sure the appropriate natural gas distribution charges are waived under the natural gas waiver for the fuel cell.

Eastern has several no-cost opportunities pertaining to its fuel cell, as well as multiple operations and energy efficiency opportunities. By implementing the suggestions of the Energy Master Plan, Eastern can continue to pursue its sustainability goals with onsite solar PV, mechanical system upgrades and improved energy management and tracking.

INTRODUCTION

As part of the Connecticut State Colleges & Universities (CSCU) Energy Master Plan, Eastern Connecticut State University's (Eastern)'s building infrastructure, energy use and energy management practices were assessed. The ultimate goal was to determine ways Eastern could improve its energy use on campus, and be an active participant in CSCU energy reduction efforts. This chapter identifies Eastern's historical energy use, future projected needs and energy recommendations.

1.1 EASTERN OVERVIEW

Eastern, one of the four universities in CSCU, is located at 83 Windham Street in Willimantic. Eastern is the state's only public liberal arts university and it consists of the School of Arts and Sciences, the School of Education and Professional Studies, the Graduate Division and the Division of Continuing Studies and Enhanced Learning. Eastern offers a wide variety of undergraduate fields of study (34 majors and 54 minors) in the arts, sciences and professional studies, and selected graduate school programs.

Eastern supported a student body of 5,261 in the fall of 2015, 4,288 of which were full-time undergraduates. Nearly 95% of Eastern students are from Connecticut, and the remaining students come from 23 different states and 52 countries. As a residential institution, 59% of all full-time students live on campus, and as of 2015, the campus housed 90% of the incoming class.

Eastern's campus spans 182 acres, with a small portion of the main campus separated to the south. The main campus is accessible from Route 6, between Routes 32 and 66. Eastern is divided into four areas: South Campus, Central Campus, North Campus, and the Mansfield Sports Complex. South Campus is the historic part of Eastern and includes buildings such as Burr Hall, the campus' first residence hall, which dates back to 1921. South Campus houses many of the classrooms and administrative functions.

North Campus, the more modern part of Eastern, is home to the Eugene Smith Library, the Planetarium, the Student Center, the Sports Center, the Media Center, and Webb Hall, which contains state-of-the-art computer technology, media resources, and interactive learning systems. In addition, North Campus has several residence halls. Central Campus is comprised of classrooms, residence halls, and many of the counseling service offices.

FIGURE 1.1: Foster Clock Tower

The Mansfield Sports Complex is located less than one mile north of Eastern's main campus. This sports complex contains most of Eastern's athletic fields and facilities and makes up 73 of the 182 total campus acres.

Eastern's campuses are served by two heating plants - the North Heat Plant and South Heat Plant. The North Heat plant provides heating to 21 buildings. The South Heat Plant historically provided steam for two buildings, Shafer Hall and Burr Hall. The plant will only provide heating for Burr Hall after the renovation of Shafer Hall.

Figure 1.2 provides a map of Eastern, and Figure 1.3 shows an image of the Mansfield Sports Complex.

Building	Year Built [Renovated]	Gross Square Feet	Building Function
182 High Street Counseling Services	1916	3,600	Office/ Administration
192 High Street Faculty Offices	1942	2,790	Office/ Administration
392 High Street	1932	2,622	Other- Storage
Admissions Building	1999	5,485	Office/Administration
Baseball Stadium*	1998	3,972	Not included
Beckert Hall	1925	4,107	Office/Administration
Center for Community Engagement	1900	6,100	Office/Administration
Clock Tower*	1998	2,010	Facilities
Communication Building	1974	37,654	Academic
Eastern Hall	2001	8,305	Academic
Eugene Smith Library	1998	130,449	Academic
Facilities Building	1986	24,568	Office/Administration
Facilities Warehouse	2013	6,777	Facilities
Fine Arts Instructional Center*	2015	128,118	Academic
Gelsi & Young Hall (Administration)	2002	45,431	Office/Administration
Goddard Hall	1967	39,212	Academic with labs
Grant House	1892	5,129	Office/Administration
Health Services	1958	4,480	Health Services
Heat Plant 1 (North)	1970	5,482	Facilities
Heat Plant 2 (South)	1928	3,037	Facilities
Honors House	1915	4,278	Office/ Administration
Hurley Hall	1999	34,516	Student Services/ Dining
Institute for Sustainable Energy	1929	3,466	Office/ Administration
Knight House	1928	4,107	Office/Administration
Mansfield Campus Athletic Support Center	2013	6,204	Athletic
Margaret Wilson Early Childhood and Family Resources Center	2005	39,407	Academic
Planetarium	1972	4,970	Academic with labs
Police Station	2009	8,636	Police Building
Science Building	2008	180,605	Academic with labs
Shafer Hall	1946	70,151	Academic*
Sports Center	1973	86,057	Athletic
Student Center	2007	78,210	Student Center
Webb Hall	1992	74,502	Academic
Wood Support Services Center	2000	45,645	Administration
Subtotal		1,110,082	
Residential Buildings			
Bernice Clark Niejadlik Hall	1998	82,793	Residence Hall
Burnap Hall	1970	21,550	Residence Hall
Burr Hall	1919	36,711	Residence Hall
Constitution Hall	2004	68,568	Residence Hall
Crandall Hall	1970	21,434	Residence Hall
High Rise Apartments	1970	60,597	Residence Hall
Laurel Hall	2005	99,362	Residence Hall
Low Rise A	1972	16,681	Residence Hall
Low Rise B	1972	12,733	Residence Hall
Low Rise C	1972	12,669	Residence Hall
Low Rise D	1972	12,443	Residence Hall
Low Rise E	1972	10,153	Residence Hall
Mead Hall	1999	117,024	Residence Hall
Noble Hall	1928 [1990]	73,016	Residence Hall
Nutmeg Hall	2005	93,733	Residence Hall
Occum Hall	1984	67,900	Residence Hall
Winthrop Hall	1958	23,556	Residence Hall
Subtotal		830,923	
Total		1,941,005	
Garages			
Cervantes Garage	2003	224,027	Parking Garage
Shakespeare Parking Garage	2010	247,850	Parking Garage
Subtotal		471,877	

TABLE 1.1: Eastern Campus Building Information

** At the time data was analyzed for Shafer Hall, the hall had an academic function. After its renovation, the building will be converted into a residence hall.*

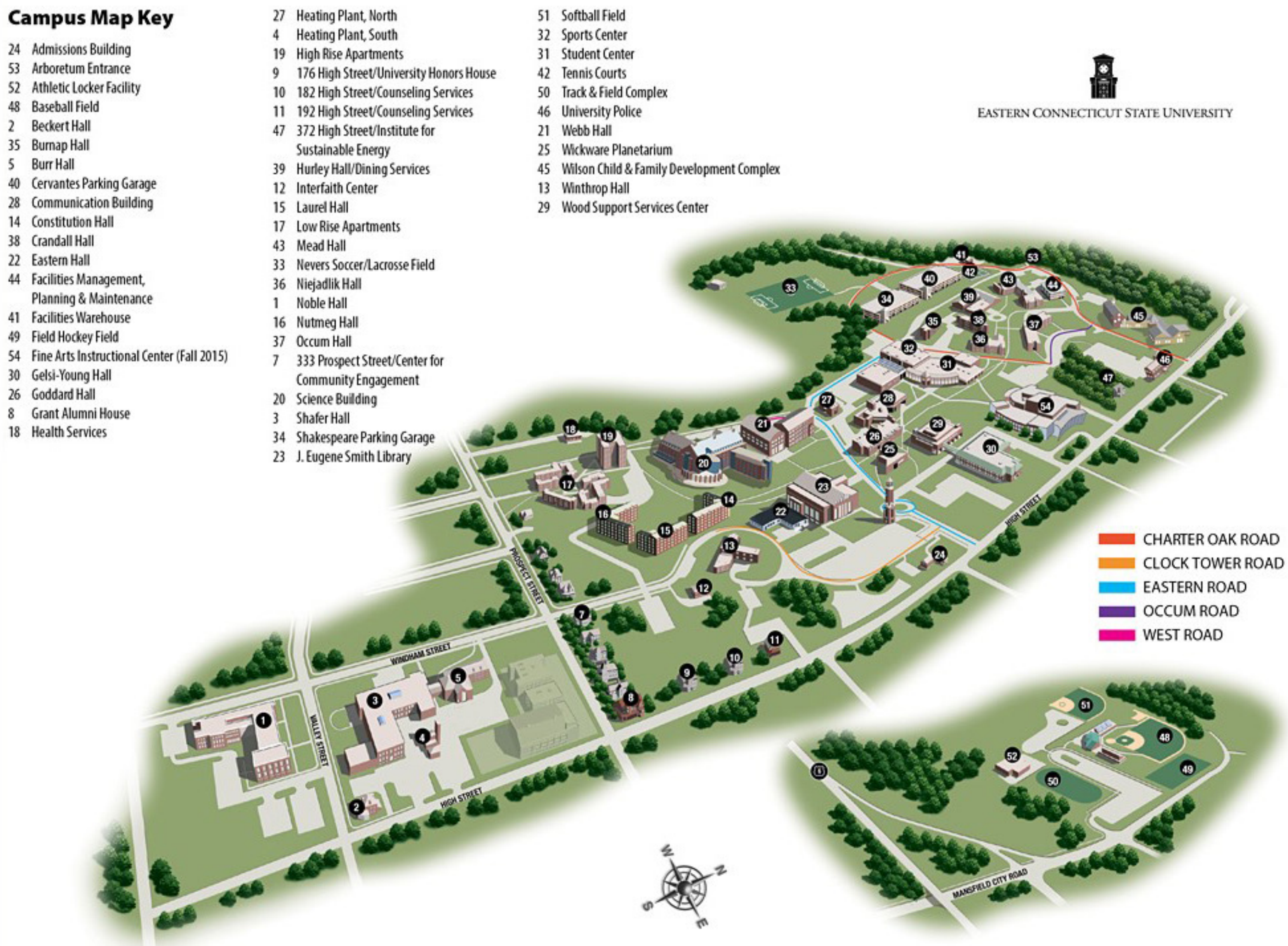


FIGURE 1.2: Eastern Campus Map

FIGURE 1.3: Mansfield Sports Complex

1.2 PREVIOUS ENERGY STUDIES & PROJECTS

Eastern is devoted to creating a sustainable campus inclusive of accomplishing energy and greenhouse gas reductions. In 2009, Eastern's President signed the Second Nature Climate Leadership Commitment establishing concrete emissions reduction goals for the campus. Based on the climate action plan, Eastern has a goal of achieving climate neutrality by 2050. Numerous associations have honored Eastern with sustainability awards, including Energy Star's Partner of the Year Award designated each year between 2010 and 2014, the 2014 Power of Change Award and a Green Building Advocate of the Year award in 2013 .

Eastern is also home to the Institute for Sustainable Energy (ISE). The organization provides energy benchmarking services as well as recommendations to increase energy efficiency and resiliency on campus, and for entities outside of Eastern. ISE has helped to track energy on campus by inputting Eastern's utility data into EPA's Portfolio Manager.

Substantial energy improvements have been completed on campus; according to stakeholders, each building on campus has had an energy audit. The list below summarizes relevant past energy projects that the campus has completed to aid in reducing its operating budget, as well as move towards climate action goals.

ALTERNATIVE ENERGY

Description: Installed a 400 kW Fuel Cell. During the first academic year of its operation, energy use was reduced by just over 2 million kWh and the fuel cell operated at an average efficiency of 87% per month.
Year: 2012
Associated Building: Science Building

Description: Installed EV Charging Station
Associated Building: Eugene Smith Library

Description: Installed EV Charging Station
Associated Building: Shakespeare Parking Garage

LEED

Description: LEED Building
Associated Building (Year):
Science Building (2008)
Constitution Hall (2004)
Laurel Hall (2005)
Nutmeg Hall (2005)

RENEWABLE ENERGY

Description: Executed the state's largest geothermal install, with 3 800 foot wells
Year: 2001
Associated Building: High Rise Apartments

Description: Installed solar powered lights.
Associated Building: Campus

LIGHTING

Description: Changed stadium lighting, and all parking lots to LED
Year: 2015
Associated Building: Baseball Stadium

Description: Installed new control system and lighting
Year: 2014
Associated Building: Planetarium

Description: Upgraded lighting to high efficiency T8s
Associated Building: Sports Center

Description: Completed lighting audit and mechanical audit with pricing
Associated Building: Facilities Building

Description: Replaced flourescent parking garage lights with LED
Year: 2015
Associated Building: Parking Garages

Description: Replaced all lighting with LED in the dining area
Associated Building: Hurley Hall

Description: Installed Encelium system, changed most of recessed cans to LED
Associated Building: Student Center

BAS/BSM

Description: Completed a Lighting Control System Upgrade with Encelium Control System. The system dims the lamps based on daylight and also allows for personal lighting control in offices.
Year: 2012
Associated Building: Eugene Smith Library

Description: Installed an Encelium Control system to maximize energy savings.
Year: 2010
Associated Building: Gelsi & Young Hall (Administration)

ENERGY CONSERVATION

Description: Installed Energy Star Refrigerators and thermostats in each room.
Associated Building: Low Rise A, Low Rise B, Low Rise C, Low Rise D, Low Rise E

HVAC

Description: HVAC Controls
Year: 2013
Associated Building: Occum Hall

HVAC AIR SIDE

Description: Updated air handler controls in the classrooms, upgraded to VAV boxes with a $257k incentive with Eversource.
Year: 2007/2013
Associated Building: Occum Hall

Description: Added cooling for several classrooms that were converted to computer classrooms since the initial construction of Webb Hall. The rooms were not designed to support the added heat load of computers.
Year: 2012
Associated Building: Webb Hall

Description: Replaced main air conditioning
Associated Building: Planetarium

CHILLER SYSTEM

Description: Installed new cooling tower.
Year: 2008
Associated Building: Occum Hall

BUILDING ENVELOPE

Description: Completed insulation and roof replacement.
Associated Building: Occum Hall

Description: Installed energy efficient windows
Year: 2010
Associated Building: Planetarium

BOILER SYSTEM

Description: Installed new condensing unit
Year: 2013
Associated Building: Facilities Building

Description: Installed hot water heater
Year: 2010
Associated Building: Hurley Hall

RETRO COMMISSIONING

Description: Retrocommissioned Phase 5 Science Building HVAC Equipment
Year: 2014
Associated Building: Science Center

Description: Completed a retrocommissioning study and recommendations including optimization of condenser water system, chilled water system, air handing units and implementation of unoccupied air flow set points.
Year: 2012
Associated Building: Science Center

Description: Completed a retrocommissioning study and recommendations including installation of air handling unit occupancy controls and optimization of air handling unit operations.
Year: 2011
Associated Building: Police Station

Description: Completed a retrocommissioning study and completed recommendations including optimization of high temperature hot water pumping and temperature control
Year: 2011
Associated Building: Heat Plant 1 (North)

Description: Completed a retrocommissioning study and recommendations including optimization of existing occupancy controls and of operations of five variable air volume systems
Year: 2011
Associated Building: Student Center

STUDY

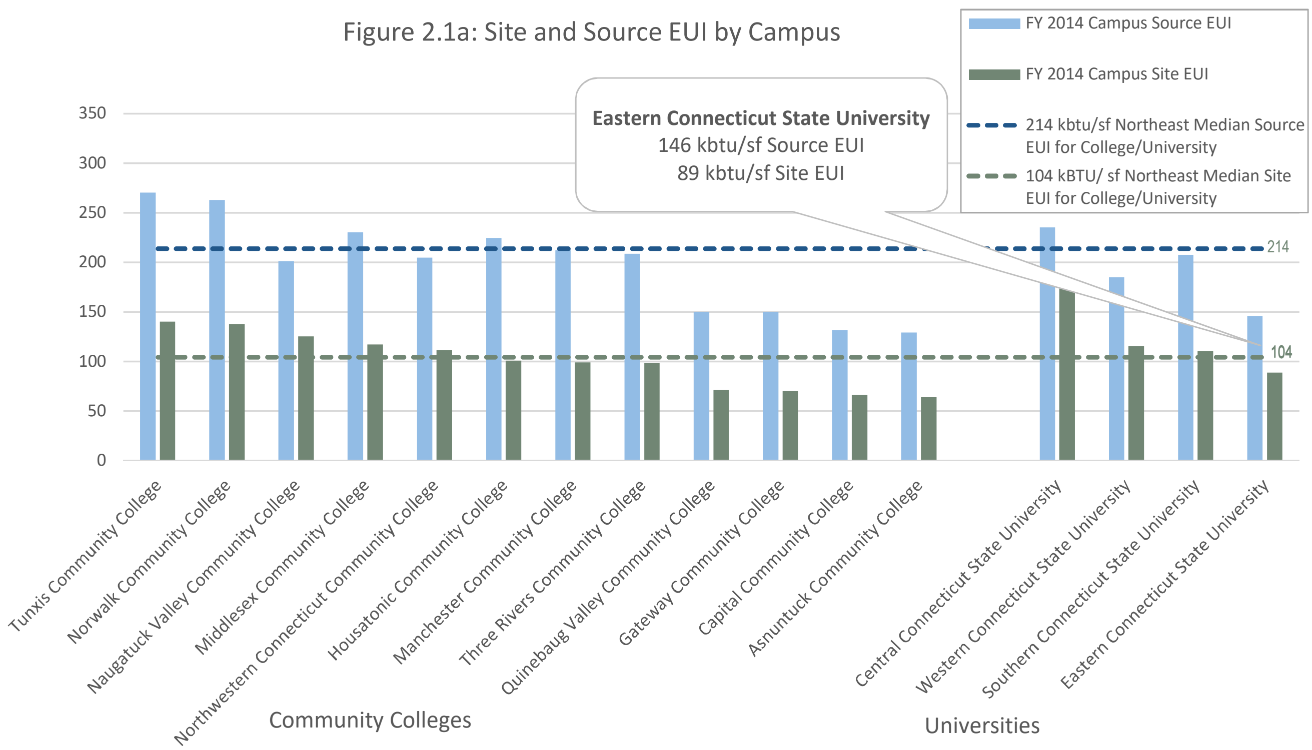
Description: Completed energy audit with caulking added
Year: 2014
Associated Building: Institute of Sustainable Energy

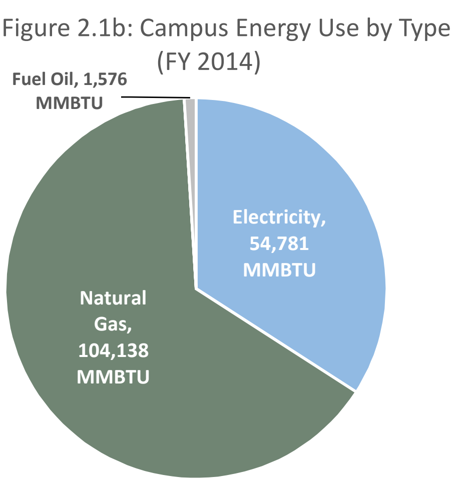
EXISTING CONDITIONS & RECOMMENDATIONS

Information on Eastern's existing conditions was captured from campus interviews, energy data and reports provided by the campus. A holistic view of existing practices, material on energy management, energy infrastructure and project implementation processes was reviewed. Analysis of the data and campus walkthroughs helped clarify recommendations with the goal of decreasing energy use, documented after each subheading.

2.1 FACILITY ENERGY BENCHMARKING AND ENERGY CONSUMPTION

The energy dashboard provides a summary of Eastern's energy use. Appendix A documents information on the assumptions and data sources used for energy benchmarking purposes. Based on the findings, Eastern's site EUI is the lowest of the four CSCU Universities, and is also below the Northeast Median Average at 89 kbtu/sq ft. Eastern should continue to measure and monitor its weather normalized site EUI.





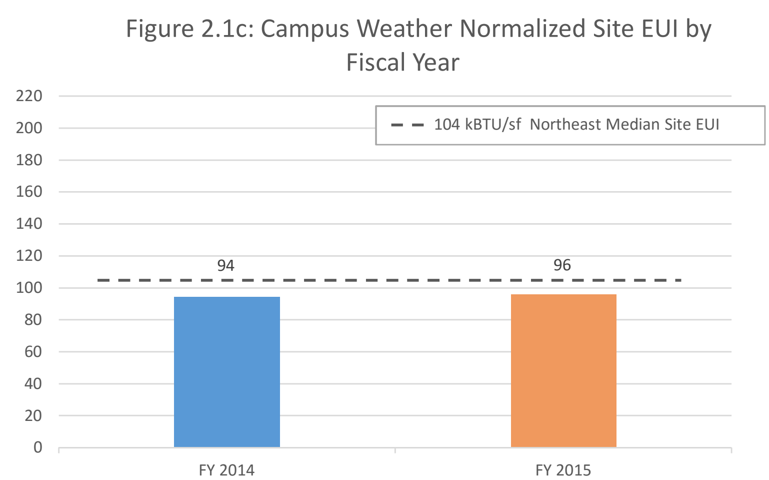


FIGURE 2.1: Eastern Connecticut State University Energy Dashboard

The overall relatively low EUI of Eastern is partly due to the numerous recommissioning, equipment upgrades, and renovation projects as previously overviewed. Another potentially large factor is the significant number of relatively new campus buildings.

- Approximately 35% of the campus buildings are less than 15 years old.
- The average building age, weighted by GSF, is 35 years old.
- Newer buildings often have better building envelopes, better controls including BAS, and more efficient HVAC equipment.

Figure 2.2 - Figure 2.5 provide Eastern building site EUIs in comparison to regional median averages for similar building types.

Only buildings that have full energy metering are included. Each of the represented buildings have a lower site EUI than the regional average for their respective function. The exceptions are the office buildings 182 High Street Counseling Services and Admissions Building (Figure 2.3) and Winthrop Hall (Figure 2.4). The majority of energy use per square foot for these buildings may be attributed to natural gas use. Eastern may want to consider energy measures that can aid in decreasing natural gas or fuel oil consumption such as through building envelope upgrades or more efficient heating equipment.

Eastern's many buildings with electrical submetering are not shown in Figure 2.2 - Figure 2.5.

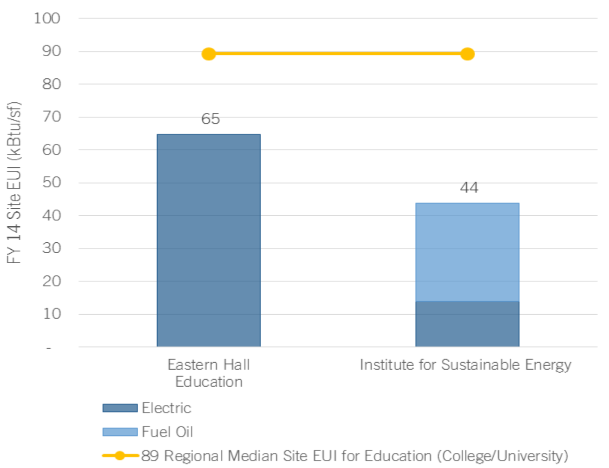


FIGURE 2.2: FY 2014 Site EUI for Education Building Type

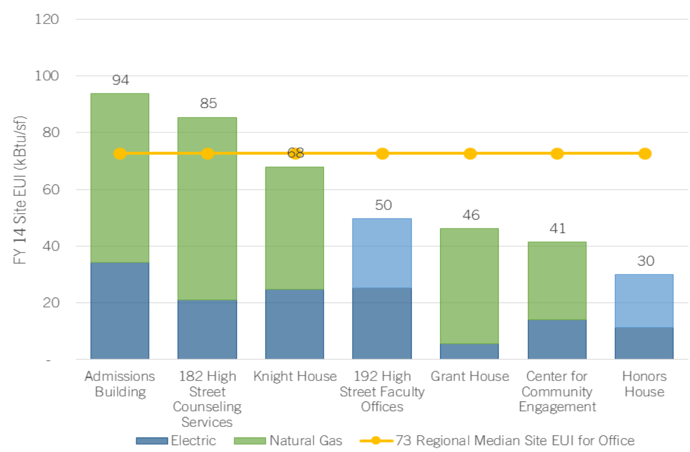


FIGURE 2.3: FY 2014 Site EUI for Office Building Type

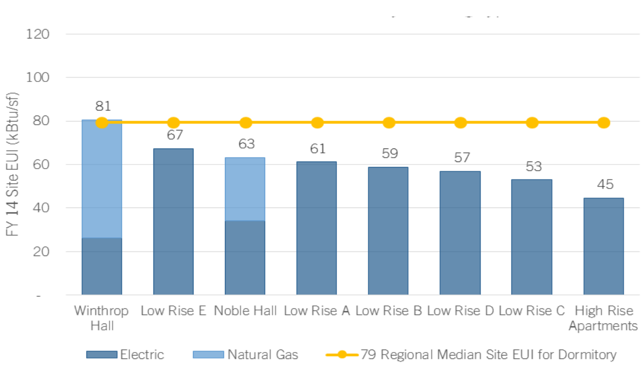


FIGURE 2.4: FY 2014 Site EUI for Dormitory Building Type

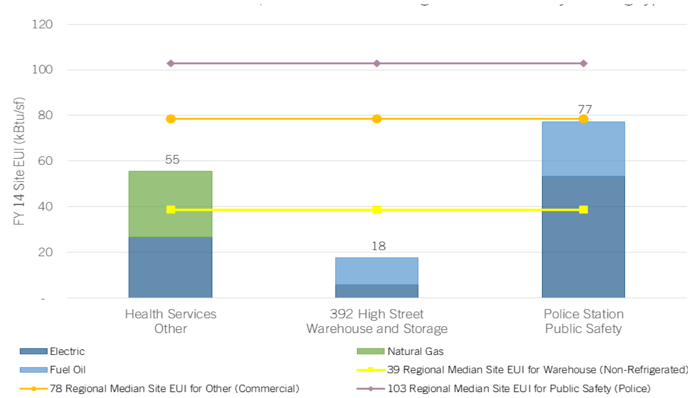


FIGURE 2.5: FY 2014 Site EUI for Other, Warehouse and Storage and Public Safety Building Type

Building	2014 Electrical Site EUI	FY 2014 Electric Use (kWh)	Value of Electricity at 14 c/kWh
Science Building	80	4,230,175	592,220
Student Center	49	1,118,040	156,530
Communication Building	101	1,113,460	155,880
Hurley Hall	81	820,865	114,920
Webb Hall	37	807,420	113,040
High Rise Apartments	45	790,560	110,680
Mead Hall	21	731,563	102,420
Noble Hall	34	730,898	102,330
Laurel Hall	25	725,480	101,570
Sports Center	27	679,870	95,180
Nutmeg Hall	24	661,630	92,630
Wood Support Services Center	49	661,511	92,610
Constitution Hall	25	510,320	71,440
Occum Hall	25	490,120	68,620
Bernice Clark Niejadlik Hall	17	403,669	56,510
Shafer Hall	19	400,782	56,110
Gelsi & Young Hall	29	382,402	53,540
Shakespeare Parking Garage	5	354,090	49,570
Eugene Smith Library	9	354,090	49,570
Low Rise A	61	299,160	41,880

TABLE 2.1: Top 20 Energy Consumers for Electrical

The top 20 energy consumers (excluding the heating plants) for electrical are in Table 2.1.

Appendix B provides the full table of buildings using electricity and the respective site EUIs. Electric Site EUI in order of largest EUI is shown in Figure 2.6.

The list below notes large energy user buildings that have high kwh consumption and site EUIs:

Communication Building: The high electrical EUI of the Communication Building is not unusual due to the large amount of communications, equipment, and laboratories. The building's electrical energy consumption per square foot is second only to the heating plants. The monthly profile peaks during the warmest months indicating the cooling load is up to 50% of building total electrical use. The building uses less than optimum efficiency direct expansion (DX) and window AC units. The building will be undergoing renovation in the next year, which will provide an opportunity for Eastern to specifically focus on energy use of the building.

Hurley Hall: With the next highest electrical EUI and electricity usage, Hurley Hall is also expected to have a high energy intensity. Food service cafeterias typically use 75% more energy than the combined average of all campus buildings. The median site EUI for similar buildings in the northeast is 155 kBtu/sf . Since hot water from the Heating Plant is not recorded, a total EUI could not be determined. It is expected the total would be near or slightly higher than the median of similar buildings.

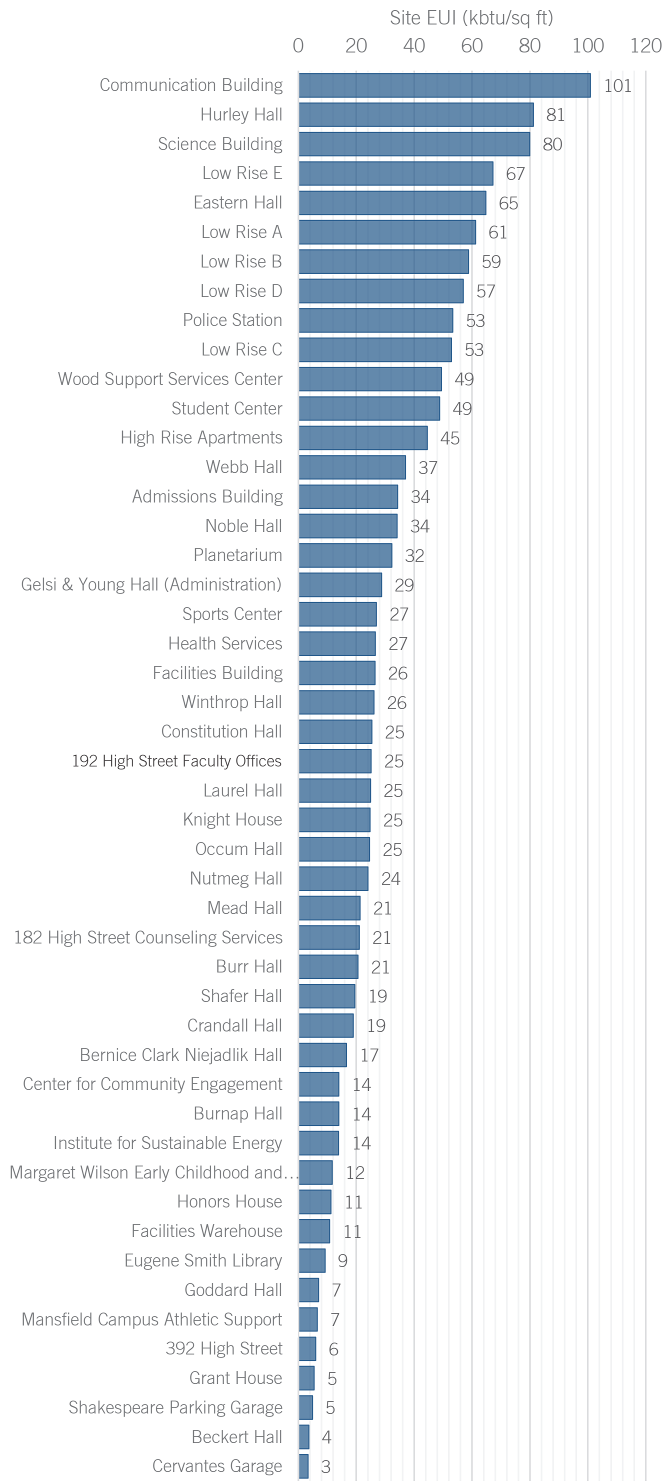


FIGURE 2.6: Eastern Electrical Site EUI by Building

Science Building: The site electrical EUI shown for the building includes the fuel cell electricity production, assuming all electricity goes to the building. Only 29 kbtu/sf of the 80 kbtu/sf is from grid imported electricity. The Department of Energy and Environmental Protection Agency created a database called the Labs21 program to aid in benchmarking laboratory buildings. Based on a cool/humid climate and a laboratory area to total area ratio of 0.33 to 0.7, the average electrical EUI of laboratory buildings is 122.8 kBtu/sf. Eastern's Science Building presents an electrical site EUI approximately 35% lower. This high performance may be attributed in part to increased efficiency from recommendations in a 2011 retrocommissioning study. Recommendations included optimizing air handling units and adjusting sequencing for the fume hood exhaust system.

Eastern should focus on buildings with both high electrical EUIs and overall energy use to result in the most savings.

Another way to view energy use is through cost on a square foot basis. Figure 2.7 separates buildings by function, demonstrating both total energy use and cost per square foot of available metered energy data. It should be noted that the commodity cost is based on the average FY 14 campus unit cost multiplied by energy usage. This method was employed as only a few buildings had associated costs. Buildings with available fuel oil costs in general have a larger cost per square foot.

As Table 2.2 demonstrates, Eastern pays approximately the average cost of electricity per kWh. The unit cost does not account for the adjusted cost of electrical generation from the fuel cell. Some electrical accounts see much higher rates per kWh, especially those with high demand, while most are near $0.14 per kWh. Eastern has a lower cost per square foot than the average of the four universities. In terms of total dollars, the campus attributes a larger percent of total operating expenses to energy spending.

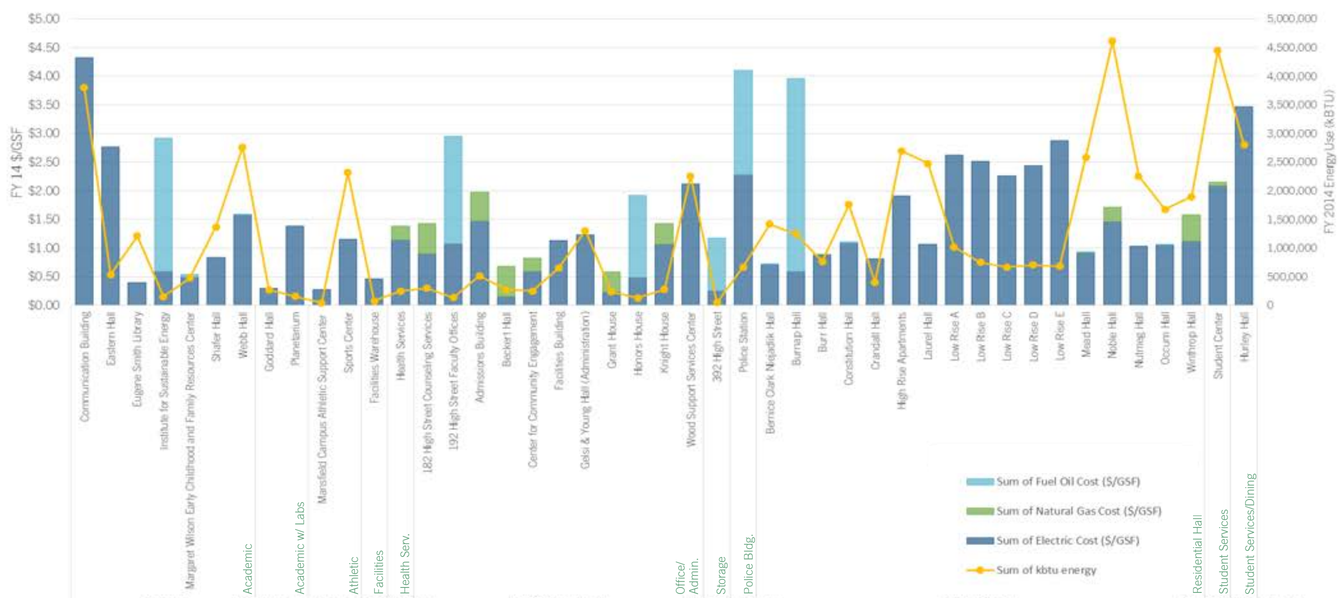


FIGURE 2.7: Eastern FY 14 Cost per Square Foot by Building

	Eastern Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 1.93	$ 2.08	$ 2.49	$ 1.67 [1]
Cost per FTE Student	$ 804	$ 677.00	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.14	$ 0.14	$ 0.14	$ 0.15 [2]
Avg. Cost per MMBtu Natural Gas	$ 8.46	$ 7.32	$ 10.06	$ 10.03 [3]
Avg. Cost per Gallon Propane	$ 2.07	$ 3.77	$ 3.46	
Total Operating Expenses	$ 127,946,490	$ -	$ -	
Total Energy Spending	$ 3,839,259	$ -	$ -	
% of Operating Expenses	3.00%	2.67%	1.95%	

TABLE 2.2: Energy Cost Comparison (FY 2014)

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - http://www.eia.gov/electricity/monthly/current_year/june2014.pdf
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm

2.2 CAMPUS UTILITIES AND DISTRIBUTION

Eastern's utility providers are listed below.

- Electricity: Eastern's electricity supplier is Eversource, formerly known as Connecticut Light & Power. North Campus has one underground electric feed distributed through transformers at each individual building. South Campus buildings have individual feeds, and each building has its own transformer. There is an advantage to adding individual buildings to a larger account, as larger accounts tend to see better bulk rates. Typically consolidating electric accounts will realize monetary savings overall.
- Natural Gas: Natural Gas is supplied through Eversource's (formerly Yankee Gas) system of underground piping.
- Fuel Oil: Dime Oil delivers Eastern's fuel oil.
- Propane: Beginning in 2014, Eastern uses propane for heat in two buildings and hot water in three buildings. Energy and cost data was not readily available at the time of this study and as the propane use is proportionally small to other fuels, a detailed analysis was not done.

2.3 ENERGY PROCUREMENT

Eastern is part of CSCU's 2013 electric supply procurement contract with Direct Energy, formerly Hess Energy, detailed further in the Energy Master Plan. In FY13 Hess Energy was also Eastern's natural gas supplier, but the local distribution company, Eversource, became Eastern's supplier in FY14.

Eastern uses a state contract for oil, which aids in bundling fuel delivery and lowering unit costs. As documented in Section 2.2, the current vendor is Dime Oil, but the vendor often changes depending on the contract.

2.4 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

2.4.1 CURRENT CONDITIONS

The Office of Facilities Management (Facilities) oversees Eastern's physical infrastructure, facilities operations and energy management practices. Eastern's Facilities team has been in the practice of proactively identifying energy improvement opportunities on campus. Facilities meets with an Eversource representative on a monthly basis to speak about issues or improvements for campus HVAC and electrical. While Facilities is able to monitor energy through the building automation system (BAS), described further in the next section, the team is not involved with energy spending. The purchasing department views and pays the bills. Additionally, according to stakeholders, only a portion of the utility budget is under Facilities' control. Facilities formerly monitored year to year savings, but has not continued the practice the last few years.

ENERGY USE INFORMATION MANAGEMENT SYSTEMS

Eastern's Allerton BAS controls approximately 90% of campus buildings. The BAS features alarm systems to notify Facilities of any issues. For instance, alarms on chilled water valves, or any critical or life threatening alarms notifies campus Public Safety. A member of the Facilities staff monitors the system daily and follows up on an issues identified. The BAS feeds data into a community accessible dashboard (see Figure 2.8). The dashboard provides building level data, month over month data and year over year data as well as interval data for the campus fuel cell. The interface is user friendly and granular, but it is unclear if anyone uses it.

For the North and South Heating Plants, Facilities uses SCADA/ Flex Preferred Instruments. The software provides load shedding controls and keeps Facilities informed by sending alarms to Facilities staff phones.

ISE has also entered utility account information into EPA's Portfolio Manager as another method for reviewing data. Overall, the campus is able to digest data through multiple forms.

Four buildings on campus are equipped with an Encelium energy management system. The J Eugene Library uses the lighting control system which has reduced electrical energy use by 26%. The Student Center , Gelsi & Young Hall and Visual Arts Center's lighting are also controlled with the software.

FIGURE 2.8: Eastern's BAS Energy Dashboard

2.4.2 RECOMMENDATIONS

Eastern is well equipped with the software and granular metering to continue to effectively manage energy on campus. Improvements relate to using the existing software on a more frequent basis, specific to energy spending and trending over time. Suggestions for the campus are as follows:

- Meet on a monthly or bimonthly basis with procurement to share utility use and to gather information on spending.
- Have an intern, ISE or a designated staff member track data more frequently to identify any monthly discrepancies or patterns and provide reports to Facilities
- Set up historical logging, specifically for buildings connected to the Heating Plant, for complete energy benchmarking

Additionally, as part of the CSCU Energy Master Plan recommendations in Section 5.2.2, it is recommended that the System Office create a template for energy tracking applicable to all campuses. Eastern can also use Eversource's Customer Engagement Platform (CEP) to view its energy costs.

2.5 EXISTING BUILDING COMMISSIONING

2.5.1 CURRENT CONDITIONS

Eastern has a significant recommissioning program in place. According to the campus, Eastern saved almost a million dollars a year over a six-year period with recommissioning. As part of the program, Eastern worked with Eversource to identify energy efficiency projects, with a three-year payback cut off. Eversource generated the building reports and paid 75% of project cost. As a result, Eastern implemented 70% of the recommissioning efforts and has seen substantial savings. The program is structured such that Eversource has deadlines for when projects have to be done, otherwise the costs of projects increase.

According to the campus, one of the largest energy saving recommissioning projects occurred at the Science Building and involved controls and sequence of operations modication. The building could continue to be monitored after the efforts since it is under the control of the BAS system. The project had a less than a two-year payback.

2.5.2 RECOMMENDATIONS

Eastern should continue to engage with Eversource to recommission buildings with Eversource's support. Continuous commissioning programs can be explored to help maintain the energy savings realized during recommissioning efforts. Buildings with BMS systems with measurable points stand to benefit the most from recommissioning. As a general rule of thumb, existing building systems should be recommissioned every 3-5 years.

2.6 MECHANICAL SYSTEMS

2.6.1 CURRENT CONDITIONS

FIGURE 2.9: South heating Plant

FIGURE 2.10: North Heating Plant

Existing mechanical system conditions consist of the following:

HTHW AND STEAM

Eastern is supplied by four main sources:

- North Heating Plant high temperature hot water (HTHW)
- South Heating Plant Steam,
- Local Heating Systems, and;
- Electric heat.

The North Heating Plant is the primary heating plant and produces HTHW which accounts for 61% of the total fuel energy consumed. It also supplies 72% of the campus in terms of gross square footage. The South Heating Plant supplies low pressure steam to Shafer and Burr Halls and accounts for only about 8% of the total fuel energy. The remaining 31% of the fuel energy is used for numerous local heating systems. (See Eastern building mechanical equipment for inventory).

The following table lists the building heating and cooling systems, if known, along with the weather normalized EUI for comparison. Sixty-three percent of the campus gross square feet (GSF) is on a small chilled water system, while 22% uses DX or window AC units for cooling. There is no central chilled water system, like there is for HTHW. Hurley, Mead and Niejadlik Halls share a chiller, the Science Building and Webb Hall share a chiller, and Gelsi &Young Hall and Wood Student Support Services share a chiller.

Building/Location	Combined Weather Normalized Site EUI	Heating System	Source	Energy Source	Cooling Source
182 High Street Counseling Services	80.82	Local heating system	Standard Boiler	Oil	DX System, Window AC Unit
192 High Street Faculty Offices	47.88	Local heating system		Oil	DX System, Window AC Unit
392 High Street	16.75	Local heating system		Oil	Window AC Unit
Admissions Building	89.5	Local heating system		Gas	DX System
Beckert Hall	61.65	Local heating system	Boiler	Gas	DX System, Window AC Unit
Bernice Clark Niejadlik Hall	17.1	HTHW	North Heating Plant	North Heating Plant	CHW
Burnap Hall	54.73	HTHW, Local Heating System	North Heating Plant	Gas (Condensing)	None
Burr Hall	20.85	Steam	South Heating Plant	North Heating Plant	DX System, Window AC Unit (minimum)
Center for Community Engagement	39.49	Local heating system		Gas	DX System
Communication Building	100.76	HTHW	North Heating Plant	North Heating Plant	DX System, Window AC Unit
Constitution Hall	25.57	HTHW	North Heating Plant	North Heating Plant	CHW
Crandall Hall	18.92	HTHW	North Heating Plant	North Heating Plant	None
Eastern Hall	60.12	Electric Heat		Electric	DX System
Eugene Smith Library	9.25		North Heating Plant	North Heating Plant	Chiller
Facilities Building	26.44	HTHW	North Heating Plant	North Heating Plant	DX System
Facilities Warehouse	10.82	Local heating system		Propane	DX System
Gelsi & Young Hall (Administration)	28.68	HTHW	North Heating Plant	North Heating Plant	CHW
Goddard Hall	6.98	HTHW	North Heating Plant	North Heating Plant	DX System, Window AC Unit
Grant House	43.31	Local heating system		Gas	DX System
Health Services	53.38	Local heating system		Gas	DX System
Heat Plant 1 (North)	19,778.84	HTHW	English Boiler	Gas	None
Heat Plant 2 (South)	1,527.54	Steam	South Heating Plant	Gas	Window AC Unit
High Rise Apartments	41.34	Local heating system	Heat Pump	Electric	Geothermal
Honors House	28.6	Local heating system		Oil	DX System, Window AC Unit
Hurley Hall	81.03	HTHW	North Heating Plant	North Heating Plant	CHW
Institute for Sustainable Energy	41.66	Local heating system		Gas	Window AC Units
Knight House	64.94	Local heating system		Gas	DX System, Window AC Unit
Laurel Hall	24.88	HTHW	North Heating Plant	North Heating Plant	CHW
Low Rise A	56.83	Electric Heat		Electric	Window AC Unit
Low Rise B	54.58	Electric Heat		Electric	Window AC Unit
Low Rise C	49.1	Electric Heat		Electric	Window AC Unit
Low Rise D	52.87	Electric Heat		Electric	Window AC Unit
Low Rise E	62.43	Electric Heat		Electric	Window AC Unit
Mead Hall	22.04	HTHW	North Heating Plant, Supplemental gas hot water	North Heating Plant/Gas	CHW
Mansfield Campus Athletic Support Center	6.52	Local heating system		Propane	DX System
Margaret Wilson Early Childhood and Family Resources Center	12.05	HTHW	North Heating Plant	North Heating Plant	Chiller
Noble Hall	61.09	Local heating system	Boiler	Dual NG/#2	Chiller
Nutmeg Hall	24.05	HTHW	North Heating Plant	North Heating Plant	CHW

Occum Hall	24.69	HTHW	North Heating Plant	North Heating Plant	CHW
Planetarium	32.26	HTHW	North Heating Plant	North Heating Plant	DX System, Window AC Unit
Police Station	75.52	Local heating system		Oil/Propane	DX System
Science Building	79.94	HTHW	North Heating Plant	Fuel Cell	CHW
Shafer Hall	19.47	Steam	South Heating Plant	South Heating Plant	DX System, Window AC Unit
Sports Center	26.96	HTHW	North Heating Plant	North Heating Plant	None
Student Center	56.2	HTHW	North Heating Plant	North Heating Plant	CHW
Webb Hall	37.04	HTHW	North Heating Plant	North Heating Plant	DX System
Winthrop Hall	76.73	Local heating system		Dual NG/#2	DX System
Wood Support Services Center	49.38	HTHW	North Heating Plant	North Heating Plant	CHW

TABLE 2.3: Building Heating and Cooling Systems

Note: The site EUI in Table 2.3 is weather normalized using fiscal year 2014 data. Buildings connected to a central plant do not show the total energy used by the building, only the gas and electric metered for the specific building.

Additional details of the largest consumer of energy, the North Heating Plant, are below.

Four boilers, installed in 1995, are rated for approximately 80% efficiency each. The total capacity is approximately 56 MMBtu/hr output, or 70 MMBtu/hr input. The boilers and distribution are setup as a primary-secondary system with four (4) pumps for the primary loop and three (3) pumps for the secondary loop. The horsepower requirements for the primary and secondary pumps are approximately 6 HP and 20 HP, respectively. While the primary pumps are not equipped with variable frequency drives (VFDs), little savings would be realized by adding VFDs. The secondary loop is equipped with VFDs. All except for the one of the pumps, which is air cooled, are cooled with once-through cooling water.

Of the various chilled water systems, the 100 Ton reciprocating compressor at Occum Hall appears to be one of the oldest and also least efficient. While water cooling improves efficiency, the compressor still operates at much lower efficiencies than modern variable speed scroll compressors, even those found on modern DX units.

FUME HOODS

The Science Building at Eastern contains fume hoods for its laboratory classes which partially accounts for the building's high energy usage. Fume hoods are high energy users that often directly discharge conditioned air. Eastern has a fume hood sash management program to educate about the importance of ensuring hoods are closed and turned off when not in use.

FIGURE 2.11: Science Building Fume Hood

DOMESTIC HOT WATER

Domestic hot water is generated mostly using HTHW to hot water heat exchangers. There are some natural gas fired heaters as well as electric heaters. Mead Hall and the Gelsi & Young Building are two buildings where electric hot water heaters were identified.

2.6.2 RECOMMENDATIONS

The following recommendations by system type would aid in optimizing efficiency, and reducing energy.

BOILER SYSTEMS

- Insulate all valves and fittings of the steam and condensate system, including condensate receivers. Eversource incentives are significant for insulation improvements since they often have high energy savings associated with the improvements. The energy in the condensate can be more than 10% of the total steam energy content in a typical system, therefore conserving as much of the remaining heat in the condensate can provide significant savings. Priority should take place first on the highest temperature piping, from largest to smallest, followed by lower temperatures, such as condensate return. Removable blankets offer sufficient insulation while still allowing access for maintenance. Following this approach, insulation should be added around HTHW valves and fittings.
- Consult with Eversource to implement a steam trap maintenance program. Steam traps may fail open or closed, wasting thousands of pounds of steam per month, or rendering steam coils inefficient or ineffective.

  a. This EEM often has the most rapid return of investment, even without utility incentives. With the incentives, the cost of the steam trap survey can be 100% covered. The repair of traps can also be substantially covered by the rebate program.
- Install parallel positioning controls (as opposed to jackshaft) on boilers along with O2 trim. Efficiency is typically increased by 3-6% while allowing for better turndown as a dual fuel boiler. Costs are typically around $12,000 - $16,000 installed, per boiler.

  a. The average fuel cost for 2014 and 2015 was near $72,500 for the South Heating Plant. Assuming a savings of 5.5% by adding the boiler controls, nearly $4,000 would be saved per year
  b. Another advantage of upgraded boiler controls is the ability to modulate better at low firing rates, and can afford greater turn down since dual fuel boilers with jackshaft controls are usually limited to the minimum firing rate of fuel oil instead of natural gas.
- After space changes, such as ones planned for the Shafer Hall building renovations, boiler sizing should be reevaluated. Install smaller condensing natural gas units where low return water temperatures are possible.
- Instead of rebuilding once through cooling pumps, replace HTHW pumps with air cooled or recirculating models to save on water costs. The campus has completed this measure with their primary pumps, secondary pumps should be considered as well.
- Where VFD's are installed on pump motors, ensure triple-duty or balancing valves at pump discharges are 100% open since they should no longer be used to control the flow rate by adding unnecessary head against the pumps.

CHILLER SYSTEMS

While traditionally direct expansion (DX) cooling systems have been seen as inferior to central plant chilled water systems, advances in technology have made modern DX system equal to or even more efficient than central plant chilled water system. With two central plants already in place, replacing older DX units with chilled water coils connected to the plant could increase efficiency. However, where location or existing layout challenges make connecting to either of the central chilled water plant unpractical, replacement with a new DX unit complete with variable speed compressors and advanced controls can provide comparable cooling efficiencies.

VFDs- In general, VFD's should be installed on any existing pumps 5 HP or greater whose flow rate could be reduced for portions of the day or year. When VFD's are added, triple-duty or balancing valves should be opened 100% since they should no longer be used to control the flow rate by adding unnecessary head against the pumps.

For example: the chilled and cooling water pumps at the Science Building, which also supply Webb Hall, account for a large portion of the electrical load. Assuming two of the three 20 HP chilled water pumps and two of the three 60 HP cooling water pumps operating for 2,000 hours per year without VFDs, approximately 200,000 kWh would be used to pump at a cost over $40,000 per year. If not already installed, drives should be evaluated for the chilled and cooling water pumps.

The Student Center contains slightly lower electrical usage than the Science Center. Similarly, the four (4) 30 HP and two (2) 25 HP pumps for the chillers and tower pump respectively, should be operated using VFD's.

Installing VFDs on cooling tower fan motors is also an opportunity, if not already implemented. As with any VFD application, drives must be properly programmed. If left at full constant speed, no savings will be realized. This recommendation is applicable to any water cooled chiller and may include, but not limited to, Noble Hall and the Student Center

There are plans to replace the Trane reciprocating compressor at Occum Hall. If the same size is needed (100 Ton), the most common option is a scroll compressor.

Eastern should complete lifecycle cost analysis between different technologies, including but not limited to air cooled, water cooled and variable speed, centrifugal and screw chillers. As practice, Eastern should always evaluate the lifecycle cost of equipment options before purchase.

HVAC AIR SIDE

While many buildings on campus have HVAC systems with higher efficiency variable air volume (VAV) controls, many opportunities still exist.

- VAV and direct digital controls (DDC)- Upgrade remaining existing air pneumatic air handling units (AHUs) with VAV and DDCs, with the goal of completely eliminating pneumatic systems and air compressors. Pneumatic mixing valves should also be replaced with digital as part of these efforts.

From a review of the many air handling units, hundreds of thousands of cfm can be exhausted at any given time.

- VFDs- The Science Building is one of largest energy consumers from an electrical standpoint on campus. It is unknown which air handler or exhaust fans, if any, are equipped with VFDs. With exhaust fan capacity totally over 200,000 cfm, significant savings can be seen by adding drives to each fan, if not already equipped. Savings could also be realized from not conditioning as much makeup air by reducing the flow rates.
- Heat Recovery- The Sports Center AHUs are equipped with heating coils and exhaust fans. There are six more exhaust fans rated for 10,000 cfm each. Adding a heat recovery system is worth exploring considering the potentially high airflow rates year round.

FUME HOODS

- Eastern should continue its existing fume hood management program and update its end users on a routine basis. Occupancy and flow sensors can help ensure wasted conditioned air and fan energy is minimized.
- Eastern should work with the CSCU to ensure appropriate set points and controls are in place for all campus fume hoods.

OTHER

- Reduce the compressed air pressure as low as possible before dropping the pressure at the first regulator for any remaining pneumatic system, especially as parts of systems are slowly converted to DDC.
    a. Every 2 psig drop in pressure can yield 1% energy savings. If the 3HP compressor operated 2,000 hours a year and pressure was reduced from 76 psig to 40 psig, 18% of the energy would be saved, equal to approximately $320.
- Where electric hot water heaters exist, replace with condensing natural gas or add supplemental heat pumps to the storage tanks. Condensing natural gas and heat pump water heaters would be the most efficient or cost effective, while purely electric heaters are the most expensive to operate. With rebates, the simple payback is often less than three years. Mead Hall and the Gelsi & Young Building were two buildings where electric hot water heaters were identified.

2.7 LIGHTING

2.7.1 CURRENT CONDITIONS

FIGURE 2.12: Eastern Interior Lighting

Facilities, with its four electricians on staff, have been upgrading existing lighting steadily over the years. Approximately 85% of outdoor lighting is LED, with all parking lots lit with LEDs. The campus consists of mixed lighting with mainly T8s and CFLs, providing additional opportunities for LED conversions. A majority of the campus has occupancy sensors and four buildings utilize the Encelium Control system. Present in the Eugene Smith Library, Student Center, Gelsi & Young Hall and the Visual Performing Arts Center, the Encelium system dims lamps in daylight hours and turns off lights when occupancy sensors indicate an empty room.

The system is interconnected to the HVAC control system reducing HVAC requirements and lighting needs when rooms are unoccupied. It was noted at the time of the site visit that lights were on in unoccupied spaces.

The campus also uses solar powered lights, reducing energy use throughout the year and providing emergency lighting in case of power outages. Eastern's parking garages are currently equipped with LEDs and controlled by sensor and timers. Facilities has plans to specifically focus on the Eugene Smith Library outside lighting upgrades, Wood Support Services lighting and controls and Webb Hall controls.

Eastern works with Eversource for lighting related studies and incentives.

FIGURE 2.13: Solar Outdoor Lighting

2.7.2 RECOMMENDATIONS

All lighting upgrades should be coordinated with Eversource to help maximize the return on investment. Eversource is offering programs to support modernization of lighting. A lighting audit is recommended with prioritization of lighting retrofits, starting with highly utilized lighting such as parking garages, lobbies or outdoor applications. Eastern should continue to replace existing lighting with more efficient LEDs, and update older lighting control systems. Building specific lighting recommendations are as follows:

- Wood Support Services Center: Install new LED lighting and controls, such as harvest control lighting
- Eugene Smith Library: Install new LED lighting.
- Cervantes Garage: Replace T8 Lighting throughout the garage with LED (completed at the time of report production).
- Change lighting in the clock tower to LED

2.8 BUILDING ENVELOPE

2.8.1 CURRENT CONDITIONS

Eastern's building assets include a mix of more recent additions, residential buildings, and a range of construction dating back to the early 1900s. According to the 2008 Eastern Connecticut State University Campus Master Plan, the following buildings on Eastern's campus are listed as historic places or as having historic significance:

- Knight House
- Counseling Services (182 High Street)
- Honors House (176 High Street)
- Grant House
- Burr Hall
- Beckert Hall
- Noble Hall
- Center for Community Engagement (333 Prospect Street)

Each of the buildings are of wood frame construction, with little to no insulation. For instance, Burr Hall has little insulation, creating ice dams during the cold months and potential structural issues. Some of the older buildings have had envelope upgrades, such as with the Center for Community Engagement which was renovated two years prior with a new roof and insulation. Another wood frame building housing the Institute for Sustainable Energy had an energy audit in 2015 along with air sealing and caulking improvements. The building is still in need of insulation.

2.8.2 RECOMMENDATIONS

Candidates for building envelope upgrades at Eastern mainly consist of the older wood frame buildings. Older wood framed buildings often have fieldstone basements which should be insulated, especially the sills between the foundation and the first floor if not anything else. These types of buildings also often have very little, settled, or no insulation in the walls and roofs. A building envelope specific audit can identify the deficiencies with thermography and physically sampling potential insulation locations. Adding insulation to the walls and increasing insulation in the attic spaces to the latest building code has the potential to cut heating costs in half. Other targets include buildings with large window expanses, such as the Wood Support Services. Crandall Hall and Burnap Hall may be candidates for window replacement, as the last window replacements were 20 years ago. Eastern may want to consider replacing older windows if drafty or using shades for added insulation benefits.

In general, Eastern should consider conducting existing building commissioning (EBCx) related to building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed the latest building code or ASHRAE 90.1 standard.

2.9 DISTRICT ENERGY / COGENERATION

2.9.1 CURRENT CONDITIONS

FIGURE 2.14: Eastern Fuel Cell - PureCell Model 400

Eastern procured its 400 kW fuel cell in 2012 through a system-wide fuel cell initiative. The PureCell Model 400 is located outside of the Science Building and provides heating and electricity for the building. The power purchase agreement (PPA) is between the campus and Doosan Energy (formerly UTC Power) over a 10-year term. Under the contract, Eastern pays a fixed payment of $24,834 a month. Contract terms and structuring notes include:

- University personnel are trained and responsible for visually monitoring the system from the outside fence on daily basis.
- Doosan provides an annual usage report by the 30th day of the last month of the calendar year during the term.
- Doosan will provide the University with information on the fuel cell for educational purposes.
- Doosan guarantees to provide an annual power output as well as an annual natural gas consumption amount.
- If the kwh output for the year does not meet the total guaranteed minimum output (GMO), Doosan will credit the University one percent of the annual payment for each one percent under delivered. A credit will only be applied if the lack of output is directly related to the system. If the output surpasses the GMO, the University must compensate Doosan using the same structure.

Based on the contract payment details outlined in the CSCU Energy Master Plan, the approximate normalized electrical cost for operation of the fuel cell is $0.158/kWh without the capture of RECs. The normalized cost is inclusive of 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. Eastern has expressed discontent with the fuel cell as it has not been operating effectively; the contract will be unattractive if Eastern fails to secure RECs and the local distribution company (LDC) natural gas waiver or if the unit has capital contribution requirements. However, as Eastern secures the RECs, the project cost is much closer to breakeven.

With the inclusion of RECs, assumed at $24.50/MWh, the normalized price drops approximately 2 cents, making it a more attractive option.

As of winter 2016, 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.

2.9.2 RECOMMENDATIONS

The thermal and electric loads at Eastern indicate a moderate CHP potential for additional cogeneration. However, the effectiveness of the system without the need for heat year round reduces the efficiency of the system if oversized beyond the minimum thermal load. Thermally driven (absorption) chillers can increase the summer heat load, but without a chiller loop on campus this is an unlikely scenario. It is recommended that electrical and thermal data continue to be collected for future cogeneration analysis. New onsite generation should be evaluated at the end of the existing 400kW fuel cell's cost effective life. Appendix B contains supporting information for these findings.

Immediate opportunities include:

Fuel Cell RECs

It appears that RECs should be paid out to Eastern quarterly, but it was unclear if the revenue was optimized given the sporadic nature of operation. With the new fuel cell, the campus should ensure the fuel cell has the most uptime possible to generate RECs. RECs are generated for every MWh produced from the fuel cell. When operating at full capacity, the fuel cell should generate somewhere between $75,000 and $175,000 of savings per year.

LDC Natural Gas Waiver

Connecticut's natural gas local distribution companies (LDCs) offer a distributed generation rider. Under the rider, some distribution charges may be waived with the installation of a natural gas distributed generation system. For instance, waived charges may include a daily demand meter charge or a delivery charge per hundred cubic feet (ccf) of natural gas. Eastern should make sure that this waiver is consistently applied on its fuel cell bill.

2.10 DEMAND RESPONSE

Eastern has participated in the regional transmission operator's, ISO New England, demand response program. The campus participates with approximately 1 MW in assets. Staff is generally given a half hour of lead time prior to the event. For load shedding, the campus generally shuts down coolers and towers. Events have been called later in the afternoons, and the campus has not had staff available to load shed, or to turn generators on.

2.10.1 RECOMMENDATIONS

In general, during the summer months when there is generally higher peak demand, Facilities staff should monitor demand of the largest accounts. Students and staff can also be engaged in demand response events, by requesting them to shut lights, air conditioning, plug loads, etc.

If Eastern plans to use newly purchased generators for demand response, the campus is recommended to purchase Tier IV compliant systems. As part of EPA's regulations, in order to participate in real time demand response, generators must meet EPA's Tier IV emissions requirements, which place stricter emission guidelines on particulate matter and nitrogen oxides.

2.11 RENEWABLE ENERGY

2.11.1 CURRENT CONDITIONS

Eastern has several renewable energy installations on campus. In 2001, the campus installed geothermal in the High Rise Residence Hall for heating and cooling. According to the campus, it has helped reduce energy use and costs by 12 percent.

Formerly, there was solar thermal system on the Sports Center, which is no longer in use. Solar pole lights and lights on bus stops are dispersed throughout the campus. While the lights provide clean energy, they require added staff time to clean off snow during the winter.

Facilities has been approached several times about solar on campus at the garages and Science Building. In the past, incentives were not substantial enough to spark interest in the proposal. As outlined in the recommendations section, available financial models are now more attractive.

2.11.2 RECOMMENDATIONS

There are several opportunities for rooftop solar photovoltaic (PV) on campus depending on roof age, plans for renovations, and availability of space not encumbered by mechanical equipment. In general, there are opportunities for small sites of less than 200 kW. With any roofing improvements, implementation of solar PV should also be considered at the same time. Integrating solar simultaneously with new roofing can help streamline both projects into one and mitigate issues the insurance provider may have for existing roofs.

Cervantes Garage and Shakespeare Garage have the largest open space available for a roof-mount solar canopy, however the future needs of the garages and the cost of garage mounted PV can be limiting. For ground-mount solar, most of the available campus land is either tree covered or used for recreational purposes. Eastern may consider further discussions around ground-mount opportunities as the campus Master Plan is implemented. Acquiring solar on campus is more favorable than in the past, with a solar PPA anticipated to provide electricity at a 20-50% discount to the campus.

Table 2.4 provides an overview of the buildings that may be considered for solar PV in the future. Following the table are images of each of the sites.

Building Name	Address	Year Built [Renovated]	GSF [FY 2015]	Building Roof sq. ft.	Roof Install/ Replacement Date	Roof Type	Array Size Potential (kW DC)[1]	Annual Generation Potential (MWh)[2]	Solar Suitability Comments
HIGHER PRIORITY PROJECTS									
Burnap Hall	8 Charter Oak Road	1970	21,550	2,564	1992	Flat Roof	12-15	15-21	A small array
Crandall Hall	6 Charter Oak Road	1970	21,434	1,364	1992	Flat Roof	6-8	8-11	A small array
Eugene Smith Library	2 Clock Tower Road	1998	130,449	32,612	1998	Standing Seam	120-157	157-201	Good candidate, need to watch snow loading
Facilities Warehouse	25 Charter Oak Road	2013	6,777	6,777	2013	Metal	25-33	33-42	
Gelsi & Young Hall (Admin)	6 Eastern Road	2002	45,431	2,162	2002		10-13	13-17	
Noble Hall	284 Valley Street	1928	73,016	24,339	1992	Rubber Roof	90-117	117-150	
Police Station	44 Charter Oak Road	2009	8,636	2,876	2009	Asphalt and Shingle	11-14	14-18	A small array
Student Center	5 Charter Oak Road	1975 [2007]	78,210	39,105	2007	Rubber Roof	144-188	188-241	There is some potential at the upper corner of the building
Wood Support Services Center		1970 [2000]	45,645	9,500	2003	Built Up	35-46	46-59	Multi-level roof building and about 25,000 sq.ft. Onlyupper floor portion considered
Subtotal				121,299			453-591	591-760	
LOWER PRIORITY PROJECTS									
Facilities Building	32 Charter Oak Road	1986	24,568	4,500		Standing Seam	21-27	27-35	
Fine Arts Instructional Center		1972	28,118	7,400	2015	Membrane	34-44	44-57	Has significant amounts of mechanical equipment, but there may be opportunity with setbacks.
Shafer Hall	83 Windham Street	2000	70,151	16,065	2000	Gypsum	59-77	77-99	Offline. It is going to be renovated into a dorm. Has mechanical equipment.
Sports Center	20 Eastern Road		86,057	13,773	2012	Rubber Roof	63-83	83-106	Has mechanical equipment. Eastern plans to demolish the southern portion of the building in the future.
Subtotal				41,738			177-231	231-297	
Total				163,037			630-822	822-1057	

TABLE 2.4: Eastern Potential Areas for Solar PV

Strategically, and to aid climate action plan goals, Eastern should attempt to implement solar on campus before the 2019 federal investment tax credit expires, unless there is an extension. The campus should also optimize available incentives, by strategically planning ZRECs and LRECs for the best savings. Off-site renewable energy should continue to be considered Eastern.

As practice, with any roofing improvements, implementation of solar PV should also be considered at the same time. Integrating solar simultaneously with new roofing can help streamline both projects into one and mitigate issues the insurance provider may have for existing roofs. Solar PV should also be incorporated into future capital planning building design.

Eastern should continue to work closely with CSCU when pursuing renewable energy options. With the rapid improvement of energy storage technology, Eastern may want to consider solar islanding in the future, whereby solar energy can be stored during the day and released at times of peak load to reduce energy costs. The campus may want to also consider a microgid, where financially advantageous and feasible. Connecticut currently has a microgrid grant program to support critical facilities

[1] Assumes that 80% of roof area is available for solar PV and that each sf of panels can generate between 4.6 and 6 Watts DC (about a third of the PVWatt Output Assumptions). Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Actual generation values would be calculated if a solar PV study was performed.
[2] Assumes that 80% of roof area is available for solar PV and that each sf of panels can generate between 6 and 7.7 kWh annually (about a third of the PVWatt Output Assumptions). Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Actual generation values would be calculated if a solar PV study was performed.

FIGURE 2.15: Eastern Solar Potential

2.12 CAPITAL PLANNING

2.12.1 CURRENT CONDITIONS

The Eastern Connecticut State University 2008 Master Plan is a ten-year comprehensive physical development plan designed to enhance the academic, residential, and community life of the campus. It identified 28 new building and renovation projects, several of which have already been completed, and others that ideally should be completed by the target year 2017. In April 2016, Eastern completed its Master Plan Update which reviewed past campus additions and planned for future space needs. These broad picture strategic space plans help to guide construction projects.

Eastern has published building standards around new construction and renovation, including building design for LEED certification. The Eastern Technical Guideline encourages:

- Green (building) design opportunities and advanced building technologies to be considered for all new buildings;
- Green design and building aesthetics
- Orienting buildings to maximize passive heating cooling and ventilation
- Maximizing use of natural light-windows and skylights
- Utilizing light colored roofs
- Minimizing building footprint, where possible
- Reducing light pollution; and
- Using landscaping and exterior design (materials) to help reduce heat absorption

Eastern has a desire to build off its existing LEED goals and achieve net-zero renovations and new construction.

Eastern's most recent construction project was the new Fine Arts Instruction Center, which was not factored into this assessment as it was constructed after FY 14. The Center is designed to meet LEED Silver green building standards. The building opened in Fall 2016 and hosts Eastern's second EV charging station.

In general, larger capital projects for Eastern are funded with money from:

- Traditional State obligation bond process
- Transform CSCU 2020
- Connecticut Health and Educational Facilities Authority (CHEFA)
- Grants

To accomplish its energy infrastructure goals, Eastern has also used the energy line item from operating funds to supplement the aforementioned sources. The campus has received grants for the parking garage lighting project from Eversource.

More information on campus expansion projects that may impact energy use is found in Section 3.1

2.12.2 RECOMMENDATIONS

Eastern should continue to collaborate with Eversource for all major building renovations, mechanical, plumbing, electrical equipment upgrades and all new construction. The campus should also coordinate with CSCU during capital planning and have a Commissioning Agent oversee project completion.

2.13 COLLABORATION/PARTNERSHIP

2.13.1 CURRENT CONDITIONS

Eastern began its partnership with Eversource starting in 2003, when it received assistance and rebates for the Gelsi & Young building updates. Starting in 2010, the campus has consistently collaborated with Eversource on building upgrades and efficiency projects. Eastern meets with Eversource representatives on a monthly basis to provide general updates and discussions around prioritization of energy projects with the team.

Eastern specifically works with Eversource on opportunities for retrocommissioning and jointly identifies projects. Eversource structures the program with project-specific deadlines, and if the projects exceed the deadline there can be cost penalties. The campus has also received grant funding in the past for a parking garage lighting project.

As mentioned in prior sections, Eastern has a partnership with ISE. The organization focuses on benchmarking and providing practical energy-related recommendations to increase sustainability on campus. ISE has entered Eastern's utility information into Portfolio Manager.

2.13.2 RECOMMENDATIONS

Eastern should continue to work with Eversource to take advantage of Utility Incentives for the EEMs presented in this plan. Incentives structures range, but Eversource has offered incentives of up to 80% of project costs in the past.

Facilities should pursue a strengthened partnership with administration to execute summer schedule cutbacks and classroom consolidations.

2.14 SUMMARY OF RECOMMENDED ENERGY EFFICIENCY OPPORTUNITIES

As a result of the campus walk through energy assessment, and interviews with campus staff, a list of potential Energy Efficiency Measures (EEMs) is presented in Table 2.5. These projects represent both low cost, immediate action measures, as well as projects that may require larger capital and therefore be longer-term.

Many energy-related projects are incentivized through utility rebates. Both of Eastern's utilities are through Eversource. This places the campus in a prime position to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project." The primary advantage of a Comprehensive Project is the maximum incentive cap is normally raised from 40% to 50%. Eversource has maximized these incentives in the past, and may also in the future, in the following ways:

- The comprehensive cost cap was increased from 50% to 80% of total cost.
- The incentive was increased from $0.30/kwh or $3.50/CCF (with 40% cost cap) to $0.40/kwh or $4.00/CCF (with 60% cost cap).

Since incentives are based on incremental energy savings; further analysis and collaboration with Eversource will be required to determine rebate amounts for each opportunity. To help Eastern navigate and prioritize the energy opportunities identified, a summary of opportunities is listed in Table 2.5. Immediate action should be taken to consider priority one and two opportunities with the goal of combining multiple opportunities for a Comprehensive Project. The simple payback in most cases cannot be reasonably estimated without detailed building models and/or more operating data. The payback periods provided are based upon the performance of past similar projects and are not necessarily indicative of future results.

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
ECSU-1	Optimize fuel cell operations and ensure RECs are received (in progress, with a new contract for a 440kW fuel cell. RECs are included for Eastern in the contract).	Fuel Cell	NA	Varies	1
ECSU-2	Work with Eversource to have the distributed generation rider added to the fuel account	Fuel Cell	NA	Instant	1
ECSU-3	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations, and/or ground mounted arrays through PPA (Eastern is evaluating Burnap Hall and Crandal Hall).	Campus	Varies	Instant - 20	1
ECSU-4	Conduct existing building commissioning (EBCx) for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Burr Hall	Varies	Varies	1
ECSU-5	Insulate all valves and fittings of steam and condensate piping, including condensate receivers (in progress).	Heat Plant (South)	Varies	<1 - 2	1
ECSU-6	Consult with Eversource on steam trap maintenance program.	Campus	Varies	<1 - 2	1
ECSU-7	Install new LED lighting and controls.	Wood Support Services Center	$ 54,394	2 - 6	1
ECSU-8	Install new LED lighting.	Eugene Smith Library	$ 24,984	2 - 6	1
ECSU-9	Replace T8 Lighting throughout the garage with LED.*	Cervantes Garage, Shakespeare Garage	$ 119,253	2 - 6	1
ECSU-10	Evaluate building envelope opportunities, including insulation and removing wall AC units.	Knight House	Varies	Varies	2

** The production of this report was a year long process. This recommendation was made at the beginning of the project and the campus has already successfully implemented the project since.*

ECSU-11	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.2 standard.	Grant House	Varies	Varies	2
ECSU-12	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	182 High Street Counseling Services	Varies	Varies	2
ECSU-13	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Institute for Sustainable Energy	Varies	Varies	2
ECSU-14	Install parallel positioning controls on boilers with O2 trim.	South Heat Plant	$12,000 - 16,000 each	3 - 4	2
ECSU-15	Ensure EBCx testing and balancing (TAB) is performed after renovations and all control points are clearly named for continuous monitoring.	Communi-cation Building	$20,000 - $130,000	1 - 5	2
ECSU-16	Ensure EBCx testing and balancing (TAB) is performed after renovations and all control points are clearly named for continuous monitoring.	Goddard Hall	$20,000 - $130,000	1 - 5	2
ECSU-17	EBCx HVAC controls, reduce outside air as much as possible to maintain indoor a quality while taking advantage of economizer modes when outside air conditions permit.	Mansfield Campus Athletic Support Center	Varies	Varies	2
ECSU-18	EBCx every 3-5 years.	Fine Arts Instructional Center	$1.00 - $3.50/sf	Varies	2
ECSU-19	Conversion from pneumatic to direct digital control (DDC) system. Upgrade to VAV AHUs if possible.	Sports Center	$419400 - $957900	Varies	2
ECSU-20	Conversion from pneumatic to direct digital control (DDC) system.	Wood Support Services Center	$ 222,500	Varies	2
ECSU-21	With building renovations install high efficiency chiller system. Consider using water cooled electric chiller possibly with heat recovery such as a YORK YK.	Communication Building	Varies		2
ECSU-22	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	Honors House (ECSU)	Varies	Varies	2
ECSU-23	Upgrade lighting and controls to take advantage of natural sunlight.	Wood Support Services Center	$ 45,652	3 - 6	2
ECSU-24	Install new Controls with lighting upgrades.	Webb Hall	74514	3 - 6	2
ECSU-25	Revaluate energy systems after space use change. Consider downsizing oversized equipment.	Shafer Hall	Varies	Varies	3
ECSU-26	Upgrade kitchen equipment with EnergyStar certified equipment, especially water heaters and dishwashers.	Hurley Hall	Varies	Varies	3
ECSU-27	Install new energy efficient windows complying with ASHRAE 90.1, the 2012 International Energy Conservation Code (IECC), or ENERGY STAR. Windows should be replaced with low emissivity, double paned, high performance windows with thermally broken frames.	Crandall Hall, Burnap Hall	$100/sf	20 - 50	3
ECSU-28	Investigate other CHP opportunities. Options include natural gas driven heat pumps to replace aging geothermal system.	High Rise Apartments	Varies	Varies	3

TABLE 2.5: Eastern Energy Efficiency Measures

ENERGY NEEDS

3.1 FUTURE DEVELOPMENT

Eastern's campus is anticipated to expand and change, guided by Eastern's 2016 Master Plan Update. Projects occurring now that may impact future energy use include the efficiency upgrades in the Communication Building, Goddard Hall and Shafer Hall renovations. Renovations of the Communications Building are scheduled to help address the need for additional classroom space. The Communication Building has the largest electric site EUI on the campus. Changes to the building provide opportunities to replace electric equipment with more efficient models and focus on energy conservation.

The renovation of Shafer Hall will repurpose the academic space into a residence hall. Shafer Hall and Burr Hall are the only two buildings served by the South Heating Plant. Since Shafer Hall is offline for construction, considerations may be made around whether the South Heating Plant is needed or if the buildings may benefit from decentralized heating equipment, moving to two pipe heating and cooling, and constructed in accordance with Connecticut's High Performance Building Standards.

In the short-term, renovation of Goddard Hall is planned after the completion of the Communications Building. Renovations of Goddard Hall will help to address the need for additional classroom space as well as provide needed upgrades to HVAC systems and electrical and data infrastructure. The renovation will also include building envelope upgrades.

The Master Plan Update provides guidance for projects in the longer term. Based on the plan, the assessment found a space need of 239,077 Gross Square Feet to meet campus projected enrollment in 10-years. Suggested new construction projects, which are highly dependent on budget and campus prioritization, include:

- Expansion of North Heating Plant
- Upgrade North Loop Transformers
- Academic Building with new Quad
- Sports Center
- Recreation Center
- and construction of 8 other buildings, including a new Dining Hall, Health and Wellness Center and three different residence halls

The Master Plan also suggests acquisition of the Windham Technical High School site to expand future development capacity.

Based on near-term projects, it is not anticipated that any additional energy infrastructure such as electric feeders or new meters will be needed. However, given the larger expansions suggested in the 2016 Master Plan Update, the North Heating Plant expansion and transformer upgrades will help support the new buildings. With higher energy intensity buildings like the new dining hall, specific focus should be made to ensure the most energy efficient equipment is installed.

FIGURE 3.1: Eastern Heating Plant

FIGURE 3.2: Shafer Hall

3.2 ENERGY RESILIENCY RECOMMENDATIONS

Eastern partook in the CSCU multi-campus hazard mitigation plan development. The CSCU Multi-Hazard Mitigation Plan provided recommendations surrounding energy resiliency that are also applicable for the Energy Master Plan. As the campus expands it is important to be able to support the electric needs for continuity of operations. Currently, not all buildings on campus have emergency generators, including the Facilities Building. For the buildings that do have generator capacity, all are diesel powered.

Recommendations from the hazard mitigation plan for improving the energy reliability and resiliency of the campus, include:

- Study and construct underground utility tunnels to multiple buildings on campus.
- Study options for redundant power and implement engineered solutions for multiple residence halls and Hurley Hall.
- Study and implement backup power generation for buildings across campus With purchases of new generators, Eastern should pursue Tier IV to be able to use the generators for ISO New England's demand response programs.
- Create a policy requiring stronger hazard resiliency in new designs of buildings.
- Study and evaluate solutions for redundant power on campus, including cogeneration and microgrids, and implement engineered solutions
- Add emergency generators to buildings not currently equipped with backup power.
- Add/expand generator capacity to include Health Services.
- Study and evaluate the potential for a satellite heating plant to reduce the demand to the central plant.
- Develop a Facilities Building Needs Assessment (to look at expansion of facilities/grounds space).
- Provide backup power generation for Noble Hall to ensure sump pump operation to prevent flooding of the basement floor apartments due to groundwater issues.
- Improve building envelopes

CONCLUSION / NEXT STEPS

Eastern's site EUI indicates it is the least energy intensive University of the CSCU Universities. As evident by the numerous completed energy projects, successful collaborations and energy management efforts, Eastern is an energy conscious campus. The most immediate and more easily implemented energy saving opportunities include air sealing and insulation for older residence style housing and lighting and DDC upgrades. Other top priority initiatives include:

- *Management:* Review existing energy data on a more frequent basis, with an eye for outliers and energy intensive buildings by month. If resources are not available for an existing staff member to continuously monitor data, investigate opportunities for data tracking and the identification of discrepancies. Ensure Facilities is apprised of total energy spending.
- *Alternative Energy:* Investigate if Eastern is receiving RECs, and if not follow up with fuel cell operator to ensure they are being generated. Also make sure the LDC natural gas waiver is applied on the fuel cell natural gas bill.
- *Renewable Energy:* Explore PPAs for rooftop and parking canopy solar. Investigate off site renewable energy.
- *Utility Incentives/ Develop Plan for EEMs:* Eastern should maximize incentive funding for EEMs by working with Eversource, and combining multiple energy saving opportunities in what is known as a "Comprehensive Project." Further analysis and collaboration with Eversource is required to determine rebate amounts for each opportunity.

A summary of further projects and priorities for the campus are listed in Table 2.5 While Eastern has the lowest energy use intensity of the CSCU Universities, there are still ample opportunities to capture savings, decrease energy use and increase energy reliability and sustainability.

4.1 CONTACT INFORMATION FOR KEY STAKEHOLDERS

Collecting all the necessary information for this planning effort required a collaborative effort. Below are the stakeholders that were active in providing their expertise about campus current conditions and future needs, and energy related decisions.

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APPENDIX A: EASTERN DATA, METHODOLOGY, ASSUMPTIONS AND NOTES

The following are the data methodology and assumptions that were used when analyzing and benchmarking data for Eastern:

Fiscal years 2013 and 2014 are the only complete years of data.

Electricity: Eversource Utility Bills (FY13,14), BAS Data (FY13,14,15), Website, and Fuel Cell Output Estimates

- Fuel cell output downloaded from the fuel cell website.
- There were discrepancies between the Eversource bills and BAS data. Buildings that appeared in both sources sometimes had drastically different electric consumption amounts. The reason behind the discrepancies was never determined. CL&P data was used.
- Facilities Warehouse's electrical consumption was only available for FY15 on the website. That value was copied into FY13, 14 as well.

Natural Gas: Eversource Online Data (FY13,14,15)

- Note: Noble Hall pilot light uses nearly as much fuel as boiler.

Fuel Oil: Dime Oil Utility Bills (FY13,14,15)

- Data from scans of bills were tabulated

APPENDIX B: EASTERN CONNECTICUT STATE UNIVERSITY (EASTERN) CHP SCREENING

INTRODUCTION

The intent of this assessment is to provide a high-level review of Eastern Connecticut State University (Eastern)'s North Heat Plant and the potential for a cogeneration/combined heat and power (CHP) application on campus. The resulting conclusions are based on monthly data review and discussion with campus plant personnel. The North Heat Plant would serve as the potential location for a CHP at the end of the existing fuel cell's useful life.

EXISTING INFRASTRUCTURE

The Eastern campus includes two separate Heat Plants identified as North Heat Plant and South Heat Plant. Two 18.5 MMBtu/h dual fuel (natural gas and fuel oil) fired boilers in the North Heat Plant provide heat energy required to support heating loads. North Heat Plant supports 22 campus buildings (approximately 72% of the square footage). The South Heat Plant supports 2 buildings (approximately 6% of the square footage) including Burr and Shafer Hall, although Shafer will no longer rely on the South Heat Plant due to construction. Eighteen buildings, which make up the remaining 22% of the campus' square footage, have local independent heating equipment. The campus does not have centralized cooling, instead features a mix of chilled water and direct expansion (DX) chillers.

In 2012, the campus commissioned a fuel cell operating behind the meter to offset electricity purchases. The fuel cell is located in the Science Center and operates in a baseload control configuration at 400 kW. In addition to electrical energy, the system generates low temperature and high temperature water used to support heating loads in the Science Center.

Note: At the time of the analysis, the 400 kW was in place. There are now plans to replace the unit with a 440 kW fuel cell.

Thermal: Medium temperature hot water is generated at the North Heat Plant for distribution to the connected buildings. As stated prior, cooling loads at the buildings meet via a mix of decentralized chilled water and direct expansion (DX) chillers. A centralized chilled water system has been evaluated and not found to be cost effective due to the significant construction that would need to be done to add cooling infrastructure to the existing underground tunnels. The minimum North Heat Plant thermal requirements in the shoulder seasons and summer months reduce the annual financial savings and may affect Renewable Energy Credit (REC) revenue eligibility associated with additional cogeneration capacity.

The South Heat Plant includes a steam boiler system to provide heat to the connected buildings. Buildings use either DX chillers in air handling units or have window air conditioning units for space cooling. This location has low potential for cogeneration due the limited heating and cooling supported by the South Heat Plant.

Electrical: A total of 33 electrical service entrances providing power from Eversource (formerly Connecticut Light & Power) were identified during the campus visit. It appears each building has a service entrance. Energy data presented on the Eastern energy dashboard indicates the electrical demand varied from approximately 1,150 kW to 2,250 kW on April 12, 2016.

The majority of the campus is served via a primary electrical service and onsite substation. Medium voltage power is distributed to each building from this location. Transformers are utilized at the building service entrances to provide the required voltage for equipment, light, and occupancy needs.

EXISTING CONSUMPTION

The campus baseline electrical energy and power used has been established through the review of the total monthly electrical energy as measured at the campus distribution substation. The data spans the period beginning July 2014 through June 2015. Figure A illustrates the total site electrical energy usage per month. Summarizing the data in this manner provides a simple means to understand that total monthly variations are due to campus occupancy.

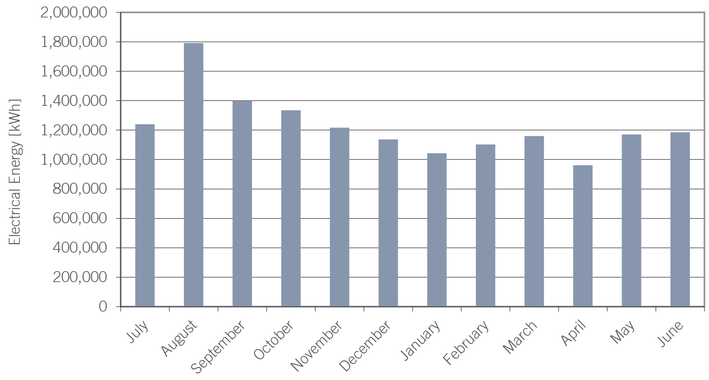

FIGURE A: FY 2014 Substation Electrical Energy

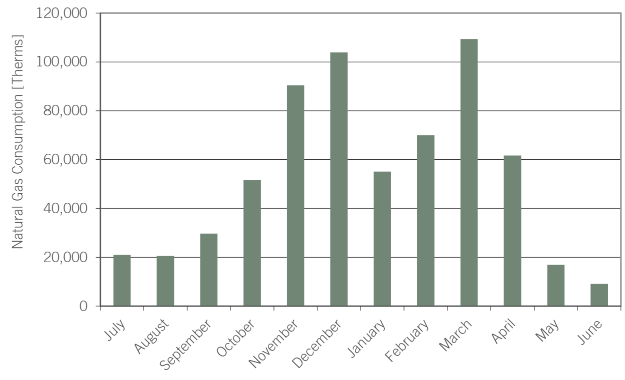

FIGURE B: FY 2014 North Heat Plant Natural Gas Consumption

The North Heat Plant provides the largest amount of thermal heat on the campus and is targeted as the best opportunity to offset boiler use. Figure B provides the Fiscal Year 2014 monthly natural gas consumption of the North Heat Plant.

OPPORTUNITY, CONCLUSIONS AND NEXT STEPS

The thermal and electric loads at Eastern indicate a moderate CHP potential for additional cogeneration. However, the effectiveness of the system without the need for heat year round reduces the efficiency of the system if oversized beyond the minimum thermal load. Thermally driven (absorption) chillers can increase the summer heat load, but without a chiller loop on campus this is an unlikely scenario. It is recommended that electrical and thermal data continue to be collected for future cogeneration analysis. New onsite generation should be evaluated at the end of the existing 400kW fuel cell's cost effective life.

6.15

SOUTHERN CONNECTICUT STATE UNIVERSITY

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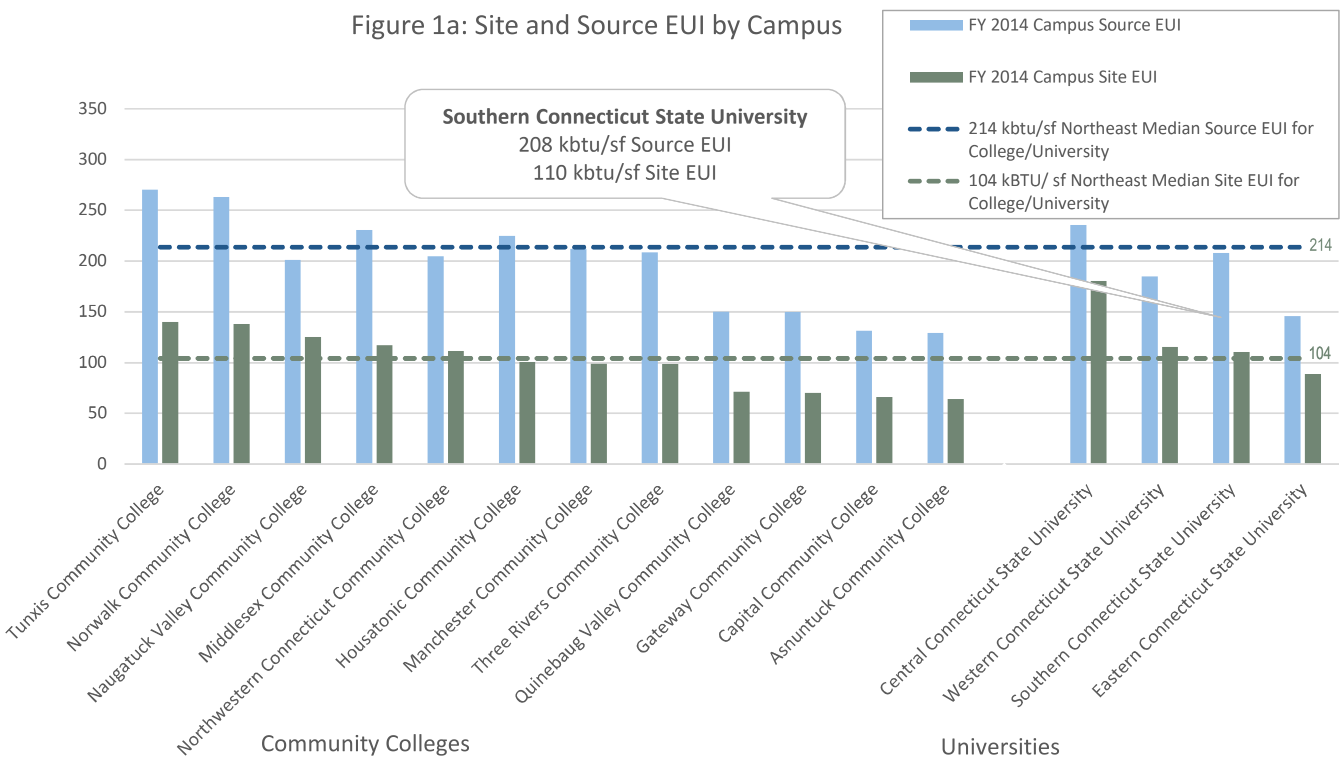
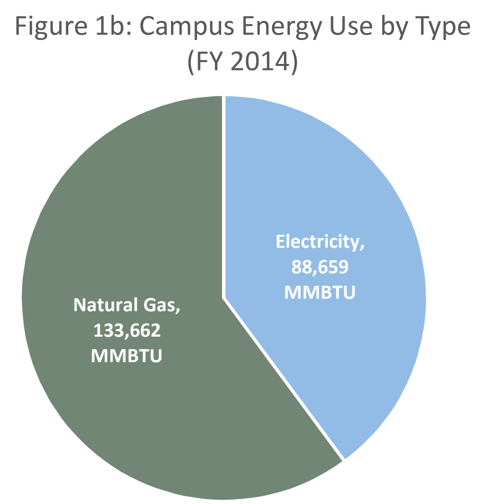
EXECUTIVE SUMMARY

The Southern Connecticut State University (Southern) Energy Master Plan aims to identify ways Southern can improve energy use on campus, and be an active participant in Connecticut State Colleges and Universities (CSCU)'s energy management, reduction and conservation efforts. Southern adopted a Climate Action Plan in 2009, exemplifying its commitment to energy conservation and sustainability. The campus completed a number of significant energy projects to date including retrocommissioning, multiple lighting re-lamping and re-ballasting and other energy conservation projects. Based on the utility data, Southern has the second smallest site energy use intensity of the CSCU universities, at 110 kbtu/sq ft. (see Figure 1 Southern Energy Dashboard). The energy use intensity (EUI) method is used for benchmarking and comparison purposes.





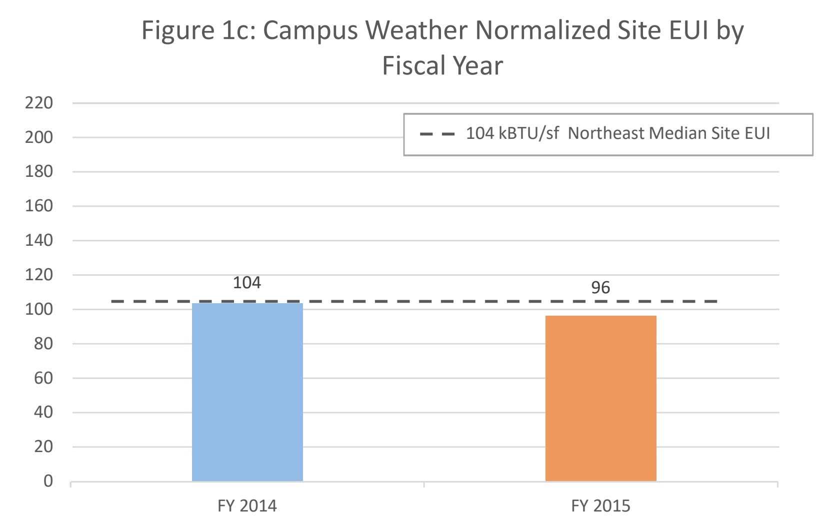


FIGURE 1: Southern Connecticut State University Energy Dashboard

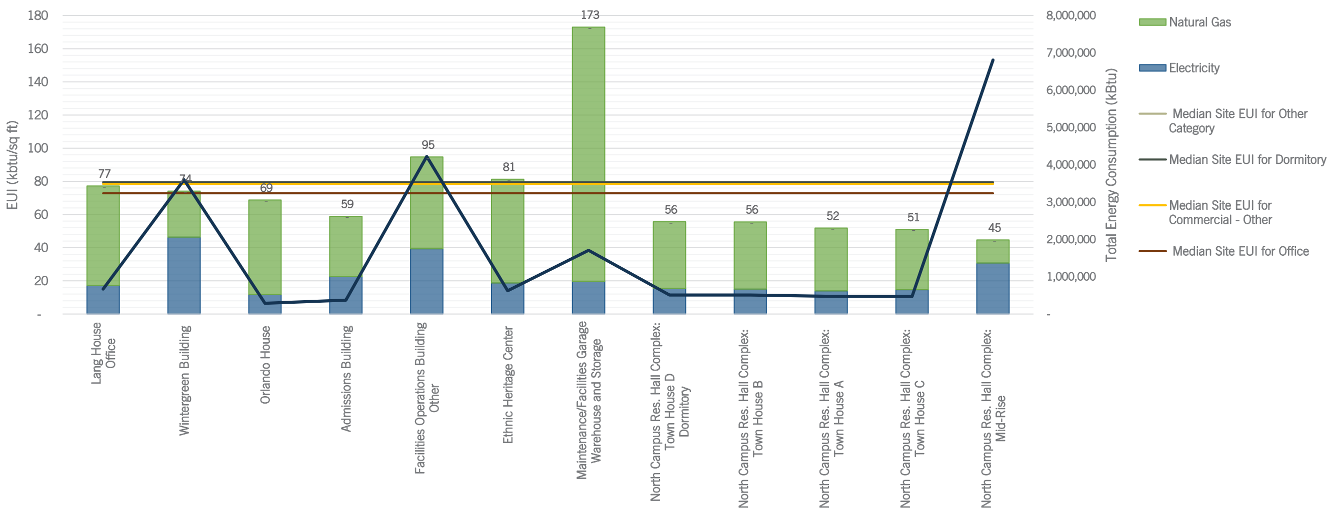


FIGURE 2: Site EUI by Building (FY 2014)

Only buildings with both electricity and fuel submetering data are shown; Southern's many buildings with unmetered steam and hot water heating distribution systems are not shown in the building level EUI figure.

Energy Spending

Table 1 provides a comparison of energy spending compared to the average of CSCU campuses and the Northeast Region Commercial Sector.

	Southern Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 2.23	$ 2.08	$ 2.49	$ 1.67
Cost per FTE Student	$ 522	$ 677.00	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.14	$ 0.14	$ 0.14	$ 0.15
Avg. Cost per MMBtu Natural Gas	$ 7.23	$ 7.32	$ 10.06	$ 10.03
Total Operating Expenses	$ 215,469,423	$ -	$ -	
Total Energy Spending	$ 4,611,016	$ -	$ -	
% of Operating Expenses	2.14%	2.67%	1.95%	

TABLE 1: Energy Cost Comparison (FY 2014)

Most of Southern's data are consistent with or below the average of the CSCU campuses, while natural gas unit costs are above the average CSCU universities unit cost. A pertinent measurement of energy intensity is cost per square foot; Southern spent less per square foot in FY14 than the average of the CSCU universities. The cost per FTE is above the average of the CSCU campuses. This may be attributed in part to Southern's expansive campus, as well as having buildings, such as residence halls, with longer operational schedules than academic or administrative buildings.

Utility Incentives/ Develop Plan for Energy Efficiency Measures (EEMs)

Both of Southern' s utilities are through United Illuminating (UI). This places the campus in a prime position to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project."

Since incentives are based on incremental energy savings, further analysis and collaboration with UI is required to determine rebate amounts for each opportunity. Table 2 demonstrates a summary of the Energy Efficiency Measures (EEMs) recommended for Southern to pursue.

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
SCSU-1	Implement a steam trap maintenance program.	East Campus	$15 / trap surveyed + repair costs	<1 - 2	1
SCSU-2	Continue recommissioning (in progress).	All	$0.50 - $3.50 /sf ($60k for continuous Cx)[1]	Varies	1
SCSU-3	Optimize BAS with Continuous Cx practices.	All	$20k/ 100k sf / year	Varies	
SCSU-4	Consolidate course offerings to certain buildings to reduce energy consumption at times of lower occupancy (in progress).	All	Varies	Varies	
SCSU-5	Explore use of BAS for capacity charge and demand response management.	All	Administration Time	2016-2017 estimated savings of $9.86/kW-month	
SCSU-6	Implement fume hood sash management as a part of a fume hood sash management campaign with goal to instill an energy efficient culture.	Various	Minimal	Varies	1
SCSU-7	Install variable speed drive for control of fume hoods in Science Labs. Also explore adding heat recovery coils if used frequently.	All	Varies	2 - 5	1
SCSU-8	Install variable speed drives. Fund with UI rebate program (in progress).	All	Varies	2 - 5	1
SCSU-9	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations, in addition to pending PPA for the Lot 9 PV array. Also investigate ground mount and additional solar canopies.	All	PPA	PPA	1
SCSU-10	Enable trending of energy data through BAS for future benchmarking and EEM savings estimates. Store at least 2-years' worth of data in 15-minute increments.	All	Varies	Varies	1
SCSU-11	Convert 1500-watt metal halide fixtures to LEDs.	Jess Dow Field	Varies	Varies	1
SCSU-12	Creation of an internal policy to promote lighting through motion sensors.	All	Administration time	Minimal	1
SCSU-13	Replace existing lighting with LED.	Pelz Gymnasium	Varies	2 - 6	1
SCSU-14	Change 250-watt metal halide fixtures in LED.	Earl Hall	Varies	2 - 6	1
SCSU-15	Replace existing fixtures with LED in lecture spaces.	Davis Hall	Varies	2 - 6	1
SCSU-16	Increase occupancy based lighting (and ventilation) controls.	Campus	Varies	Varies	2
SCSU-17	Focus energy efficiency projects on buildings with a high EUI and a high total energy consumption.	All	Varies	Varies	2
SCSU-18	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops and garages.	Maintenance/Facilities Garage	Varies	3 - 6	2
SCSU-19	Add insulation around HTHW valves and fittings.	Connecticut Hall	Varies	1 - 2	2

SCSU-20	Explore or conduct a further study for a 600 kW Internal Combustion CHP engine at the Energy Center, near 600 kW. The system should be sized for year-round operation, and may possibly include a thermal buffer tank. The campus should also explore capturing additional benefits from CHP like reduced natural gas pricing with the LDC waiver. [1]	Energy Center	Varies, $3k - $4k per installed kW capacity	Varies	2
SCSU-21	Upgrade mechanical systems upgrade, including an AHU replacement	Lyman Center for the Performing Arts, Davis Hall	Varies	Varies	2
SCSU-22	Replace all 7 AC units with more efficient models.	Moore Field House	Varies	Varies	2
SCSU-23	Complete a mechanical and electrical systems upgrade, dependent on Master Plan and fate of the building.	Pelz Gymnasium	Varies	Varies	2
SCSU-24	Straightlines: Complete an electrical systems upgrade and a mechanical systems upgrade and piping for AC	Campus	Varies	Varies	2
SCSU-25	North campus mechanical upgrade w/ wireless BAS controls.	North Campus	Varies	Varies	2
SCSU-26	Add ventilation heat recovery for art spaces with high operating hours.	Various	$2 per CFM of capacity	Varies	3
SCSU-27	Connect new buildings to west campus loop (previously recommended).	Future	Varies	Varies	3
SCSU-28	Preheat DHW using condensate return from steam loop.	East Campus	Varies	Varies	3
SCSU-29	Explore ~150 kW backpressure turbine after steam generator on East Steam Loop and connect extra 40 MMBtu Boiler at Energy Center.	East Steam Loop	Varies	Varies	3
SCSU-30	Install Heat Recovery Ventilator (HRV) for pool ventilation and dehumidification, if pool continues to be used (Pelz Gymnasium may be taken offline).	Pelz Gymnasium	$2 per CFM of capacity	Varies	3
SCSU-31	Install condensing economizer on central heating plant boilers and supply low temperature hot water to nearby or new buildings.	Energy Center	$350,000, N.I. demand side modifications	9-10 based on UC Davis and JAX studies	3
SCSU-32	Increase HVAC zoning and/or add individual room controls to BAS.	Various	Varies	Varies	3
SCSU-33	Replace older cooling equipment, especially those greater than twenty years old. Consider replacing DX units with new variable speed compressor units or installing a central water cooled chiller plant when infrastructure permits.	Various	Varies	Varies	3
SCSU-34	Upgrade building envelope including window replacements	Earl Hall	Varies	Varies	3

TABLE 2: Southern Energy Efficiency Measures

In addition to the suggested EEMs, next steps for Southern are below:

Next Steps

Management

Southern maintains a cross-department energy management effort, including working with administration to control summer programs and space use. The campus can expand this effort by working with residence advisors and other on campus groups to educate about the importance of energy management. Southern should continue to monitor building level energy use, including tracking energy use and comparing energy spend to available budgets. The campus should also expand training and staffing capabilities for increased management of BAS controls and advance existing building recommissioning plans and policies. Southern should also focus on managing demand costs on campus, including informing students and faculty of the benefits of curbed consumption during peak times.

Renewable Energy

Southern should continue to explore work with CSCU to implement Power Purchase Agreements (PPAs) for rooftop solar and/or ground mounted arrays. CSCU has received favorable pricing for PPA projects with possible discounts on the order of 20% to 50% of purchased power costs. Solar PV should also be incorporated into future capital planning building design. Southern should also continue to strategically plan for solar locations based on meter sizing and application into the Connecticut Zero Emissions Renewable Energy Credit (ZREC) programs.

Alternative Energy

Southern should further explore the addition of Internal Combustion CHP engine at the Energy Center. A unit sized for year-round operation is suggested, near 600 kW, with the final size and feasibility based on further study. The addition of a CHP unit would also assist with reducing peak demand in the summer months.

By implementing the recommendations of the Energy Master Plan, Southern has the opportunity to create local and cost-effective power through solar PV, increase energy efficiency operations, and continue to manage energy as the campus evolves in the future.

INTRODUCTION

As part of the Connecticut State Colleges & Universities (CSCU) Energy Master Plan, Southern Connecticut State University (Southern)'s building infrastructure, energy use and energy management practices were assessed. The ultimate goal was to determine ways Southern could improve its energy use on campus, and be an active participant in CSCU energy reduction efforts. This chapter identifies Southern's historical energy use, future projected needs and energy recommendations.

FIGURE 1.1: Southern Buley Library

1.1 SOUTHERN OVERVIEW

Southern is one of four state universities in the Connecticut State Colleges and Universities, located in the City of New Haven, Connecticut (New Haven County), at 501 Crescent Street. In the fall of 2015, Southern enrolled 10,473 students (8,106 undergraduate and 2,367 graduate students)[1], 440 full-time faculty members and an additional 512 part-time lecturers.[2] The campus has 2,617 students in on-campus housing, which represents 38% of the student body.[3]

Southern consists of three campuses- East Campus, West Campus, and North Campus. The three campuses are all connected and situated along Fitch Street (Route 10), Crescent Street, Wintergreen Avenue, Farnham Avenue, and Pine Rock Avenue. Southern is comprised of a total of 171 acres featuring 13 residence halls, an art center, a student center, a central dining hall, a library, an athletic complex, and 21 other administrative and classroom buildings. The campus also features sports fields, 12 main parking lots, and 3 parking garages. Many of Southern's building's hot water and heating needs are supported by the Energy Center on North Campus.

Table 1.1 summarizes the list of existing buildings on the East, West, and North campuses.

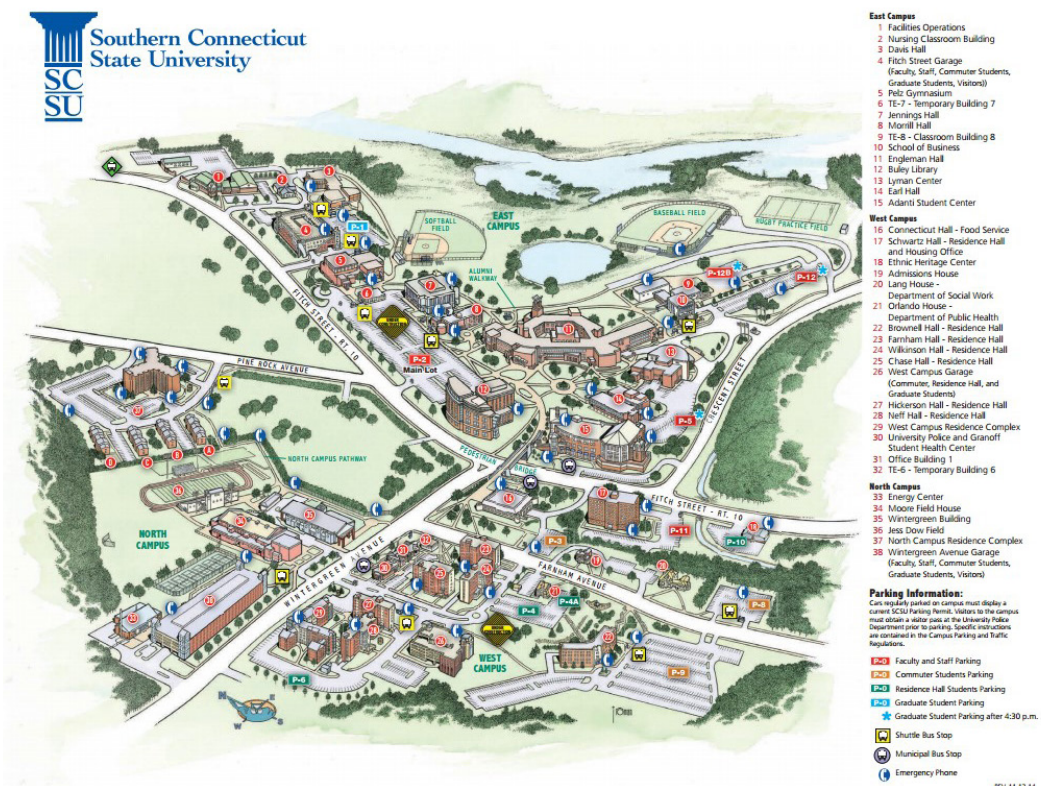


FIGURE 1.2: Southern Campus Map

[1] Southern Connecticut State University. "Fall 2015 Enrollment Information." Web. 10 February 2016. http://www.southernct.edu/offices/management/currentenrollment.html
[2] Southern Connecticut State University "Part-Time Faculty Headcount &FTE by Year." Web. 10 February 2016. http://factbook.southernct.edu/faculty_part_time_headcount_fte_fall.html
[3] Southern Connecticut State University "Campus Housing by Year." Web. 10 February 2016. http://factbook.southernct.edu/campus_housing_fall.html

Campus	Building	Year Built [Renovated]	Gross Square Feet	Building Function
East Campus	Academic Laboratory and Science Building*	2015	103,608	Academic with labs
East Campus	Buley Library	1968 [2015]	249,412	Academic
East Campus	Davis Hall	1969 [1998]	49,614	Academic
East Campus	Earl Hall	1960 [1992]	46,027	Academic
East Campus	Engleman Hall	1953 [2004]	224,599	Academic
East Campus	Facilities Operations Building	2000	44,609	Facilities
East Campus	Jennings Hall	1982	130,026	Academic
East Campus	Lyman Center for the Performing Arts	1967 [1994]	53,058	Academic/Arts
East Campus	Maintenance/Facilities Garage	2000	9,855	Facilities
East Campus	Michael J. Adanti Student Center	2006	129,607	Mixed Use
East Campus	Morrill Hall	1959 [1990]	42,050	Academic
East Campus	Nursing Building	2005	5,000	Academic
East Campus	Pelz Gymnasium (including Pelz Storage Building)	1952 [1993]	71,211	Athletic
East Campus	Student Center (School of Business)	1958 [1959]	100,293	Academic
East Campus	Temporary Bookstore (TE-8)	2001 [2006]	4,961	Other
West Campus	Admissions Building	1900 [1997]	6,299	Office/Administration
West Campus	Connecticut Hall	1973 [1994]	45,569	Dining
West Campus	Ethnic Heritage Center	1970	7,690	Office/Administration
West Campus	Granoff Hall/Police Station/Health Services	1972 [1995]	10,874	Police Building
West Campus	Lang House	1903 [1993]	8,661	Office/Administration
West Campus	Office Building 1 (OB1)	2006	12,000	Office/Administration
West Campus	Orlando House	1890	4,188	Office/Administration
West Campus	Temporary Office Building 6 (TE-6)	2001	6,128	Academic
North Campus	Energy Center	2003	16,580	Facilities
North Campus	Moore Field House	1976 [1996]	145,992	Athletic
North Campus	Wintergreen Building	1994	48,551	Office/Administration
North Campus	Jess Dow Field	1991	1,346	Athletic
Subtotal			1,577,808	
Residential Buildings				
West Campus	Brownell Hall	1982 [1998]	67,157	Residence Hall
West Campus	Chase Hall	1967 [1998]	59,266	Residence Hall
West Campus	Farnham Hall	1964 [1995]	57,047	Residence Hall
West Campus	Hickerson Hall	1967 [1996]	59,266	Residence Hall
West Campus	Neff Hall	1969 [1996]	48,150	Residence Hall
West Campus	Schwartz Hall	1957 [1995]	22,973	Residence Hall
West Campus	West Campus Residence Complex	2004	112,722	Residence Hall
West Campus	Wilkinson Hall	1965 [1998]	63,828	Residence Hall
North Campus	North Campus Res. Hall Complex: Mid-Rise	1985 [1992]	152,517	Residence Hall
North Campus	North Campus Res. Hall Complex: Town House A	1991 [1992]	9,165	Residence Hall
North Campus	North Campus Res. Hall Complex: Town House B	1991 [1992]	9,165	Residence Hall
North Campus	North Campus Res. Hall Complex: Town House C	1991 [1992]	9,165	Residence Hall
North Campus	North Campus Res. Hall Complex: Town House D	1991 [1992]	9,165	Residence Hall
Residence Hall Subtotal			679,586	
Building Total GSF			**2,257,394**	
Garages				
East Campus	Fitch Street Parking Garage	2000	193,605	Parking Garage
West Campus	West Campus Parking Garage	2004	148,098	Parking Garage
North Campus	Wintergreen Parking Garage	2013	355,172	Parking Garage
Parking Garage Subtotal			696,875	

TABLE 1.1: Southern Campus Building Information

1.2 PREVIOUS ENERGY STUDIES & PROJECTS

Southern takes pride in its campus sustainability efforts and commitment to achieve carbon neutrality by or before 2050. In 2008, Southern signed the Second Nature Climate Leadership Commitment. The program now includes a pledge for climate resilience planning and implementation, which Southern signed. According to the campus, by implementing energy projects, primarily related to switching from fuel oil to natural gas, has led to overall greenhouse gas emission reductions of 1.5%. The reductions occurred even considering a significant increase in gross square feet of additional building expansions. The campus is working on an interim 2020 goal of 20% reduction below 2007-09 baseline in scope 1 and 2 greenhouse gas emissions, aided by plans for onsite solar power.

Southern received the Sustainable Endowments Institute (SEI) and Green Revolving Investment Tracking System (GRITS) first place award for the recommissioning of Adanti Student Center in 2015. Adanti Student Center was awarded for the highest average annual energy savings in a single project for a mid-sized institution. Southern was also nominated for the EBie Award by U.S. Green Building Council for the Adanti recommissioning effort.

Southern has also received recognition for its energy efforts. In 2015, the Princeton Review recognized Southern as one of 332 most environmentally responsible colleges and the University earned statewide recognition when it received the Power of Change Top Building Innovation Award. The new award recognizes state energy efficiency projects, and Southern was among seven awardees. Southern earned the award for its efforts to reduce electricity in nine residence halls during a nationwide electricity and water reduction competition, the College Conservation Nationals (CCN) .

To achieve climate action goals, strategic goals and to recognize savings from utility energy consumption, Southern has completed multiple energy projects and initiatives. The list below provides examples of completed and ongoing projects. Appendix B presents a list of the additional numerous lighting upgrades and residence hall conservation efforts.

CHP

Description: Performance Cogeneration study
Year: 2015
Associated Building: All

SOLAR

Description: Feasibility study for onsite solar through United Illuminating's Business Sustainability Challenge.
Year: 2015
Associated Building: All

Description: RFP for 1 MW solar on campus
Year: In Progress
Associated Building: All

BAS/BMS

Description: Implementation of BAS setbacks for night temperature, lighting based on occupancy schedules and with building HVAC.
Year: Ongoing
Associated Building: All

Description: Optimize BAS
Year: In Progress
Associated Building: All

CAPITAL PLANNING / STRATEGIC

Description: Pursuing incorporating revolving utility rebates into energy projects to accelerate efficiency on campus.
Year: Ongoing
Associated Building: All

Description: Efforts to reduce peak demand
Year: Ongoing
Associated Building: All

Description: Interior renovations
Year: 2015
Associated Building: Wintergreen Building

Description: Completed building renovations
Year: 2012
Associated Building: Farnham Hall

RETROCOMMISSIONING

Description: Ameresco recommissioning projects and reports for optimizing building controls; Recommissioning effort for entire campus
Year: Ongoing
Associated Building: All

Description: Recommissioned building equipment
Year: 2015
Associated Building: Engleman Hall

Description: Recommissioned building equipment
Year: 2014
Associated Building: Adanti Student Center

RENEWABLE ENERGY

Description: Instal solar PV
Year: Planned/Future
Associated Building: All

ENERGY CONSERVATION

Description: Consolidate course offerings to certain buildings to reduce energy consumption at times of lower occupancy.
Year: In Progress
Associated Building: All

Description: Installed low flow showerheads.
Year: 2014
Associated Building: Brownell Hall

Description: Purchased Energy Star rated appliances.

HVAC AIR SIDE

Description: Install variable speed drives.
Year: In Progress

LIGHTING

Description: Replace existing lighting with LEDs.
Year: In Progress
Associated Building: North Campus Res. Hall
Schwartz Hall
Neff Hall
Remaining Parking Garages
Classrooms and Exterior Lighting

Description: Replace existing lighting with LEDs.
Year: 2013
Associated Building: Energy Center

Description: Replace existing lighting with LEDs.
Associated Building: Wintergreen Parking Garage
West Campus Residential Complex

Description: Installed CDM and LED lighting
Associated Building: West Campus Parking Garage

Description: Installed T5 fluorescent bulbs, induction lighting, and LEDs
Associated Building: Pelz Gymnasium

Description: Upgraded lighting
Associated Building: Adanti Student Center

Description: Installed T-5 fluorescent bulbs with sensors
Year: 2014
Associated Building: Moore Field House

CHILLER SYSTEMS

Description: Installed new chiller
Year: 2016
Associated Building: Student Center (School of Business)

Description: Installed new chiller
Year: 2014
Associated Building: Lyman Center for the Performing Arts

LEED

Description: LEED gold/silver certification
Year: 2015
Associated Building: Academic Laboratory and Science Building

Description: LEED gold/silver certification
Year: 2012
Associated Building: Schwartz Hall

BUILDING ENVELOPE

Description: Roof replacement
Year: 2015
Associated Building: Lang House

Description: Roof Replacement
Year: 2014
Associated Building: Moore Field House

OTHER

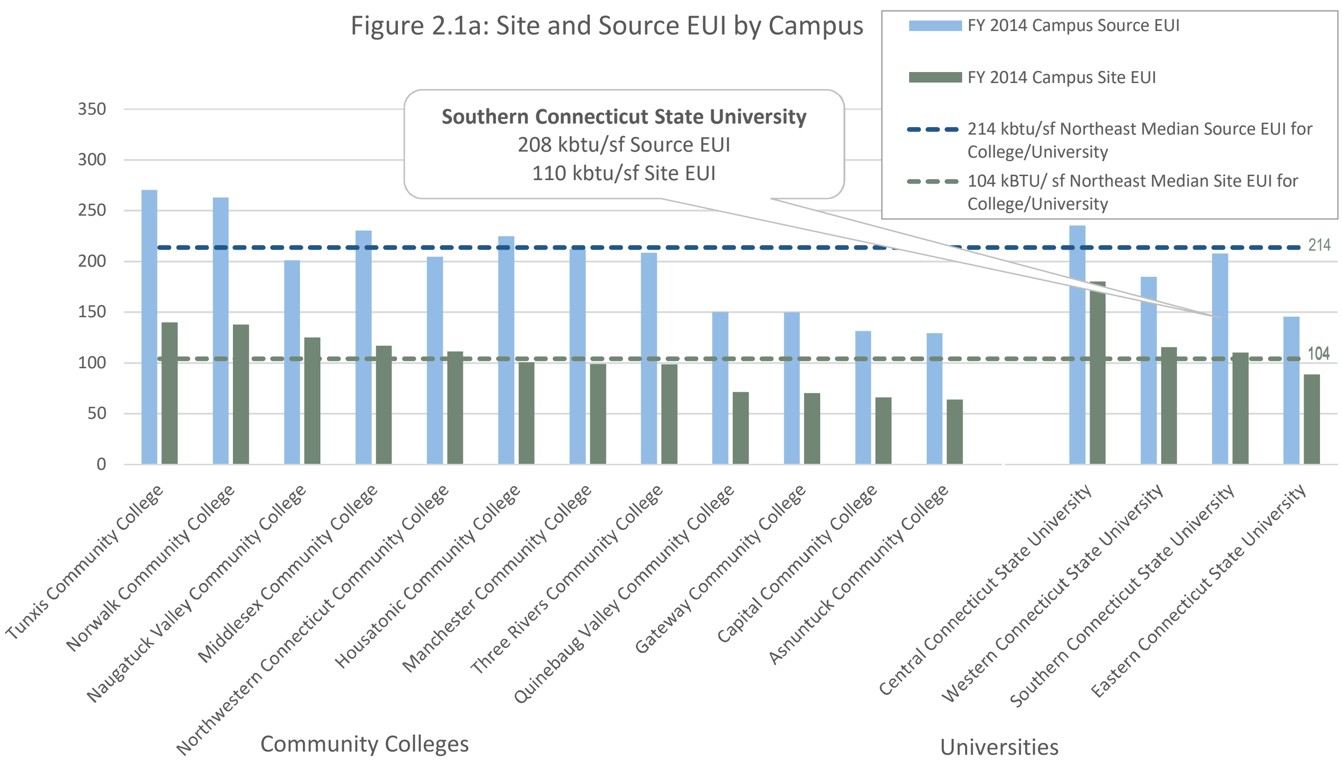
Description: Upgraded electrical systems
Year: 2012
Associated Building: Jennings Hall

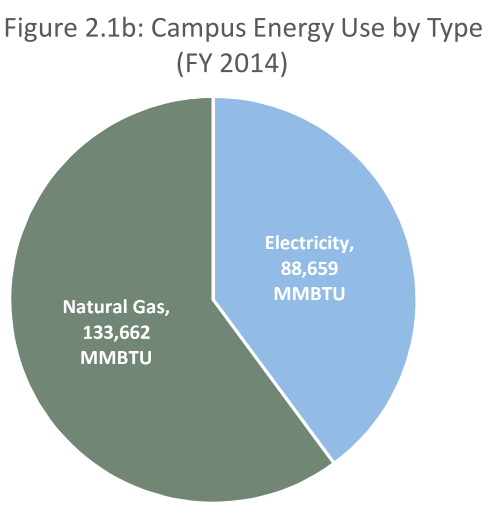
EXISTING CONDITIONS & RECOMMENDATIONS

Information on Southern's existing conditions was captured from campus interviews, energy data and reports provided by the campus. A holistic view of existing practices, material on energy management, energy infrastructure and project implementation processes was reviewed. Analysis of the data and campus walkthroughs helped clarify recommendations with the goal of decreasing energy use, documented after each subheading.

2.1 FACILITY ENERGY BENCHMARKING AND ENERGY CONSUMPTION

A summary of Southern's energy use is shown in the energy dashboard, based on fiscal year 2014 and 2015 data. Appendix A documents information on the assumptions and data sources used for energy benchmarking purposes. Southern has the second smallest site energy use intensity of the CSCU universities, at 110 kbtu/sq ft.





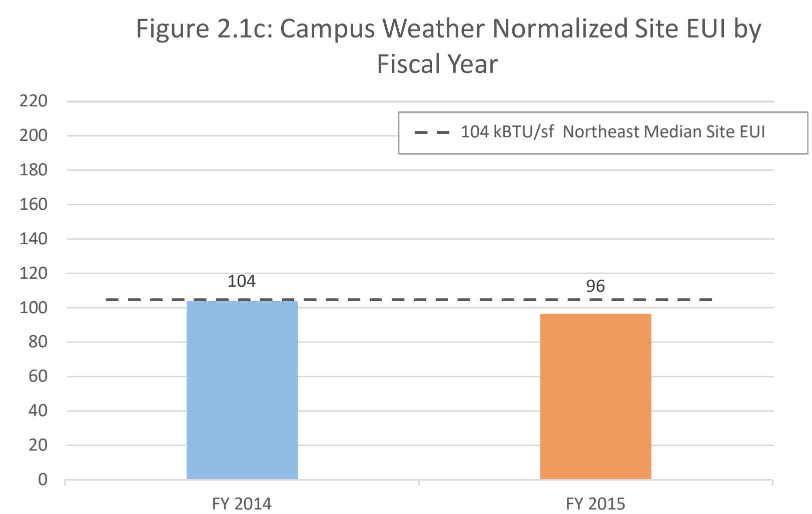


FIGURE 2.1: Southern Connecticut State University Energy Dashboard

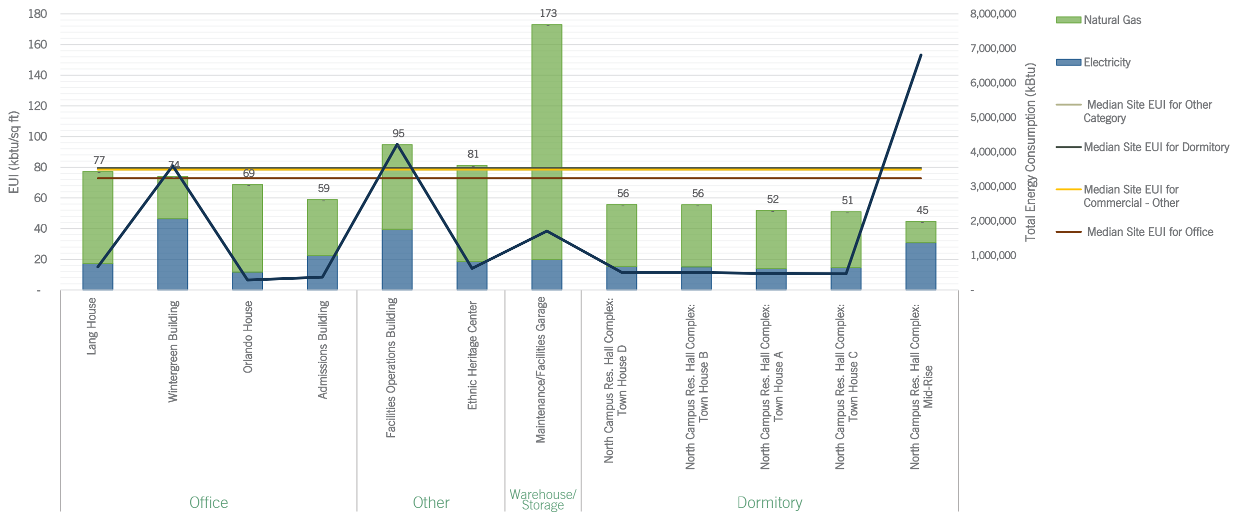


FIGURE 2.2: Site EUI by Building (FY 2014)

The ability to accurately measure energy use intensity (EUI) is dependent on the granularity of building level data. While there are natural gas accounts for a large portion of the buildings, the EUI does not include steam or high temperature hot water (HTHW) from the Energy Center. The buildings in Figure 2.2 represent the buildings that use natural gas and electricity only and are not heated by the Energy Center. The buildings are grouped by category to compare against the Northeast median average site EUIs for buildings of the same type. Particularly in the dormitory category, Southern is far below the median average. The campus has made significant efforts to reduce energy in the residence halls which is reflected by the FY14 data.

The purple line represents the total energy use for the building over FY 14, and can be compared to the site EUI. Buildings such as the Wintergreen Building and Facilities Operations have a higher kBtu/year value and are above the Northeast median average for the category, and therefore would be relevant areas of focus. For the Wintergreen Building, most of the site EUI is attributed to electricity; energy updates related to lighting and increased efficiency of electric equipment would contribute to the lowering of the EUI and decrease overall energy use. An obvious outlier is the Maintenance Facilities Building which has a natural gas EUI of 152 which is more than double the EUIs of other buildings using natural gas. A large energy user with a low EUI is the Mid-Rise Residence Hall.

While there was not adequate data to definitively depict each building's EUI, based on existing available natural gas and electric EUIs, more than 50% of the buildings have natural gas which comprises the majority of the EUI. Opportunities to reduce natural gas use may be targeted, such as through building envelope upgrades that will decrease space heating needs and more efficient heating equipment. Focus should be attributed to buildings that have a higher energy use as well as a high EUI.

Table 2.1 provides a comparison of FY 2014 energy spending compared to the average of CSCU campuses and the Northeast Region Commercial Sector.

Southern spends less than the average CSCU Universities per square foot, suggesting lower energy use overall, since unit costs are greater or equal to the average. Southern also spends a smaller percent of its total operating expenses on energy than the CSCU universities on average.

	Southern Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 2.23	$ 2.08	$ 2.49	$ 1.67
Cost per FTE Student	$ 522	$ 677.00	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.14	$ 0.14	$ 0.14	$ 0.15
Avg. Cost per MMBtu Natural Gas	$ 7.23	$ 7.32	$ 10.06	$ 10.03
Total Operating Expenses	$ 215,469,423	$ -	$ -	
Total Energy Spending	$ 4,611,016	$ -	$ -	
% of Operating Expenses	2.14%	2.67%	1.95%	

TABLE 2.1: Energy Cost Comparison (FY 2014)

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - http://www.eia.gov/electricity/monthly/current_year/june2014.pdf
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm

DRAFT

2.2 CAMPUS UTILITIES AND DISTRIBUTION

As shown in Figure 2b, Southern's two sources of energy are electricity and natural gas. In FY 14, natural gas comprised 60% of total energy use. Southern's utility providers and relevant distribution information include:

Electricity

Buildings are fed electricity through three main avenues: the campus utility, United Illuminating (UI), and through the West Campus distribution Loop or through the East Campus distribution loop. The East Campus switchgear originates on Crescent Street and feeds 11 buildings, and the West Campus loop switch gear is located in the Energy Center providing energy to 14 buildings. The remaining 13 buildings are direct from UI.

Note: Only buildings analyzed for EUI benchmarking are summarized; for instance, Wintergreen Parking Garage which is fed by the West Campus Loop is not factored.

Natural Gas

United Illuminating Holdings (UIL), formerly Southern Connecticut Gas, provides natural gas to the campus. Most natural gas use is provided to the Energy Center for distribution as HTHW, which is converted to steam at the building level for domestic hot water and space heating.

Table 2.2 provides a summary of Southern's available building submetering.

	Electricity	Natural Gas
Total Number of Buildings Consuming Energy Type	38	38
Number of Building with Accounts	13	27
Number of Building Submetered or on an Individual Account	38	27
Percent of Buildings with Building Level Data	100%	71%

TABLE 2.2: Southern Submetering by Energy Type

2.3 ENERGY PROCUREMENT

Southern is part of CSCU's 2013 electric supply procurement contract with Direct Energy (formerly Hess Energy), presented further in the Energy Master Plan. In FY13 and FY 14 Direct Energy was also the natural gas supplier, but the local distribution company (LDC) UI became Southern's supplier in FY14.

2.4 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

Facilities Operations (Facilities) at Southern is largely responsible for the energy-related efforts on campus. Responsibilities range from incorporation of energy efficient design in capital planning, to daily operation of building systems and energy monitoring.

Scheduling

The campus remains widely used throughout the summer for classes, programs, and staff. Moreover, the highest electrical demand month is in August when cooling requirements are at a peak. Southern has been aware of the long term price effects of the high demand in August and has spread awareness and implemented classroom consolidation practices. Southern recently received support from administration to execute scheduling changes during the summer months. Some examples per a May 19, 2016 announcement from the Provost and Vice President for Academic Affairs are:

- The Temporary Bookstore TE-8 will be off line all Summer (there are no bathroom facilities and no offices in the building).
- 3rd Floor of Engleman Hall will be shut down for the month of August.
- Pelz Gymnasium classrooms will be shut down June 26th through August 25th.
- Morrill Hall classrooms shut down August 1st through August 28th.

ENERGY USE INFORMATION MANAGEMENT SYSTEMS

Automated Logic is used as the energy management software (EMS). There is viewer access to Energy Reports (Automated Logic building energy analytics). However, only limited historical data is logged and stored for reference while viewing the system. Only the past 24 hours of information appeared to be readily available. As part of an Ameresco contract, detailed in Section 2.5, Southern also has access to data for 17 buildings on campus. The software provides dynamic trending related to year over year energy use, energy per square foot and other useful comparison parameters.

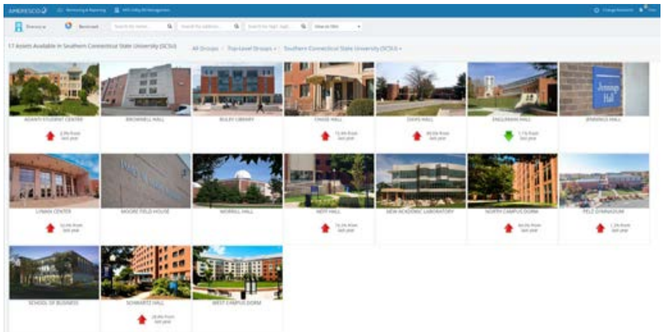


Figure 2.3: Ameresco Building Analytics Dashboard

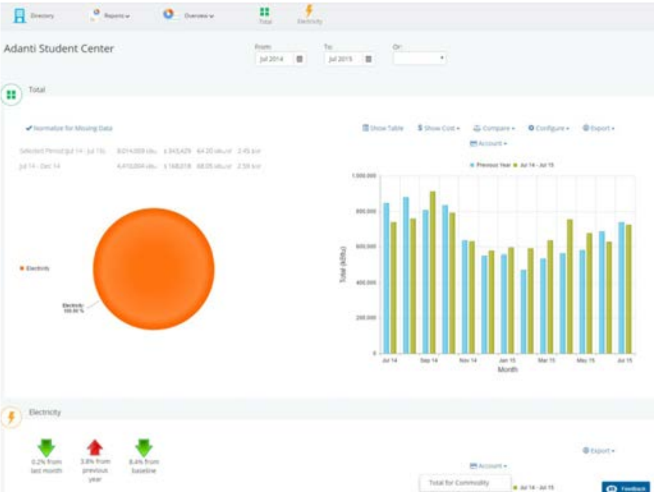


FIGURE 2.4: Building Analytics Available for Adanti Student Center

At current staff levels, time demands related to keeping existing equipment operational prevent Southern from taking full advantage of potential energy savings.

2.4.2 RECOMMENDATIONS

As part of the CSCU Energy Master Plan recommendations in Section 5.2.2, it is recommended that the System Office create a template for energy tracking applicable to all campuses. Southern should use this template to track energy over time including monitoring weather normalized EUI over time, and associated costs compared to existing budgets.

The following are recommendations for Southern to expand its energy management practices:

- Continue to work with administration to control and administer summer programs and space use
- Continue to take measures to consolidate building use to the most efficient spaces during summer break, and spread awareness of the effect of energy use on campus budgets and in pursuit of increased sustainability.

    a. Involve residence advisors and other campus student leaders to educate the community on the importance of building consolidations

- Advance building recommissioning plans and policies.
- Work with CSCU to develop temperature set point guideline based on seasonal and specific zone indoor air quality (IAQ) conditions
- Expand training and staffing capabilities for management of BAS controls, particularly related to any new technological improvements of the BAS over time. This may include using a third party to supplement their staffing levels, or working with existing staff members to expand training.

2.5 EXISTING BUILDING COMMISSIONING

2.5.1 CURRENT CONDITIONS

Southern has implemented existing building commissioning practices with Seldera, an Ameresco® company. Building Dynamics monitoring based commissioning services for the Adanti Student Center were implemented in January 2014. A snapshot of the project case study indicates the project was highly successful.

Project Overview

- 2,490,455 kWh average annual electricity consumption with a cost of $463,234
- 4–month payback

Building Overview

- 125,000 square feet
- Construction completed in 2006
- Building used 24/7 for different activities: restaurants, computer rooms, gym, radio station, classrooms, offices, ballroom, theater, recreational spaces
- State-of-the art Automated Logic BAS

Project Results

- Operational changes implemented in January 2014
- Consumption reduced by 208,035 kWh (17.3%) or $38,695 from baseline during the first 6 months of the project
- When accounting for weather, consumption has dropped by more than 303,766 kWh (23.5%) or $56,500

FIGURE 2.5: Image from SELDERA Case Study (2014)

Engleman Hall was part of the recommissioning efforts. Examples of findings and recommendations, with respect to air handling unit (AHUs) operations included :

1. AHU-1 operates 24/7 without setbacks for any parameter

2. Hot water valve seems to stay at fixed (fully open or fully closed) position

3. Fan coil units (FCUs) are scheduled to start too early at 4:00 AM for most of them.

> **a.** An Optimum Start / Stop BAS program was recommended

4. Whole building load profiles indicate that a large part of daily maximum electric load is still ON at night (~300 kW out of 420 kW maximum).

> **a.** Consider opportunities to decrease night-time load when ALL FCUs are OFF

5. Chilled Water System operates with negligible chilled water delta T –

> **a.** Maximize use of airside economizer and / or optimizing the chilled water flow to maintain at least 10 degrees delta-T.

6. Interlock Chilled Water Pumps and Condenser Water Pumps operation

7. Verify necessity of running two hot water pumps and two condenser water pumps in parallel

The following observations were made with respect to Primary Systems Performance:

1. Chilled Water System operates 24/7 (alternating two chilled water pumps), even if AHUs are OFF at nights and on most of weekends

2. Both chilled water pumps are equipped with VFDs, but maintain constant speed not modulating flow in accordance with load

3. Hot Water System runs in parallel with chilled water system, operating at least one pump at a time

4. The strategy of complementing lead hot water pump with another (lag) pump is not clear – it looks like a second pump was activated without obvious need, and in parallel with the chilled water system

5. Two Condenser Water Pumps run in parallel most of the time, but at the end of the presented period switched to one pump operations without any visible change on chilled water side. Revise strategy activating second (lag) hot water pump

6. Cooling Tower System switches from one cell to two cells operations without any visible condenser water flow increase

> **a.** Revise a cells start-up controls

7. Presented April-May time interval can be the most beneficial from Water-side economizer operations point of view.

> **b.** Verify the Condenser Water Temperature set-point

Due to the success at Adanti Student Center and Engleman Hall, Southern is planning on implementing the Building Dynamics continuous commissioning program at all campus buildings connected to the existing Automated Logic BAS. The contractor would work to identify building specific BAS issues, and create monitoring strategies for continuous building system optimization. Ameresco estimates the project could yield annual savings up to $350,000.

2.5.2 RECOMMENDATIONS

Buildings with BMSs with measurable points stand to benefit the most from recommissioning. Guidelines for selecting the best candidates for existing building commissioning (EBCx) are available in the Energy Master Plan.

Although State buildings built after 2011 are required to have a commissioning agent new buildings may have not been properly and thoroughly commissioned at numerous campuses. A properly commissioned building should be turned over with a thorough commissioning report, complete with checklists and testing and balancing (TAB) reports for each piece of equipment, even windows and lighting. If this documentation is not available, it is a good indication the building was not properly commissioned. Newer buildings with a higher than average EUI are also indicative of a poorly commissioned building.

As a general rule of thumb, recommissioning of existing building systems every 3-5 years is recommended. However, the continuous commissioning practices Southern is implementing is one step better and should be continued, using the BAS to its full potential.

Trending of the data available in the BMS, including all temperatures, flow rates and damper/valve positions will help aid not only future energy benchmarking, but also any recommissioning activities.

2.6 MECHANICAL SYSTEMS

2.6.1 CURRENT CONDITIONS

Existing mechanical system conditions consist of the following:

HTHW AND STEAM

Southern's buildings are served by a central plant, the Energy Center, constructed in 2003. The Energy Center's three boilers support building needs depending on the season. Two 40,000MBH boilers operate in the winter, while a 10,000MBH is used for summer loads. In the colder months, water temperature is maintained at approximately 350°F, while in the summer season, water temperature is reduced to 250°F. Three operations shifts are currently required in the winter, while only two are needed in the summer.

There is an additional 40,000MBH boiler housed in the building that is not installed.

The Energy Center supplies domestic hot water, high temperature hot water (HTHW) for heating to fourteen buildings and steam generation to six buildings. Eleven buildings have a natural gas supply in addition to campus HTHW or steam.

DOMESTIC HOT WATER

Domestic hot water is mainly distributed to buildings from water heaters supplied by the Energy Center's HTHW loop. The West Campus buildings are all supplied in this way. The remaining buildings are supplied by either steam distribution, electric hot water storage heaters or natural gas hot water storage heaters. Steam is generated from HTHW as the source for domestic hot water. As this process requires conversion of HTHW to steam, it is somewhat less efficient than using HTHW directly as the heating source. Buley Library, Davis Hall, and Morrill Hall use electrically heated domestic hot water storage tanks. Natural gas storage heaters are generally used in the North Campus residence halls.

Figure 2.6 provides a map of HTHW and steam distribution to Southern's buildings.

CHILLED WATER

Southern does not have a central chilled water system. Instead, cooling is supplied to buildings through various methods including chilled water, direct expansion (DX) and heat pumps. Four residence halls, Wilkinson Hall, Chase Hall, Hickerson Hall and Neff Halls, do not have any cooling systems installed.

The existing building systems table in Table 2.3, provided from a past infrastructure study, summarizes the heating and cooling systems at Southern. Upon review of various sources, it should be noted that there were some discrepancies around available systems. For instance, another source indicated that in addition

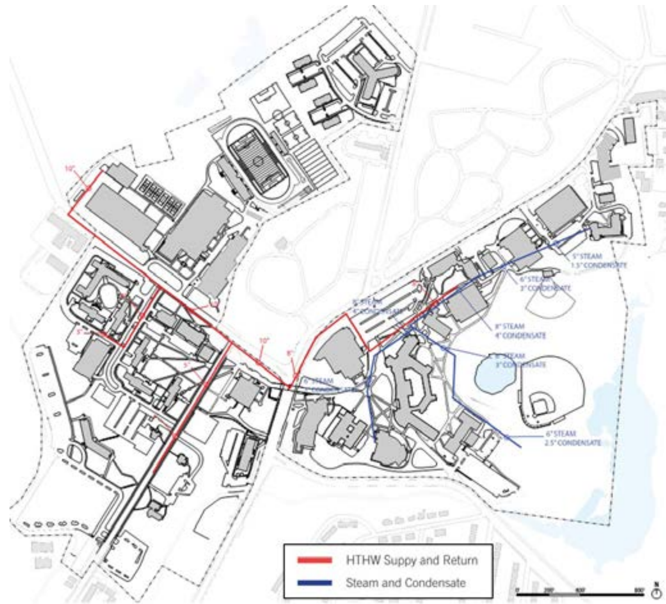


FIGURE 2.6: Southern HTHW and Steam Distribution

to the buildings listed as having no cooling systems, the Nursing Classroom Building, Ethnic Heritage Center, Lang House and Orlando House, all do not have cooling systems.

General observations and notes from talking to staff during the walk-through audit include:

- The central HTHW loop has leaks and the system has a large amount of makeup water. Some sections are being replaced.
- Buildings are not submetered for steam and HTHW, and rooms are not individually controlled or broken into zones.
- Hot water for the Pelz Gymnasium pool is heated using high efficiency Lochinvar water heaters. There were no dehumidification controls used for the pool area.
    - **a.** There are plans to deconstruct or take Pelz Gymnasium offline in the next five years.
- Insulation around hot water piping is not fully adequate at Connecticut Hall.

		Heating + DHW			Cooling				Electrical Service		
Bldg #	Name	Campus HTHW	Campus Steam	Natural Gas (SCG)	CHW System	DX System	None	Heat Pump	UI	East Campus Loop	West Campus Loop
1	Facilities Building/Receiving										
2	Facilities Grounds Garage										
3	Nursing Building										
4	Davis Hall										
5	Parking Garage - Fitch Street										
6	Petz Gym										
7	TE-7 Temporary Building 7										
8	Jennings Hall										
9	Morrill Hall										
10	TE-8 Temporary Building 8										
11	Business School										
12	Engleman Hall										
13	Buley Library										
14	Lyman Performing Arts Center										
15	Earl Hall										
16	Michael J. Adamti Student Center										
17	Connecticut Hall - Food Services										
18	Schwartz Hall - Residence Hall										
19	Ethnic Heritage Center / Storage										
20	Admissions House										
21	Lang House										
22	Orlando House										
23	Brownell Hall - Residence Hall										
24	Farmham Hall - Residence Hall										
25	Wilkinson Hall - Residence Hall										
26	Chase Hall - Residence Hall										
27	Parking Garage - West Campus										
28	Hickerson Hall - Residence Hall										
29	Neff Hall - Residence Hall										
30	West Campus Residence Complex										
31	Granoof Hall - University Polive & Health										
32	Office Building One										
33	TE-6 Temporary Building 6										
34	Energy Center										
35	Moore Field House										
36	Wintergreen Building										
37	Jess Dow Field										
38	North Campus Mid Rise										
38A	North Campus Town House A										
38B	North Campus Town House B										
38C	North Campus Town House C										
38D	North Campus Town House D										
	Wintergreen Ave Garage										

TABLE 2.3: Southern Existing Building Systems

Source: SCSU Energy Memorandum by ARUP, February 2015.
Note, the TE-7 building has since been demolished.

2.6.2 RECOMMENDATIONS

The following lists are recommendations by system type that would aid in optimizing efficiency, and reducing energy.

BOILER SYSTEM

- Implement a steam trap management program. Steam traps may fail open or closed, either wasting thousands of pounds of steam per month, or rendering steam coils inefficient or ineffective.

  a. This EEM often has the most rapid return of investment, even without utility incentives. With the incentives, the cost of the steam trap survey can be 100% covered. The repair of traps can also be substantially covered by the rebate program.

- Add insulation around HTHW valves and fittings. Priority should take place first on the highest temperature piping, from largest to smallest, followed by lower temperatures, such as condensate return. Removable blankets offer sufficient insulation while still allowing access for maintenance.
- Domestic hot water for buildings that use steam can be heated using the condensate return. Building heat will typically require higher temperatures, where domestic hot water (DHW) is usually not much greater than 140 °F. Using a separate heat exchanger for the DHW can extract heat from the condensed steam after it has been used to provide heat for the building.
- If steam is being used as the only means of heating DHW in the summer months, new condensing natural gas boilers designated for DHW should be installed.

- Install condensing economizers on the central heating plant boilers if continuous operation is expected throughout the year. The low grade hot water from the economizer, if not used to preheat makeup water, can be used in new or existing buildings with fin-tube radiators or better, and radiant floor heat where low fluid temperatures can be used.

CHILLER SYSTEM

- While new central plant chilled water systems traditionally offered higher efficiencies than smaller distributed direct expansion (DX) cooling units, advances in technology have made modern DX system equal to or even more efficient than central plant chilled water system. Southern should still consider replacement of numerous smaller units with central plant cooling. Replacement will require an in-depth study of the existing loads and infrastructure. A study to implement a central chilled water system versus replacing DX units should be performed when a majority of the existing equipment is 10-15 years old. Where location or existing layout challenges make connecting to a central chilled water plant unpractical, replacement with new DX units complete with variable speed compressors and advanced controls can provide comparable cooling efficiencies.
- Since chiller efficiencies have dramatically improved over the last twenty years, consider replacing those installed prior to year 2000 in priority of oldest first. Modern chillers compliant with ASRAE 90.1 are up to 50% more efficient than typical chillers 10 to 20 years old. Some chillers identified for replacement due to poor energy efficiency include:

  a. Brownell Hall- Trane 100 Ton unit manufactured in 1982, Model Number CGWA1006RB51CC4B4C311HEB

  b. Schwartz Hall- Trane 110 Ton unit manufactured in 1989, Model Number CGWCD116RDNKL623ABCFGPRT

HVAC AIR SIDE

- Add energy recovery units (ERV) for heat recovery in art spaces with high operating hours.

  a. Depending on the existing ductwork configuration, use either a sensible heat wheel or plate heat exchangers (if intake and discharge are near), or run-around coils between more distant intake and discharge duct.

For an initial estimation on savings when pursuing ERV options, only location, occupied building hours, and cubic feet per minute (CFM) of outdoor air are needed. There are many manufacturers of ERVs; Figure 2.7 provides an example estimate based on an assumption of 10,000 CFM.

- Increase HVAC zoning, adding controls for individual rooms to help prevent overheating or overcooling of spaces. Variable refrigerant flow (VRF) systems are one way of providing this flexibility.

AIRXCHANGE

AIRX ESTIMATOR
FOR CENTRAL PLANT SYSTEMS

RETURN TO ASSUMPTIONS AIRX-ESTIMATOR HELP PRINT RESULTS PAGE

Bridgeport, Connecticut

$0.83/therm; $0.13/kWh; $8/kW Demand Charge
0.7 kW/ton; 80% Heating Efficiency; 70% Airxchange Effectiveness
24x5 Operation; 10,000 CFM OA

AIRXCHANGE WHEEL COOLING CAPACITY (tons):		21.4
AIRXCHANGE WHEEL HEATING CAPACITY (mbh):		622
PEAK DEMAND REDUCTION (kW):		15
ANNUAL COOLING ENERGY SAVED (kWh):		5,848
ANNUAL HEATING ENERGY SAVED (mbtu):		1,075,907
COOLING OPERATING COST (savings):	$	(760)
PEAK DEMAND COST (savings):	$	(720)
HEATING OPERATING COST (savings):	$	(11,163)
AIRXCHANGE WHEEL FAN OPERATING COST (savings):	$	4,867
TOTAL:	**$**	**(7,775)**
CHANGE IN COST OF CHILLER (savings):	$	(10,711)
CHANGE IN COST OF BOILER (savings):	$	(15,543)
COST OF ERV:	$	20,000
NET CAPITAL EXPENDITURE:	$	-6,254
PAYBACK PERIOD (years):		**instant**
ANNUAL ROI (%):		**-**

This program is designed to generate a financial analysis for HVAC systems that utilize Airxchange energy recovery wheels. The program uses ASHRAE weather data and ASHRAE 97.5% design days for the cities listed.

Utility rates and installed costs vary depending on location and equipment selection. Default values are provided in order to demonstrate estimator results. For actual rates and installed costs, consult your local utility and HVAC contractor.

For engineering analysis of specific applications, please use Airxchange's performance and selection software.

www.airxchange.com 85 Longwater Drive Rockland MA 02370 781-871-4618

FIGURE 2.7: ERV Savings Estimate

FUME HOODS

- Implement a fume hood sash management program to ensure hoods are closed and turned off when not in use.
- Install variable frequency drives (VFDs) on fans for additional control of science laboratory fume hoods.

2.7 LIGHTING

2.7.1 CURRENT CONDITIONS

Southern's Facilities team has completed extensive LED upgrades between 2012 and 2015. As of 2016, Southern has installed LED in all garages, Moore Field House Gymnasium, Pelz Gymnasium, the Energy Center and Adanti Student Center.

Ongoing lighting replacements are in progress for the residence halls: North Campus Residence Hall, Schwartz Hall and Neff Hall. A summary of the replacement projects is included in Appendix B along with other existing projects.

- In addition to completed conversions, Southern has plans for the following projects:
- Converting all fluorescent lighting throughout West Campus to LED
- Finish converting outdoor perimeter building security lighting around residence halls from high pressure sodicum (HPS) to LED
- Finish converting parking lot lighting from HPS to LED in all lots.
- Converting light fixtures from metal halide and incandescent to induction and LED at Moore Field House's pool and bleacher area
- Converting all fluorescent lighting to LED in the main dining area, Barnes and Noble floor space and back storage area of the Adanti Student Center.

The campus also pursued re-lamping for the West Campus Residence Complex with T8s and LEDs. An electrical company provided Southern with a quote of under $49,000 on a materials basis to update over 1,600 fixtures in the residence hall.

The approximate incentives for the lighting projects from UI exceed $100,000.

2.7.2 RECOMMENDATIONS

Southern has already prioritized lighting upgrades and continues to do a superior job in creating low cost, quick savings with relamping efforts. Additionally, the partnership with UI has yielded substantial savings. To complement the upgrades, Southern should consider the following:

- Increasing occupancy based lighting (and ventilation) controls
- Photosensor installation with exterior lighting upgrades
- Creation of an internal policy to promote lighting through motion sensors
- LED replacement specific to Pelz Gymnasium
- Convert 1500-watt metal halide fixtures to LEDs in Dow Field
- Change 250-watt metal halide fixtures in Earl Hall to LED
- Installation of LED fixtures in Davis Hall

2.8 BUILDING ENVELOPE

2.8.1 CURRENT CONDITIONS

In 1981, Connecticut implemented its first energy-related state wide standards for buildings. For buildings constructed prior to 1981, it is assumed there is limited insulation, air sealing and other energy-related building envelope features that are now standard practice. Southern's buildings construction dates range from 1890 (Orlando House) to the Academic Laboratory and Science Building, constructed in 2015. Twenty-two buildings, or over half of Southern's building assets, were constructed prior to 1981. Earl Hall was one building specifically identified to be in need of building upgrades and window replacements.

FIGURE 2.8: Admissions Building constructed prior to 1981, likely in need of energy improvements

2.8.2 RECOMMENDATIONS

In general, Southern should consider conducting existing building commissioning (EBCx) related to building envelope on buildings built before 1981, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed the latest building code or ASHRAE 90.1 standard. Southern should insulate wood frame residential buildings constructed prior to 1981 as they are assumed to not have had to abide by stricter building codes. The following sections provide best practices for building envelopes that can be considered by Southern:

- Review and ensure ventilation set points are not excessive per the latest edition of ASHRAE 90.1
- Address air infiltration issues by sealing doors and windows
- Conduct a thermography study using ASTM C1060 or ISO 6781 of buildings built prior to 1980 to identify where there are defects or a lack of insulation.

- Hire a certified consultant to commission the building envelope for new construction using the National Institute of Building Sciences (NIBS) Guideline 3-2012 to include:
    - **a.** Design & construction document review
    - **b.** Laboratory and/or on site performance verification tests
    - **c.** Construction visual QA/QC Inspections
        1. Air, water, water vapor, and thermal barriers
- Include building envelope in recommissioning activities.

2.9 DISTRICT ENERGY / COGENERATION

2.9.1 CURRENT CONDITIONS

While Southern has HTHW distribution at the Energy Center, there is no central chilled water loop or cogeneration system. Southern explored the potential for a fuel cell in 2011 along with the other three Universities, as part of CSCU's fuel cell initiative. No plans were made at the time; however, the campus has interest in revisiting fuel cells.

Southern also commissioned a cogeneration study in 2010 and 2015 by the same firm. Results of the analysis in 2010 identified using a FCE DFC300, 300 kW unit as an option. According to the most recent study, a simple payback near 5 years could be expected before incentives or Renewable Energy Credits (RECs) as shown in Table 2.4. Although not listed in the study summary table, it appears a 1.5 MW Fuel Cell CHP unit was considered.

The information obtained from the previous study did not report on the thermal baseload but rather the electric load. The useable thermal energy generated by a 1.5 MW CHP unit would provide about twice the thermal energy than can be used by the campus for nearly half of the year.

The "Boiler gas displaced by cogen" shown in Table 2.4 indicates the 1.5 MW CHP will need to operate at a significant turndown during portions of the year or dump the excess heat since many packaged CHP unit manufacturers will not let their engines operate at more than 50% turndown. A five-year payback may be optimistic considering the turndown likely required for the 1.5 MW CHP. Before incentives, the return on investment for fuel cells is longer than for internal combustion (IC) engines due to the higher equipment costs associated with fuel cells.

2.9.2 RECOMMENDATIONS

Despite the fact Southern does not have a chilled water distribution loop from the Energy Center, utility data indicates the thermal load alone at the Energy Center could still support operation of a CHP without adding an absorption chiller or additional infrastructure. Instead of a 1.5 MW CHP, as suggested in the study reviewed, Southern is recommended to consider a 600 kW CHP. This smaller application would most likely present a 5 year or less payback, as it would be sized to avoid turndown. CHP recommendations based on thermal and electrical loads include:

BASECASE			33% HIGHER GAS & ELECTRIC		33% LOWER GAS & ELECTRIC	
Boiler gas displaced by cogen	235,480	ccf/year	235,480	ccf/year	235,480	ccf/year
Unit cost of boiler gas	$0.6051	per ccf	$0.8048	per ccf	$0.4054	per ccf
Boiler gas savings	$142,489	per year	$189,510	per year	$95,467	per year
Purchased electricity displaced by cogen	13,193,999	kWh/year	13,193,999	kWh/year	13,193,999	kWh/year
One half of historical purchased electricity	11,613,000	kWh/year	11,613,000	kWh/year	11,613,000	kWh/year
Unit cost of purchased electricity	$0.1310	per kWh	$0.1742	per kWh	$0.0878	per kWh
Net metering electrical savings for up to 1/2 of total annual usage at $0.1310/kWh	$1,521,303	per year	$2,023,333	per year	$1,019,273	per year
Net metering electrical savings for remainder of displaced electricity at $0.0786/kWh	$124,266	per year	$124,266	per year	$124,266	per year
Total electrical savings	$1,645,569	per year	$2,147,599	per year	$1,143,540	per year
Cogen gas consumption	1,228,317	ccf/year	1,228,317	ccf/year	1,228,317	ccf/year
Unit cost of cogen gas	$0.5301	per ccf	$0.7298	per ccf	$0.3304	per ccf
Added cost of gas due to cogen	$651,116	per year	$896,390	per year	$405,842;	per year
Cogen system maintenance cost at $.025/kWh	$329,850	per year	$329,850	per year	$329,850	per year
Net annual savings due to cogen	$807,092	per year	$1,110,869	per year	$503,315	per year
Estimated cogen implementation cost	$4,000,000		$4,000,000		$4,000,000	
Cogen grant at $450/kW I	$900,000		$900,000		$900,000	
Value of RECs at $26/MWH	$343,044	per year	$343,044	per year	$343,044	per year
Payback w/o grant or RECs	5.0	years	3.6	years	7.9	years
Payback w/ grant & w/o RECs	3.8	years	2.8	years	6.2	years
Payback w/ grant & RECs	2.7	years	2.1	years	3.7	years

TABLE 2.4: CHP Cost and Saving Analysis per 2015 Study

Thermal

The existing infrastructure Southern provides could potentially support an internal combustion (IC) CHP installation if installed at the Energy Center and connected to the HTHW loop. The existing hot water and steam loop would allow the CHP to run near peak load throughout the year, despite not having a chilled water loop to increase load over the summer months.

The monthly FY 14 natural gas energy use data for the Energy Center indicates at least 20,000 Therms are used throughout the summer months. The daily average would be near 27 Therm/hr and could support an internal combustion CHP of 600 kW. A thermal storage buffer tank would likely be necessary to balance out the load throughout the day.

An alternate location for a potential CHP is on the steam distribution loop using a back pressure turbine. A back pressure turbine is suggested for study as it is well suited where boilers are oversized and capable of generating steam in excess of 100 psi. Since details on the steam system are unknown, no analysis for this option has been performed. A negative consideration to factor is the increased electrical load due to pumping more HTHW through the water to steam heat exchanger.

Electrical

The 15-minute interval data for the West Substation indicates a 500-1000 kW CHP could connect behind-the-meter without any need to connect to the East Substation network, as would be necessary for any larger CHP units. Alternatively, virtual net metering could be explored; CHP systems are classified as a Class III renewable energy in Connecticut and are therefore eligible for virtual net metering, if it meets a minimum 50% overall efficiency. Virtual net metering would allow up to five electrical services to benefit from the excess generation on one service. In theory, excess generation at the West Substation could offset use at the East Substation even though they are not physically connected. UI would need to be consulted to confirm eligibility and specifics.

Results

For consideration other than the 2015 cogeneration study, a 600 kW CHP may be well suited for Southern. Generally, about 25 kW of electricity can be generated by an internal combustion CHP for every therm of useful heat generated. Assuming an existing boiler efficiency of 83%, a 600 kW CHP may be adequate.

A 600 kW CHP could be base-loaded throughout the year and would maximize runtime and efficiency. Additionally, the generator would not need to be physically connected to the East Substation network since the load profile on the West Substation appears to have the load to handle the CHP nearly the entire year. A 5 year or less simple payback is likely based on utility costs used by the 2015 study, monthly UI data, and an installed IC CHP cost of $3,250/kW of capacity.

With any installation of a cogeneration unit, Southern should pursue RECs and additional benefits through the utility offered natural gas LDC distributed generation rebate rider.

The addition of a CHP system with the LDC rebate should significantly lower the total Energy Center natural gas bill. The total gas usage will increase, as energy is needed to generate electricity, but the significantly lower rate on fuel is expected to reduce the overall bill.

2.10 DEMAND RESPONSE

2.10.1 CURRENT CONDITIONS

Southern has been exploring opportunities to reduce demand charges on campus, starting with understanding when historically peak demands have occurred.

Based on provided calendar year 2014 fifteen-minute data, the West and East Substations have a base load of at least 500 kW and 1000 kW, respectively for most of the year (Figure 2.9 and Figure 2.10)

The East Substation peaks into the two and even three megawatt demand region during peak cooling hours in the summer. Southern's Energy Reports indicate peak demand dates for available meters, which happened to both be the Wednesday before Labor Day in both 2014 and 2015. Figure 2.11 provides the Energy Reports summary page, with the large West Campus Electric Meter showing the most obvious peak towards the end of the day on the September 9th.

The East Campus account is not available in Energy Reports. Southern has also received recommendations to install a real-time meter on the campus' largest account, attributed to the East Campus Loop, to more actively respond to peaking demands.

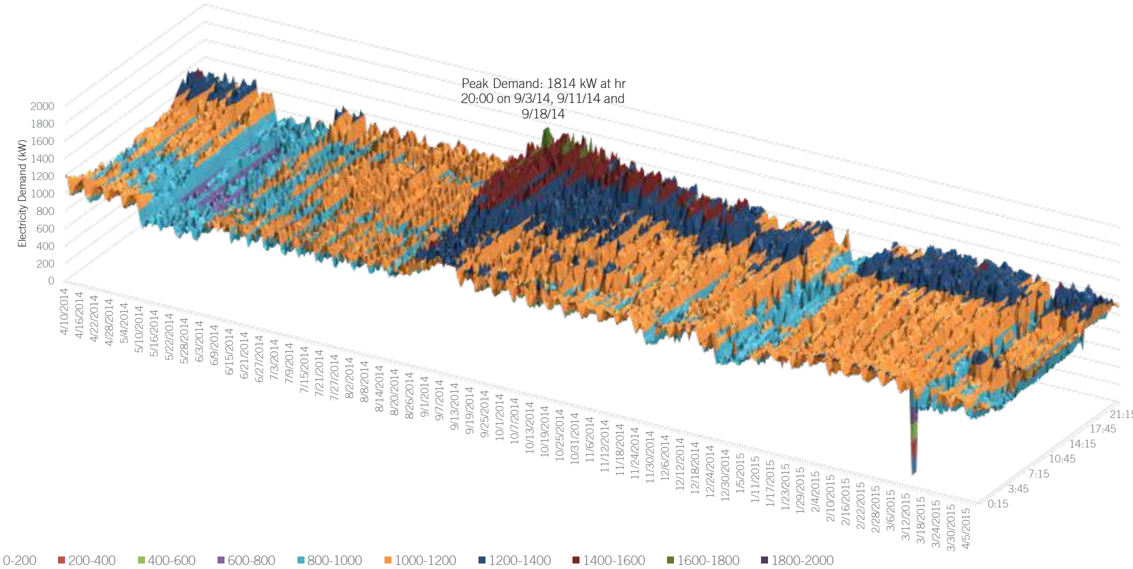


FIGURE 2.9: West Substation Load Data (kW)

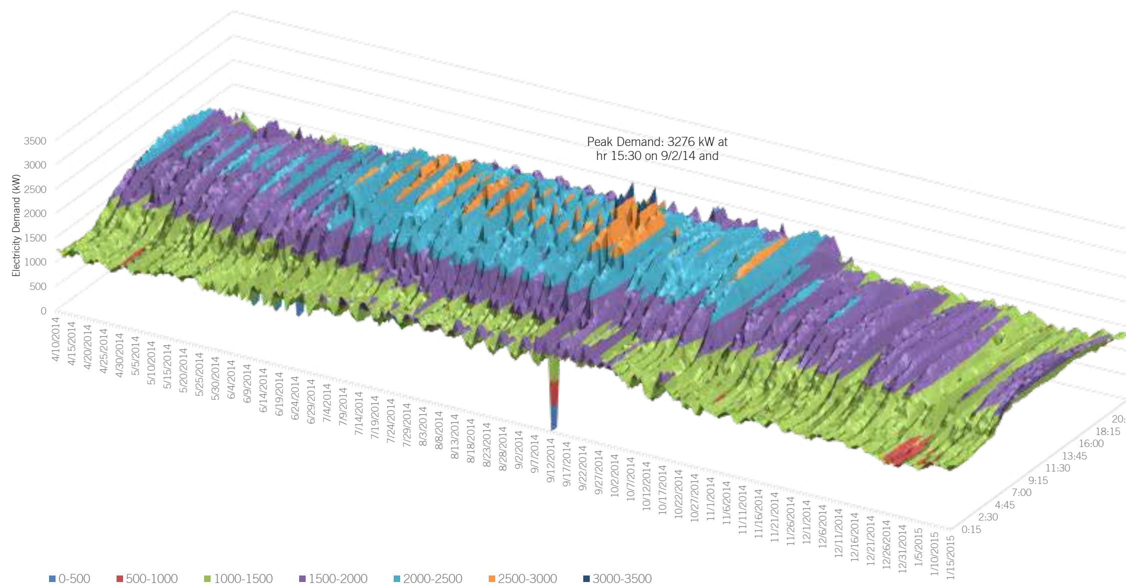


FIGURE 2.10: East Substation Load Data (kW)

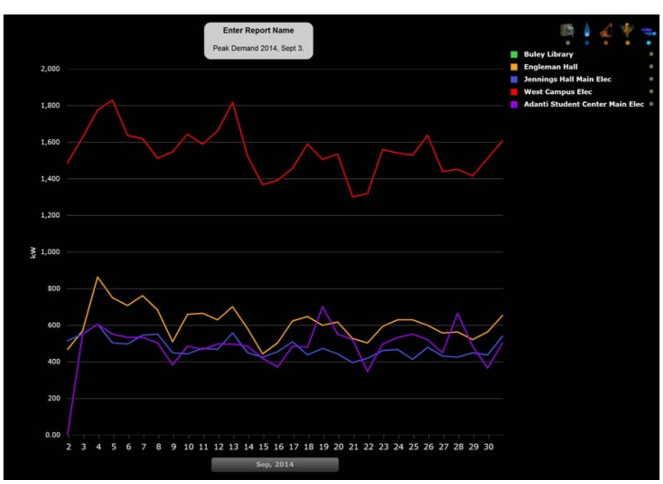


FIGURE 2.11: 2015 Peak Day in Southern Energy Reports

2.10.2 RECOMMENDATIONS

As demonstrated by the load data, there is opportunity for peak shaving during cooling hours in the summer. To further Southern's current demand response efforts, the addition of on-site generation can help to offset electricity use need during peak hours. As suggested in the cogeneration section, cogeneration has multiple benefits including aiding in demand response. If Southern intends to purchase additional generators to be used for demand response as well as emergency generation, Southern should purchase Tier IV compliant generators. As part of EPA's regulations, in order to participate in real time demand response, generators must meet EPA's Tier IV emissions requirements.

In addition to managing peak days on campus, Southern should manage demand on the days in which the regional electric grid is at its peak. Each end-user has an Installed Capacity (ICAP) tag, which represents the end-user's share of New England's requirement for generation capacity. The ICAP tag determines a portion of a customer's electric supply costs for the following year and it is set by the customer's load in the peak hour during the regional electric grid's highest usage. In the past, peak day has generally occurred between July and September. The 2015 peak day was July 29th from 4-5PM. Knowing when the peak days are projected to occur provides a significant opportunity to manipulate supply costs. Capacity savings for 2017-2018 are estimated at $9.86/kW-month. For instance, if peak load was reduced by 200 kW on peak day alone, the campus could see supply savings of $23,665.

Predicting electric grid peak days can be difficult, although in the past they tend to occur on hot and high humidity days. In order to prepare for events, Southern can monitor ISO-NE's predicted loads, available on their website, or have a third-party demand response group provide warning in advance.

Strategically, Southern should work with administration and residence advisors to provide materials to students and faculty about times to reduce electricity consumption. Easily implemented efforts to suggest could include turning off lights and powering down AC units. Framing demand response as an effort to promote sustainability by reducing the need for energy-intensive peaking plants may be aid in increasing buy-in.

2.11 RENEWABLE ENERGY

2.11.1 CURRENT CONDITIONS

Southern received favorable responses to its 2016 solar PV request for proposal (RFP) featuring a cumulative 1 MW of ground-mount, parking canopy and roof mount solar PV. Renewable energy was proposed at three locations during the April RFP Process. The contract will be in the form of a PPA. Wintergreen Parking Garage is included in the base bid for approximately 100-150 kW AC roof mounted PV solar system. The other base bid includes an area of 72,000 feet at Parking Lot #9 for an anticipated 400-500 kW ground mount system.

A supplemental bid is for the parking lot main section at approximately 95,000-sf for up to a 650-750 kW AC fixed parking solar PV canopy. The campus also has solar PV existing on Brownell Hall.

2.11.2 RECOMMENDATIONS

There are several other potential opportunities for rooftop solar PV on campus depending on roof age, plans for renovations, and availability of space not encumbered by mechanical equipment. In general, there are opportunities for small sites of less than 200 kW. For ground-mount solar, most of the available land is either tree covered or used for recreational purposes. However, a suitable ground-mount installation may be adjacent to the Wintergreen Parking Garage and tennis courts. Tree removal may provide additional opportunities for ground-mount. The campus should continue to consider additional parking lot canopies.

Table 2.5 provides an overview of the buildings that may be considered for solar PV in the future. Following the table are images of each of the sites.

Strategically, and to aid climate action plan goals, the campus should attempt to implement solar on campus before the 2019 federal investment tax credit expires, unless there is an extension. As practice, with any roofing improvements, implementation of solar PV should also be considered at the same time. Integrating solar simultaneously with new roofing can help streamline both projects into one and mitigate issues the insurance provider may have for existing roofs. Solar PV should also be incorporated into future capital planning building design.

Other suggestions include:

- Optimize available incentives including:
  - **a.** Strategically plan for small, medium, and large ZRECs and LRECS for best savings
  - **b.** Site plan based on meter size, associated limits on installed KW and other legal restrictions
- Pursue Off-site Solar
  - **a.** Consider purchasing renewable energy offsite, as part of system wide electricity procurement.
  - **b.** If an offsite PPA is pursued, the campus should look for a longer than 10-year price guarantee.

Southern should continue to work closely with CSCU when pursuing renewable energy options. With the rapid improvement of energy storage technology, Southern may want to consider solar islanding in the future, whereby solar energy can be stored during the day and released at times of peak load to reduce energy costs. The campus may want to also consider a microgid, where financially advantageous and feasible. Connecticut currently has a microgrid grant program to support critical facilities .

Building Name	Address	Year Built [Renovated]	GSF [FY 2015]	Building Roof sq. ft.	Roof Install/ Replacement Date	Roof Type	Array Size Potential (kW DC)[1]	Annual Generation Potential (MWh)[2]	Solar Suitability Comments
HIGHER PRIORITY PROJECTS									
Buley Library	377 Fitch	1968	249,412	7,913	2015	EPDM	36-47	47-61	
Chase Hall	Wintergreen	1967	59,266	9,500		AHDERED. EPDM	22-29	29-37	
Energy Center	21 Wintergreen	2003	16,580	5,714		Metal	26-34	34-44	
Engleman Hall	501 Crescent	1953	224,599	21,242		ADHERED EPDM	98-127	127-164	
Fitch Street Parking Garage	525 Fitch Lot 1GA	2000	193,605	64,535		NA	237-310	310-398	Solar canopy
Lyman Center for the Performing Arts	501 Crescent	1967	53,058	42,000	1994	EPDM	97-126	126-162	
Moore Field House	11 Wintergreen	1976	145,992	42,602	2013	BITUMEN/G RAVE	157-204	204-262	
Neff Hall	112 Wintergreen	1969	48,150	8,100		EPDM	19-24	24-31	
Nursing Building	555 Fitch	2005	5,000	3,500		SHINGLES	13-17	17-22	
School of Business	324 Fitch	1958	100,293	12,500		BITUMEN MD.	29-38	38-48	
West Campus Parking Garage	108 Wintergreen	2004	148,098	25,395		NA	93-122	122-156	Solar canopy
Earl Hall	501 Crescent	1960	46,027	32,000		EPDM	74-96	96-123	Some shading
Land area adjacent to Tennis Courts and Wintergreen Parking Garage							423-552	552-709	Ground-mount
Subtotal							1324-1726	1726-2217	
LOWER PRIORITY PROJECTS									
Hickerson Hall	100 Wintergreen	1967	59,266	8,000	1994	EPDM	22-29	29-37	Could be good candidate but roof condition is said to be poor
North Campus Res. Hall Complex: Mid-Rise	180 Pinerock Ave	1985	152,517	25,600	2012	MOD. BUR	94-123	123-158	Structural analysis needed
North Campus Res. Hall Complex: Town House A	182 Pinerock	1991	9,165	1,354			42529	42592	Could reduce shading, small array
North Campus Res. Hall Complex: Town House B	184 Pinerock	1991	9,165	2,430			42689	15-19	Could reduce shading, small array
North Campus Res. Hall Complex: Town House C	186 Pinerock	1991	9,165	1,354			42529	42592	Could reduce shading, small array
North Campus Res. Hall Complex: Town House D	188 Pinerock	1991	9,165	2,430			42689	15-19	Could reduce shading, small array
Subtotal							150-198	198-253	
Total							1474-1924	1924-2470	

TABLE 2.5: Southern Potential Areas for Solar PV

[1] Assumes that each sf of panels can generate between 4.6 and 6 Watts DC (about a third of the PVWatt Output Assumptions). Actual generation values would be calculated if a solar PV study was performed.
[2] Assumes that each sf of panels can generate between 6 and 7.7 kWh annually (about a third of the PVWatt Output Assumptions).Actual generation values would be calculated if a solar PV study was performed.

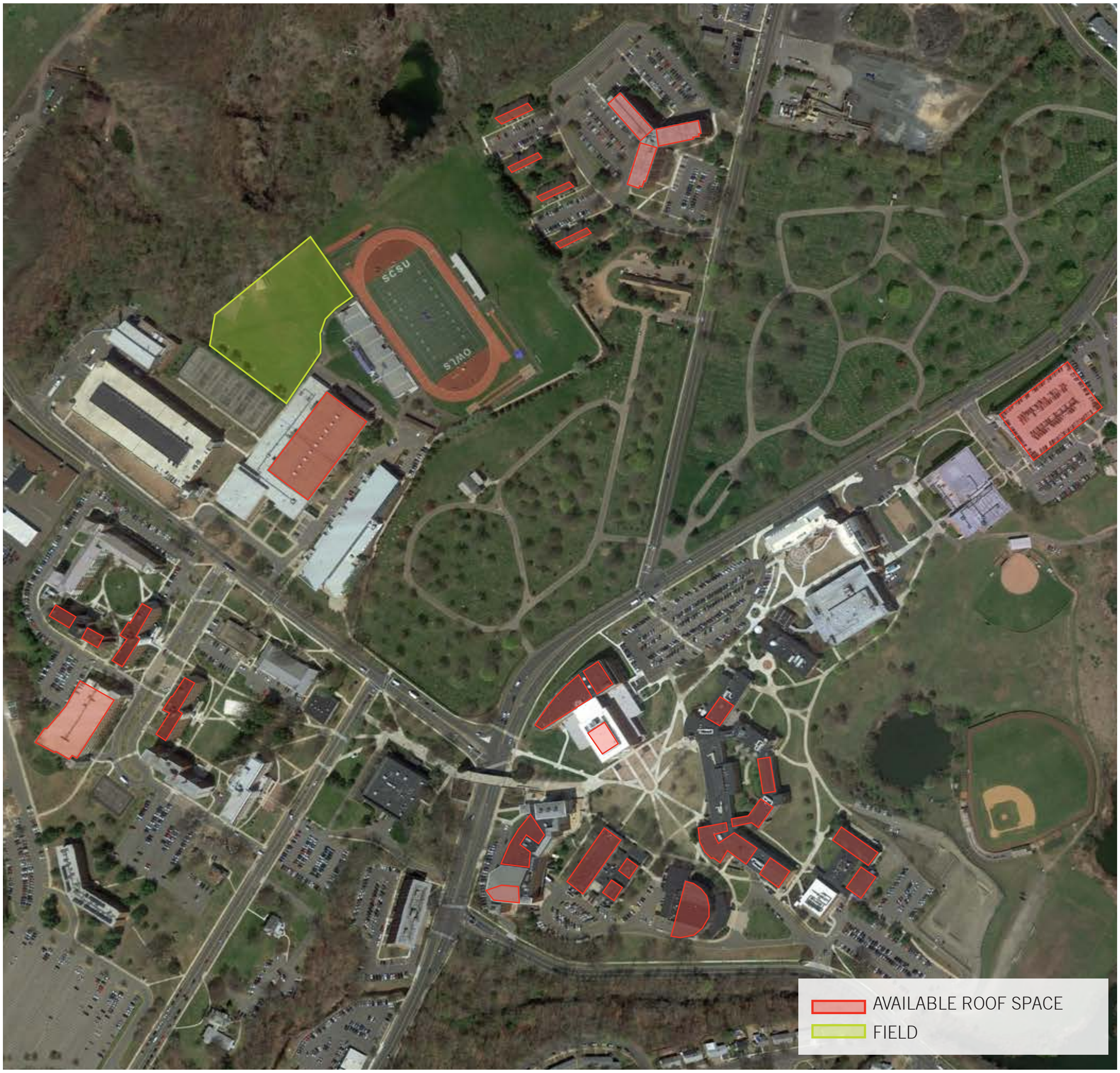


FIGURE 2.12: Southern Campus Solar Potential

2.12 CAPITAL PLANNING

2.12.1 CURRENT CONDITIONS

The dedicated Facilities staff oversees planning, design, construction and maintenance of Southern campus facilities. The University Master Plan, the 2020 Program, the Climate Action Plan, and the University's Strategic Plan all help shape Facilities' long-term responsibilities, inclusive of preparing for new construction projects and renovations to existing infrastructure. Facilities has regular meetings regarding large capital planning projects. The campus also has numerous deferred maintenance projects, that if addressed would also reduce energy intensity. According to Southern, deferred maintenance projects in order of priority, include:

- Lyman Center for the Performing Arts: Mechanical systems upgrade/ AHU replacement
- Moore Field House: replace all 7 AC units and upgrade pool lighting
- Davis Hall: Mechanical systems upgrade/ replacement
- Pelz Gymnasium: Mechanical and electrical systems upgrade, with a return on investment of 1-2 years. The Gymnasion is recommended for demolition
- Recommendations from a return on physical assets benchmarking study including mechanical systems upgrade and piping for AC / electrical systems upgrade
- North campus mechanical upgrade with wireless BAS controls
- Earl Hall: Building envelope, window replacement
- Upgrade Jess Dow field lighting when financially advantageous

FIGURE 2.13: Lyman Center per 2006 Master Plan

To accomplish its energy infrastructure goals, Southern relies on financing and funding from the System Office and the State. The System Office provides annual code compliance and infrastructure funds. Larger capital projects are also funded under CSCU 2020, as of FY 2015.

More information on campus expansion projects is found in Section 3.1.

2.12.2 RECOMMENDATIONS

As Southern plans for energy upgrades, collaboration with UI in the planning stages may be beneficial. In general, Southern should continue to collaborate with UI for all major building renovations and all new construction, as well as mechanical, electrical and plumbing equipment upgrades. Additionally, milestone bid reviews for renovations or new construction should include review and comments by a dedicated energy manager from CSCU and a Commissioning Agent.

While budgets are allocated to expansion projects, ideally capital funding would be allocated to address energy related deferred maintenance at the campus. The capital funding to support deferred maintenance energy projects would lead to lasting yearly savings and a decreased operating budget.

2.13 COLLABORATION / PARTNERSHIP

2.13.1 CURRENT CONDITIONS

UI has provided support to Southern to accomplish significant energy projects. Since 2000, UI has provided Southern with a total of $468,914 in electricity incentives alone. The utility was involved with providing incentives for a total of 47 lighting, cooling and heating projects. UI estimates over 2.5 million net kwh savings from the projects.

Southern's Facilities team has also had success working with administration in a concerted effort to improve campus scheduling and shut downs in summer months. The collaboration is expected to decrease kW demand, helping to save on peak charges and shave electricity spending.

2.13.2 RECOMMENDATIONS

Southern should continue to have regular meetings with UI, preferably on a monthly basis. Administratively, supplying the utility with a list of all capital projects, deferred maintenance and the suggested EEMs in this report would help to align existing incentives and potentially maximize rebates through bundling of projects. Involving the utility in the early stages of planning is important to understand the latest equipment that may receive additional incentives.

Incentives structures range and vary by program, but UI has offered incentives of up to 80% of project costs in the past. Southern should coordinate with UI to maximize available incentive structures through:

- Enhanced rebates
- Bundled rebates
- Performance design rebates

The Energy Master Plan provides a list of available incentives programs in Chapter 4.

2.14 SUMMARY OF RECOMMENDED ENERGY EFFICIENCY OPPORTUNITUES

As a result of the campus walk through energy assessment, and interviews with campus staff, a list of potential Energy Efficiency Measures (EEMs) is presented in Table 2.6. These projects represent both low cost, immediate action measures, as well as projects that may require larger capital and therefore be longer-term.

Many energy-related projects are incentivized through utility rebates. Currently, Southern can maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project." The primary advantage of a Comprehensive Project is the maximum incentive cap is normally raised from 40% to 50%. UI has maximized these incentives in the past, and may also in the future, in the following ways:

- The comprehensive cost cap was increased from 50% to 80% of total cost.
- The incentive was increased from $0.30/kwh or $3.50/CCF (with 40% cost cap) to $0.40/kwh or $4.00/CCF (with 60% cost cap).

Since incentives are based on incremental energy savings; further analysis and collaboration with UI will be required to determine rebate amounts for each opportunity. Immediate action should be taken to consider priority one and two opportunities with the goal of combining multiple opportunities for a Comprehensive Project. The simple payback in most cases cannot be reasonably estimated without detailed building models and/or more operating data. The payback periods provided are based upon the performance of past similar projects and are not necessarily indicative of future results.

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
SCSU-1	Implement a steam trap maintenance program.	East Campus	$15 / trap surveyed + repair costs	<1 - 2	1
SCSU-2	Continue recommissioning (in progress).	All	$0.50 - $3.50 /sf ($60k for continuous Cx)[1]	Varies	1
SCSU-3	Optimize BAS with Continuous Cx practices.	All	$20k/ 100k sf / year	Varies	
SCSU-4	Consolidate course offerings to certain buildings to reduce energy consumption at times of lower occupancy (in progress).	All	Varies	Varies	
SCSU-5	Explore use of BAS for capacity charge and demand response management.	All	Administration Time	2016-2017 estimated savings of $9.86/kW-month	
SCSU-6	Implement fume hood sash management as a part of a fume hood sash management campaign with goal to instill an energy efficient culture.	Various	Minimal	Varies	1
SCSU-7	Install variable speed drive for control of fume hoods in Science Labs. Also explore adding heat recovery coils if used frequently.	All	Varies	2 - 5	1
SCSU-8	Install variable speed drives. Fund with UI rebate program (in progress).	All	Varies	2 - 5	1
SCSU-9	Investigate roof-top solar PV opportunities, specifically with new construction or roof renovations, in addition to pending PPA for the Lot 9 PV array. Also investigate ground mount and additional solar canopies.	All	PPA	PPA	1
SCSU-10	Enable trending of energy data through BAS for future benchmarking and EEM savings estimates. Store at least 2-years' worth of data in 15-minute increments.	All	Varies	Varies	1
SCSU-11	Convert 1500-watt metal halide fixtures to LEDs.	Jess Dow Field	Varies	Varies	1
SCSU-12	Creation of an internal policy to promote lighting through motion sensors.	All	Administration time	Minimal	1
SCSU-13	Replace existing lighting with LED.	Pelz Gymnasium	Varies	2 - 6	1
SCSU-14	Change 250-watt metal halide fixtures in LED.	Earl Hall	Varies	2 - 6	1
SCSU-15	Replace existing fixtures with LED in lecture spaces.	Davis Hall	Varies	2 - 6	1
SCSU-16	Increase occupancy based lighting (and ventilation) controls.	Campus	Varies	Varies	2
SCSU-17	Focus energy efficiency projects on buildings with a high EUI and a high total energy consumption.	All	Varies	Varies	2
SCSU-18	Lower temperature and use natural gas infrared heaters with infrared thermostats in maintenance shops and garages.	Maintenance/Facilities Garage	Varies	3 - 6	2
SCSU-19	Add insulation around HTHW valves and fittings.	Connecticut Hall	Varies	1 - 2	2

SCSU-20	Explore or conduct a further study for a 600 kW Internal Combustion CHP engine at the Energy Center, near 600 kW. The system should be sized for year-round operation, and may possibly include a thermal buffer tank. The campus should also explore capturing additional benefits from CHP like reduced natural gas pricing with the LDC waiver. [1]	Energy Center	Varies, $3k - $4k per installed kW capacity	Varies	2
SCSU-21	Upgrade mechanical systems upgrade, including an AHU replacement	Lyman Center for the Performing Arts, Davis Hall	Varies	Varies	2
SCSU-22	Replace all 7 AC units with more efficient models.	Moore Field House	Varies	Varies	2
SCSU-23	Complete a mechanical and electrical systems upgrade, dependent on Master Plan and fate of the building.	Pelz Gymnasium	Varies	Varies	2
SCSU-24	Straightlines: Complete an electrical systems upgrade and a mechanical systems upgrade and piping for AC	Campus	Varies	Varies	2
SCSU-25	North campus mechanical upgrade w/ wireless BAS controls.	North Campus	Varies	Varies	2
SCSU-26	Add ventilation heat recovery for art spaces with high operating hours.	Various	$2 per CFM of capacity	Varies	3
SCSU-27	Connect new buildings to west campus loop (previously recommended).	Future	Varies	Varies	3
SCSU-28	Preheat DHW using condensate return from steam loop.	East Campus	Varies	Varies	3
SCSU-29	Explore ~150 kW backpressure turbine after steam generator on East Steam Loop and connect extra 40 MMBtu Boiler at Energy Center.	East Steam Loop	Varies	Varies	3
SCSU-30	Install Heat Recovery Ventilator (HRV) for pool ventilation and dehumidification, if pool continues to be used (Pelz Gymnasium may be taken offline).	Pelz Gymnasium	$2 per CFM of capacity	Varies	3
SCSU-31	Install condensing economizer on central heating plant boilers and supply low temperature hot water to nearby or new buildings.	Energy Center	$350,000, N.I. demand side modifications	9-10 based on UC Davis and JAX studies	3
SCSU-32	Increase HVAC zoning and/or add individual room controls to BAS.	Various	Varies	Varies	3
SCSU-33	Replace older cooling equipment, especially those greater than twenty years old. Consider replacing DX units with new variable speed compressor units or installing a central water cooled chiller plant when infrastructure permits.	Various	Varies	Varies	3
SCSU-34	Upgrade building envelope including window replacements	Earl Hall	Varies	Varies	3

TABLE 2.6: Southern Energy Efficiency Measures

Footnote: 1)A 2010 study identified a 300 kW fuel cell installed near the Energy Center would have total installed cost of $2.7M and annual savings of $119,718 (2010 CSUS Fuel Cell Evaluation Report)

ENERGY NEEDS

3.1 FUTURE DEVELOPMENT

Overall energy use may be impacted by campus expansions and renovations. In April 2015, Southern opened its $31 million, 98,000 square foot renovated wing of the Buley Library. Also completed in 2015 is Southern's new $49 million, 103,608 square foot Academic Laboratory and Science Building. CSCU 2020 includes construction of a Health and Human Services (HHS) instructional building at Southern, and centralizing departments and providing upgraded clinical facilities to support growing programs in Nursing. Southern plans to locate the HHS adjacent to Pelz Gym. The building is in Phase 1 of the project, with CSCU pursuing funding for Phase 2 which entails further expansion for the planned HHS building and demolition of Pelz Gymnasium.

According to the 2015 Master Plan Update, and based on 10-year enrollment projections, Southern's campus is in need of an additional 294,000 Assignable Square Feet (ASF). Including the aforementioned HHS, the Master Plan also suggests:

- Jennings Hall and Morrill Hall Renovation to include undergraduate biology labs,
- Construction of a 110,000 GSF School of Education Building,
- Construction of 80,000 GSF School of Business,
- West Campus new residence halls, and
- Numerous other space use and campus beautification recommendations.

Southern is also considering removing several energy inefficient buildings from its current assets. The buildings under consideration include:

- Old Student Center
- Temporary buildings- TE 6 and 8 when no longer needed
- Office Building 1 and Granoff Hall

FIGURE 3.1: Energy Center per 2015 Master Plan Update

Southern had an infrastructure-specific study conducted in concurrence with its updated Master Plan. Based on the findings, commissioning the unused 40,000MBH boiler in the Energy Center would support all heating and DHW needs in a campus expansion. The addition of the boiler would both be of no significant capital cost to the campus, and also support 100% redundancy for the Energy Center. It was also recommended to continue to evaluate cooling options on a building by building basis. Additional recommendations include:

- Eliminate individual natural gas use for the eleven buildings that have both HTHW/steam and a UIL account. Instead, buildings can use HTHW for heating and DHW needs to increase boiler efficiency
- Re-evaluate building systems for the buildings that use steam for heating and DHW
- Connect new buildings to the East Campus or West Campus electrical loops, rather than being supplied directly from UI.

Focus on energy optimization should especially be placed on future buildings that are generally more intensive such as academic buildings with laboratories and dining halls. In general, Southern should take the opportunity to complete energy efficiency upgrades during building renovations.

3.2 ENERGY RESILIENCY RECOMMENDATIONS

As the campus grows it is important to be able to support the electric needs in case of power outages and unreliable energy situations. Southern has 11 generator assets on campus, ranging from 17 kW to 1.5 MW. The largest generator provides 100% redundant power to the West Campus Loop, while an 800 kW Kohler generator supplies full power to the Facilities Building. Most of the smaller capacity generators serve individual buildings for purposes of providing lighting and elevator use.

For increased power reliability, Southern may want to consider employing a microgrid, especially if the campus pursues fuel cells or combined heat and power. Connecticut's Department of Energy & Environmental Protection (DEEP) offers $10 million in funding for round three grants.

In 2015, Southern partook in the CSCU multi-campus hazard mitigation planning initiative which identified energy resiliency opportunities that are also applicable for the Energy Master Plan. The following presents recommendations from the hazard mitigation plan for improving the energy reliability and resiliency of the campus.

- Study and evaluate solutions for redundant power on campus, including cogeneration and implement engineered solutions.
- Increase generator capacity, particularly for the East Campus Loop
- Add transient surge suppression to block large voltage spikes in Adanti Student Center.
- Install and maintain surge protection on critical electronic equipment.
- Improve building envelopes
- Develop a debris management plan.
- Bury power lines to provide uninterrupted power after severe winds
- Add building insulation to prevent burst pipes and other winter-related impacts.

CONCLUSION / NEXT STEPS

Southern has an advanced energy program and access to varied forms of energy data. Southern's program is inclusive of recommissioning efforts and includes deliberate shut downs coordinated with administration to save energy. Southern's continued efforts are largely guided by climate action goals, a desire to keep sustainability in the forefront of campus actions and to reduce costs. As evident by the relatively low EUI, Southern is doing an excellent job managing energy use with the existing systems.

Improvements for Southern relate to enhancing existing practices to bolster utility incentives, and seeking alternative forms of energy that will provide cost and energy savings. Top priority initiatives include:

- Alternative Energy: Explore an Internal Combustion CHP engine at the Energy Center. A unit sized for year-round operation is suggested, near 600 kW, with the final size and feasibility based on further study.
- Renewable Energy: Explore additional PPAs for on-site solar, as well as off-site, where economically advantageous.
- Utility Incentives/ Develop Plan for EEMs: Maximize incentive funding for EEMs by working with UI, and combining multiple energy saving opportunities in what is known as a "Comprehensive Project." Further analysis and collaboration with UI is required to determine rebate amounts for each opportunity.

A summary of further projects and priorities for the campus are listed in Table 2.6. While Southern has the second lowest energy use intensity of the four CSCU Universities, there are remaining substantial energy optimization opportunities that will aid in decreasing energy use and increasing energy reliability and sustainability.

4.1 CONTACT INFORMATION FOR KEY STAKEHOLDERS

Collecting all the necessary information for this planning effort required a collaborative effort. Listed are the stakeholders that were active in providing their expertise about campus current conditions and future needs, and energy related decisions.

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APPENDIX A: WESTERN DATA, METHODOLOGY, ASSUMPTIONS AND NOTES

The following are the data methodology and assumptions that were used when analyzing and benchmarking data for Southern:

All three fiscal years have "complete" consumption data. There is no information to indicate that the campus uses propane, fuel oil, purchased chilled water or steam.

Electricity: UI Summary Report (FY13,14,15) and BAS Data (FY13,14)

- Total campus consumption is taken from the UI report.
- BAS data in the form of the east-west pivot, residence halls sheet, and academic buildings sheet were used to break out building level numbers for buildings under the east and west loops.
- No information was found for the Nursing Building, which was noted as having a UI account.

Natural Gas: UI Report (FY13,14,15)

APPENDIX B: SUMMARY OF PAST ENERGY PROJECTS

Energy Conservation

2015

1- Entire campus-Converted 750 HPS Granville outdoor light pole fixtures to LED-20% energy savings
2- Entire campus-Converted all elevator lighting from fluorescent to LED
3- Schwartz Hall-Converted all hallway, stairwell, and room lighting from fluorescent to LED
4- North Campus-Converted all hallway, stairwell, bedroom and foyer lighting from fluorescent to LED
5- Brownell Hall-Converted hallway lighting in dorm rooms from fluorescent to LED
6- West Campus garage-Converted all stairwell lighting from fluorescent to LED
   Replaced all HPS ramp light fixtures with LED fixtures
7- West Campus garage-Replaced 150 HPS ramp lighting with LED lighting
   Replaced all HPS ramp light fixtures with LED fixtures
8- Fitch St. garage-Replaced all stairwell HPS lights with LED lights
9- Pelz Gym-replace all perimeter HPS wall pack light fixtures with new LED light fixtures
10- Moore Field House-Replaced 1000 watt metal halide main gym lights with t-8 fluorescent light fixtures
11- Pelz Gym-Replaced 400 watt metal halide light fixtures with t-8 fluorescent light fixtures
   Pelz Pool-Replaced 400 watt metal halide light fixtures at with induction light fixtures
12- North Campus parking lot and Condos- Converted all outdoor parking lot lights and condominium wall pack light fixtures from HPS to LED
13- Parking Lot #12- Replaced all HSP pole lights with new LED light fixtures
14- Lyman Auditorium-Replaced all perimeter building wall pack HPS light fixtures with LED light fixtures.

15- Schwartz Hall parking lot and Lot #10-Replaced all parking lot light HPS light fixtures with new LED light fixtures.

16- Schwartz Hall-Converted all outdoor perimeter HPS security lighting to LED

17- Conn Hall- Replaced all outdoor HPS perimeter security and wall pack light fixtures with LED light fixtures.

18- Conn Hall-Replace 120 watt incandescent lamps throughout entire dining room area with 28watt LED lamps.

19- En A120 and C112 lecture halls, replaced 120 watt incandescent ceiling lamps throughout lecture halls with 28 watt LED lamps.

20- Barnes and Noble Bookstore-replaced all track lights with LED lights

21- Guard shacks throughout campus-replaced all incandescent outside accent soffit lights with LED lamps.

Res Life energy efficiency 2015

In reference to energy efficiency projects, residence life has completed the following:

- Low flow showerheads have now been installed in all 6 first/second year residence halls.
- All refrigerators and dishwashers are replaced using energy star rated units.
- Residence Life has worked with our laundry contractor to install only front loading, energy star rated units in the residence halls.
- LED lighting has been installed in all hallway and room fixtures in Schwartz Hall and North Campus.
- LED lighting has been installed in all Brownell room common areas.
- Motion sensors have been installed in all common area kitchen units and most study spaces as well as the Farnham Programming space.
- All 1500 lamps in the residence halls have been equipped with CFL bulbs
- We just completed an RFP process for 911 energy star rated small refrigerator/microwave combination units which are energy star/CRE Free.

  I wanted to mention a few other items to highlight which are not related to "energy" but might be useful ...
- Residence hall rooms now painted with zero VOC paint which is GreenGuard® Indoor Air Quality Certified and GreenGuard® Certified for Children and Schools.
- Recycling stations exist in all residence halls for batteries, fluorescent lights and cellular phones.
- For the Fall of 2015 we have moved to an online/paperless room selection process.

6.16

WESTERN CONNECTICUT STATE UNIVERSITY

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EXECUTIVE SUMMARY

The Western Connecticut State University (Western) Energy Master Plan aims to identify ways Western can improve energy use on campus, and be an active participant in Connecticut State Colleges & Universities (CSCU)'s energy management, reduction and conservation efforts. Western has been active in completing energy-related upgrades, and focusing on energy improvements. The utility data received indicates Western is a medium performing CSCU University from an energy perspective (see Figure 1 Western Energy Dashboard). The energy use intensity (EUI) method is used for benchmarking and comparison purposes.

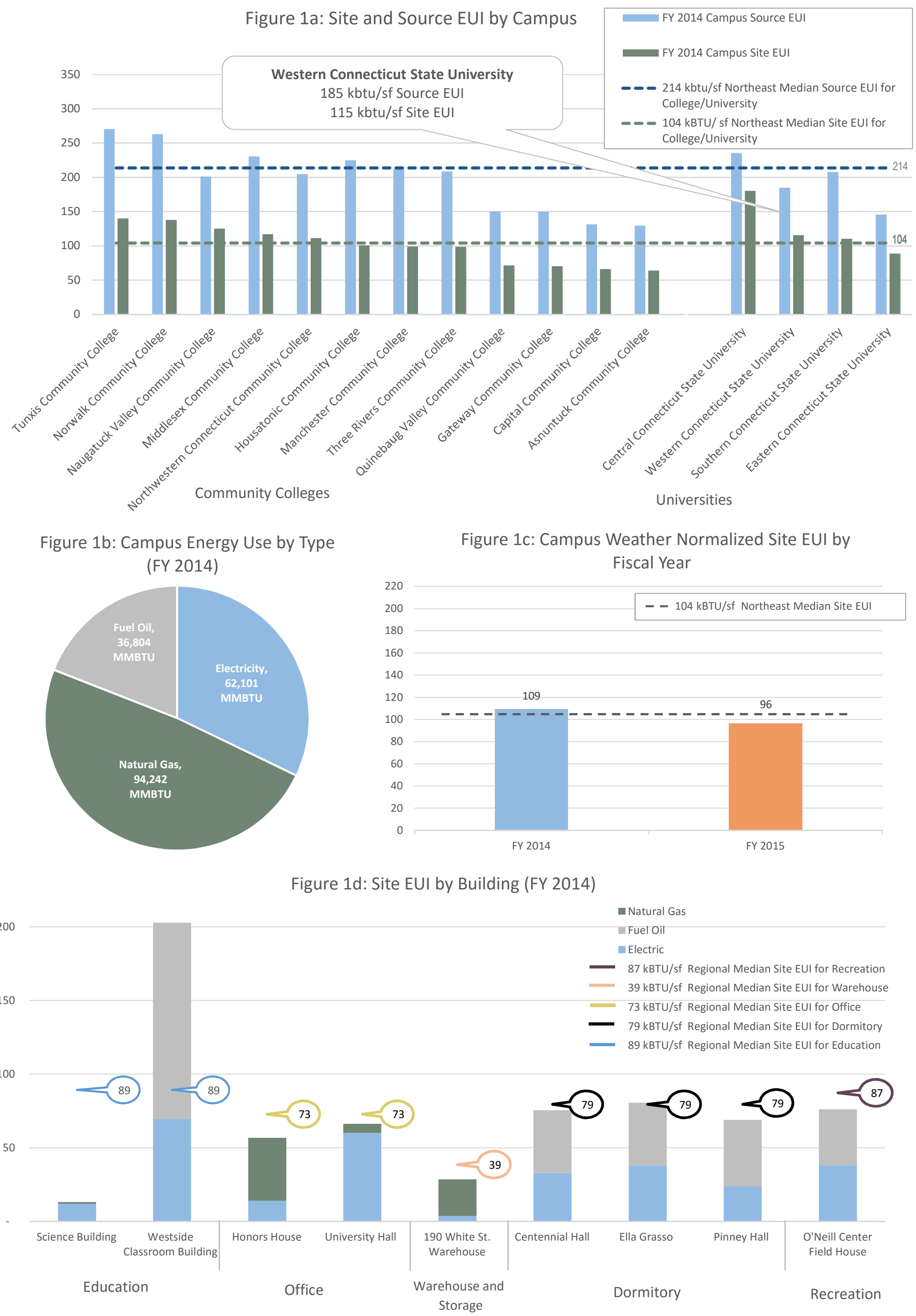

FIGURE 1: Western Connecticut State University Energy Dashboard

* Only buildings with both electricity and fuel submetering data are shown
** Note The Science Building's heating and electricity are largely provided by a 400 kW fuel cell. The EUI does not reflect the building consumption of the fuel cell's generation as separate metered data is not available at this time

Energy Spending

Table 1 provides a summary of energy spending compared to the average of CSCU campuses and the Northeast Region Commercial Sector.

	Western Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 2.60	$ 2.08	$ 2.49	$ 1.67 [1]
Cost per FTE Student	$ 900	$ 677.00	$ 311	$ -
Avg. Cost per kWh Electricity from Grid	$ 0.14	$ 0.14	$ 0.14	$ 0.15 [2]
Avg. Cost per MMBtu Natural Gas	$ 8.43	$ 7.32	$ 10.06	$ 10.03 [3]
Total Operating Expenses	$ 127,325,717	$ -	$ -	
Total Energy Spending	$ 4,449,692	$ -	$ -	
% of Operating Expenses	3.49%	2.67%	1.95%	

TABLE 1: Energy Cost Comparison (FY 2014)

[1] Energy $/sf in the Northeast region from CBECS 2012 report; education building type - http://www.eia.gov/consumption/commercial/data/2012/c&e/cfm/c6.cfm
[2] Electricity $/kWh in the Northeast region from EIA Electric Power Monthly June 2014 - http://www.eia.gov/electricity/monthly/current_year/june2014.pdf
[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm

Utility Incentives/ Develop Plan for Energy Efficiency Measures (EEMs)

Both of Western's utilities are through Eversource. This places the campus in a prime position to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project."

Since incentives are based on incremental energy savings, further analysis and collaboration with Eversource is required to determine rebate amounts for each opportunity. Table 2 demonstrates a summary of the EEMs recommended for Western to pursue.

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
WCSU-1	Optimize fuel cell operations and ensure REC payments are received.	Fuel Cell	Engineering/ Administration Time	Instantaneo us	1
WCSU-2	Continue to pursue connecting the Westside Campus to Natural gas.	Westside	$1.5 Million	3.5	1
WCSU-3	Pursue Solar PV PPA	Multiple, presented in Renewable Energy Section	PPA	PPA	1
WCSU-4	Continue to recommission existing buildings every 3-5 years. (Consult with Eversource). Focus on buildings using a strategy identified in the Energy Master Plan.	All	$0.50 - $3.50 / sf	Varies	Varies
WCSU-5	Program energy submetering historian to store at least one year's data from district steam loop so total building energy use can be calculated and archive annually after review. Existing JCI EMS can be used.	Midtown	Minimal	Varies	1
WCSU-6	Retrocommission Boiler House to manage flow and/or return temperatures, adding or tuning temperature resets.	Central Plant	Varies	<1 - 3	1
WCSU-7	Continue to coordinate operations scheduling with consolidating building occupants.	All	Varies	Varies	1
WCSU-8	Explore reducing boiler system pressure further from 80 psi based on outdoor air temperature. Refer to the DOE Best Practices Steam Technical Brief http://www.nrel.gov/docs/fy06osti/37853.pdf	Midtown	Minimal	Instantaneo us	1
WCSU-9	Further insulate piping, focusing first on steam, including fittings and valves.	Midtown	$ 65,000	<1 - 3	1

WCSU-10	Explore a steam trap maintenance program, either automatic, such as Armstrong Steam-Eye, or perform at least an annual survey of all steam traps using ultrasonic or other means of detecting failed traps. (Consult with Eversource for a free/heavily subsidized audit)	Midtown	Minimal	<1 - 2	1
WCSU-11	Consult with Eversource to update lighting in Garage to LED.	White Street Parking Garage	$50,000 - $150,000	1.2 - 2.5	1
WCSU-12	Conduct a comprehensive lighting audit.	Campus-Wide	Varies (Possibly Free)	1 - 3	2
WCSU-13	Install individual thermostats on steam radiators.	Old Main, Higgins Hall	$160 - $315 per thermostat	1 - 5	2
WCSU-14	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	White Hall	Varies	Varies	2
WCSU-15	Convert pneumatic controlled HVAC systems to DDC.	Old Main, Higgins, White Hall, Berkshire Hall, Westside Building, Ella Grasso Dormitory	$2.50 - $5 /sf	Varies	2
WCSU-16	Investigate alternative energy system such as district ground source geothermal system (closed loop).	Westside	Varies	Varies	3
WCSU-17	Monitor wind incentive programs for Westside Campus.	Westside	-	-	3
WCSU-18	Monitor Fuel Cells/CHP for Westside Campus (certain fuel cells may not need a thermal load).	Westside Campus	-	-	3

TABLE 2: Western Energy Efficiency Measures

Next Steps

Management

Western should continue to review energy spend, including tracking building level energy use with Utility Direct and comparing energy spend to available budgets. The campus should also pursue building shut downs and consolidations during Winter break, to the extent possible.

Alternative Energy

Explore Power Purchase Agreements (PPAs) for rooftop solar and/or ground mounted arrays. Western should work with the System Office to explore PV options. CSCU has received favorable pricing for PPA projects with possible discounts of 20% to 50% of purchased power costs. Western may consider monitoring for wind turbine incentives, and possibly evaluate wind feasibility.

Western should also consider pursuing natural gas service on the Westside Campus, given energy cost savings, and a lower environmental impact. For Western's fuel cell, Facilities should investigate whether Renewable Energy Credits (RECs) are being secured.

By implementing the suggestions of the Energy Master Plan, Western has the opportunity to create local and cost-effective power through solar PV and changing energy sources to increase energy efficiency operations, and continue to manage energy as the campus evolves in the future.

INTRODUCTION

As part of the Connecticut State Colleges & Universities (CSCU) Energy Master Plan, Western Connecticut State University (Western)'s building infrastructure, energy use and energy management practices were assessed. The ultimate goal was to determine ways Western could improve its energy use on campus, and be an active participant in CSCU energy reduction efforts. This chapter identifies Western's historical energy use, future projected needs and energy recommendations.

1.1 WESTERN OVERVIEW

Western is a public university, serving approximately 5,826 undergraduate and graduate students. Western prides itself on its intimate classroom settings, with a student faculty to ratio of 13.8 to 1. In the fall of 2015, Western's Instructional Faculty consisted of 205 full-time and 388 part-time staff. Western's total workforce is 1,118 people.

Western has two campuses; Midtown, the 34-acre main campus in Danbury, and Westside, a 364-acre campus located approximately three miles from the main campus. The Midtown Campus is the original campus, located at 181 White Street near the Main Street Historic District in downtown Danbury, and is home to most of the University's administration as well as the School of Arts and Sciences and the School of Professional Studies. The campus includes three residence halls - Fairfield Hall, Litchfield Hall, and Newbury Hall. The Midtown Student Center, Connecticut's first state-funded LEED building and the Ruth Haas Library are located on this campus .

FIGURE 1.1: Western Connecticut State University

Western's Central Heating Plant, located on the Midtown campus in the same building as the police department, provides HVAC capabilities to the Midtown campus in conjunction with a few individual heating systems. To increase performance, Western replaced the Central Heating Plant's two boilers in 2012. In 2013, a new fuel cell began operation to provide heat and electricity to the Science Building.

The Westside campus, situated on the outskirts of Danbury, was purchased in the 1970s. The campus includes the Ancell School of Business, student Campus Center, nature center, amphitheater, three residence halls, playing fields, and athletic facilities. A new LEED Silver Visual and Performing Arts (VPA) Center opened in the Fall of 2014. There are future plans to further expand the campuses' assets with a new police station and residence hall.

Western's campuses encompass 29 owned buildings. A list of campus buildings is included in Table 1.1.

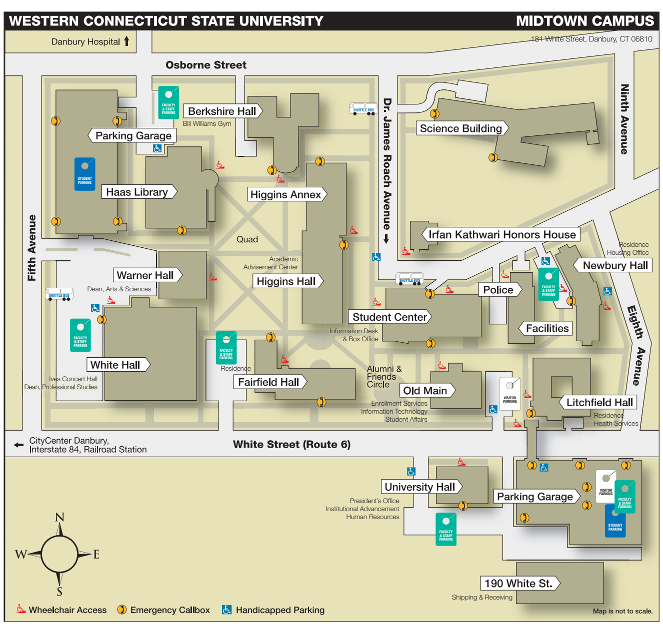

FIGURE 1.2: Western Midtown Campus

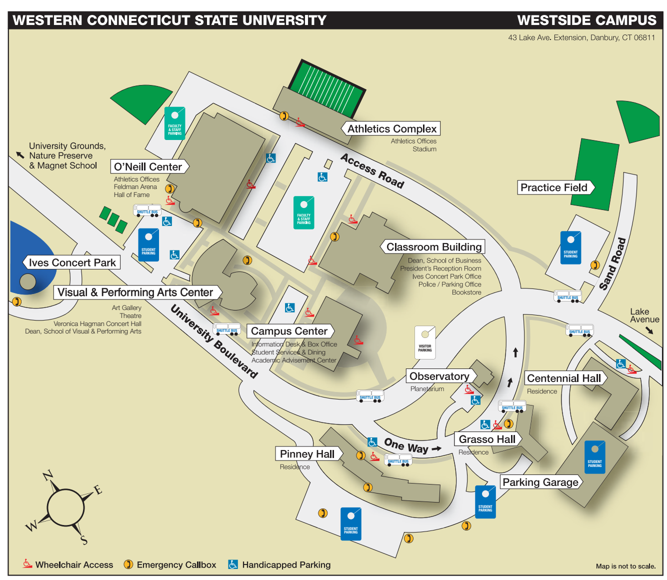

FIGURE 1.3: Western Westside Campus

Campus	Building	Year Built [Renovated]	Gross Square Feet	Building Function
Midtown	190 White St. Warehouse	1983	56,732	Warehouse and Storage
Midtown	Berkshire Hall	1958	84,796	Mixed Use
Midtown	Boiler Plant/Police/Trades	1959	10,773	Facilities
Midtown	Higgins Hall	1950	85,674	Academic
Midtown	Honors House	1932	8,434	Office/Administration
Midtown	Ives Concert Hall		2,500	Other
Midtown	Midtown Student Center	1959 [1998]	71,880	Mixed Use
Westside	Observatory	1995	2,694	Other
Midtown	Old Main Administration Building	1904	42,207	Office/Administration
Westside	O'Neill Center Field House	1994	167,581	Athletics
Midtown	Ruth Haas Library	1969[2000]	113,021	Library
Midtown	Science Building	2005	111,542	Academic
Midtown	University Hall	1984	20,302	Office/Administration
Westside	Visual and Performing Arts Center	2014	137,330	Other
Midtown	Warner Hall	1999 [2006]	34,078	Office/Administration
Westside	Western Athletic Complex	2004	18,273	Recreation
Westside	Westside Campus Center	2007	49,074	Mixed Use
Westside	Westside Classroom Building	1981	96,110	Academic
Westside	Westside Maintenance Facility	1998	2,566	Other
Midtown	White Hall	1925	133,869	Academic
Subtotal			1,249,436	
Residential Buildings				
Westside	Centennial Hall	2004	131,038	Residence Hall
Westside	Ella Grasso Dormitory	1983	78,811	Residence Hall
Midtown	Fairfield Hall	1927 [2008]	45,231	Residence Hall
Midtown	Litchfield Hall	1964-1966	53,357	Residence Hall
Midtown	Newbury Hall	1969	60,158	Residence Hall
Westside	Pinney Hall	1999	193,772	Residence Hall
Residence Hall Subtotal			562,367	
Building Total GSF			1,811,803	
Garages				
Westside	Centennial Parking Garage	2004	138,215	Parking Garage
Midtown	Midtown/5th St/Student Parking Garage	2006	257,500	Parking Garage
Midtown	White Street Parking Garage	1996	215,421	Parking Garage
Parking Garage Subtotal			611,136	

TABLE 1.1: Western Campus Building Information

1.2 PREVIOUS ENERGY STUDIES & PROJECTS

According to Western, approximately a third to two thirds of the buildings on the two campuses have been audited. The campus has also strategically implemented the following measures:

- Lighting retrofits,
- Energy efficiency upgrades,
- Expanded building automation and controls,
- HVAC system renovations that provide access to natural gas as an alternative to oil use at most Midtown campus buildings,
- Boiler replacements,
- Demand Response, and
- Energy monitoring

Western has completed extensive building automation system (BAS) optimization actions since 2007, totaling over $3 million in savings to date.* Western was also recently recognized for environmental responsibility with the 2015 Green Award by the Morris Media Group.** The group commended Western for energy reduction in Pinney Hall, facilitated by investing over $450,000 in smart-building technology. Other accomplishments related to achieving LEED Silver status for the VPA building and installation of four electric vehicle (EV) charging stations. Western's efforts continue to exemplify a commitment to energy conservation and efficiency.

*EnerNOC, List of Past Projects.
** Hill, Sherri. "WCSU earns 2015 Green Award from Morris Media Group," 2015. Web. http://www.wcsu.edu/facilities/pdfs/WCSUearns2015GreenAwardfromMorris%20MediaGroup.pdf

EXISTING CONDITIONS & RECOMMENDATIONS

Information on Western's existing conditions was captured from campus interviews, energy data and reports provided by the campus. A holistic view of existing practices, material on energy management, energy infrastructure and project implementation processes was reviewed. Analysis of the data and campus walkthroughs helped clarify recommendations with the goal of decreasing energy use, documented after each subheading.

2.1 FACILITY ENERGY BENCHMARKING AND ENERGY CONSUMPTION

The energy dashboard in Figure 2.1 provides an overview of Western's energy use, based on fiscal year 2014 and 2015 data. These results are intended to be indicative of general performance only and not by any means directly correlated to absolute performance given that each campus has different academic uses, occupancy patterns and program goals. The utility data received indicates Western is performing at the average of the CSCU campuses from an energy perspective. Recently installed condensing gas domestic hot water boilers at the Midtown campus are expected to further reduce the campus EUI. Western's site EUI of 115 kbtu/sq ft is above the Northeast median for colleges/universities.

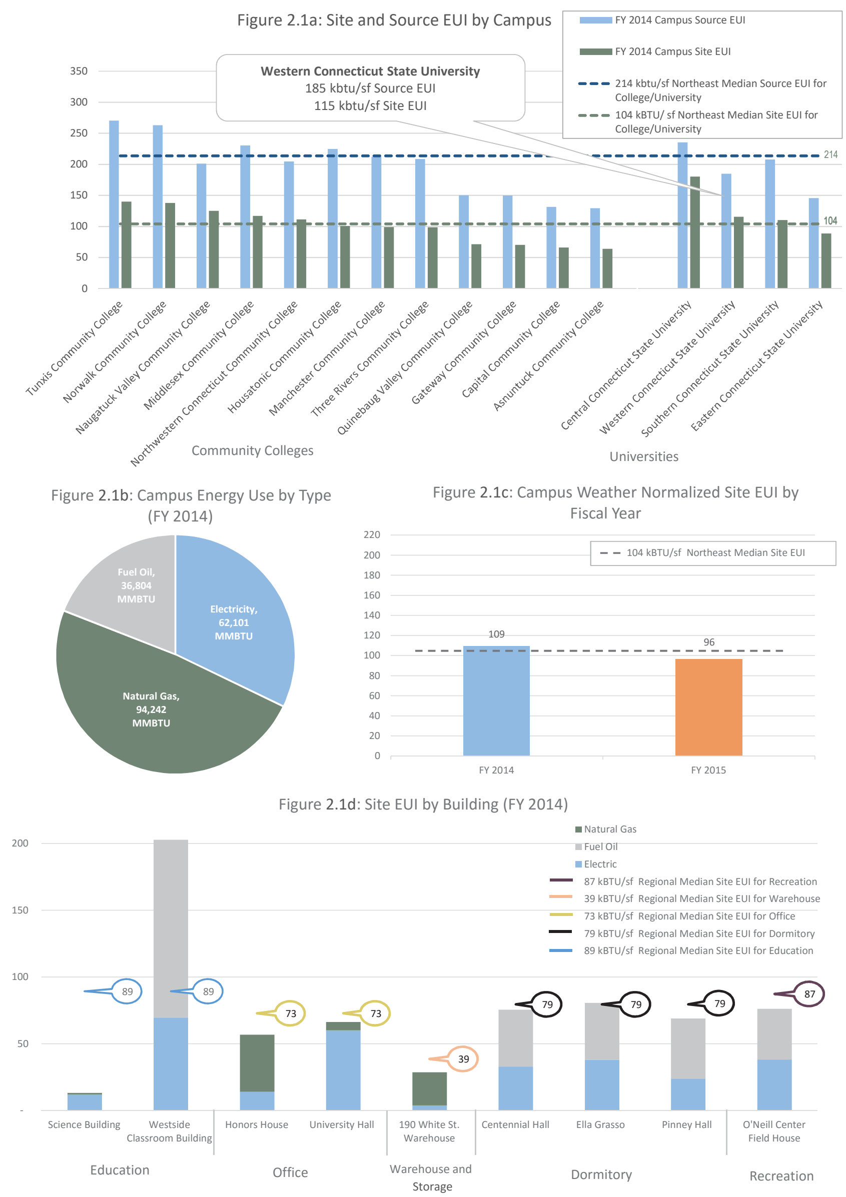

FIGURE 2.1: Western Connecticut State University Energy Dashboard

* Only buildings with both electricity and fuel submetering data are shown
** Note The Science Building's heating and electricity are largely provided by a 400 kW fuel cell. The EUI does not reflect the building consumption of the fuel cell's generation as separate metered data is not available at this time.

Figure 2.1d, displays campus site EUIs for the buildings with full metering data, with the exception of the Science Building in which the EUI does not include fuel cell generation metering. Aside from the Westside Classroom Building, each of the buildings with available EUI data are less than the regional median site EUI for the same building type. The Westside Classroom Building relies on fuel oil for heating which contributes to more than half of the EUIs. Other than the Westside Classroom Building, the data suggests Western is performing well.

While each building at Western has its own electric and gas account, those that rely on steam or hot water heating are not displayed in the EUI in Figure 2.1d. The fuel use for the buildings on steam or hot water are not a clear indicator of actual energy use since the steam from the Central Plant is not metered.

Table 2.1 provides a comparison of FY 2014 energy spending compared to the average of CSCU campuses and the Northeast Region Commercial Sector.

Energy spending per gross square foot (GSF) per year for each building with full submetering is broken out in Figure 2.2. If a building is not shown, energy submetering is recommended to complete the total energy use profile for each building.

While most of Western's data are consistent with or below the average of the CSCU campuses, the cost per FTE is approximately 50% more than the average of the other CSCU universities. This may be attributed in part to Western's population density. Western has a 25%-40% higher gross area per student than Southern and Central, but less than Eastern. Additionally higher cost/FTE may be a factor of Western's expansive and use of higher cost fuel oil for the Westside Campus. Buildings such as residence halls with longer operational schedules than academic or administrative buildings, along with various summer programs, cause the universities in general to have higher costs per FTE student than community colleges.

2.2 CAMPUS UTILITIES AND DISTRIBUTION

Western consumes primarily three energy sources- electricity, natural gas and fuel oil. There is limited propane and diesel use as well. The Midtown campus buildings are distributed from the central steam plant, operating on natural gas. The Westside Campus buildings are heated by distributed systems fueled by oil, since the Westside campus does not currently have any access to natural gas.

	Western Connecticut State University	Average of CSCU University	Average of CSCU Community College	Northeast Region Commercial Sector
Cost per Square Feet	$ 2.60	$ 2.08	$ 2.49	$ 1.67 [1]
Cost per FTE Student	$ 900	$ 677.00	$ 311	$ -
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[3] Natural gas $/MMBtu in the Northeast region from EIA Connecticut Price of Natural Gas - *http://www.eia.gov/dnav/ng/hist/n3020ct3m.htm*

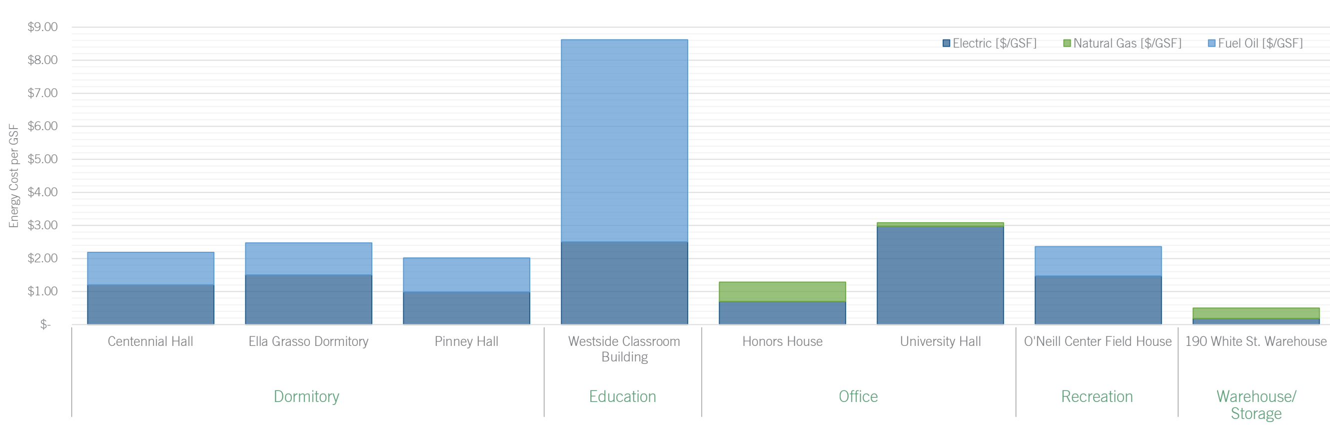

FIGURE 2.2: Western FY14 Energy Cost per GSF by Building Type

Note: Buildings missing from the graph do not have available submetering. To complete a total energy use profile, energy submetering is recommended.

There is no central cooling on either campus. Western's utility providers include:

Electricity: Eversource, formerly Connecticut Light & Power

Natural Gas: Eversource, formerly Yankee Gas

Fuel Oil: Dime Oil*

Propane: Leahy Fuels*

From a long-term strategic standpoint, Western should switch from fuel oil to natural gas on the Westside Campus. The campus is recommended to switch to natural gas for a number of reasons:

- Lower carbon energy source than fuel oil
- Typically, lower cost per MMBTU of natural gas compared to fuel oil
- Eliminates maintenance costs associated with oil heat
    - **a.** Can eliminate holding tanks for fuel oil storage requirements (if not using dual fuel)
    - **b.** Eliminates the need for trucking fuel deliveries
- Enables the use of more widely available, higher efficiency condensing boilers

In 2016, Western commissioned a study with Eversource to expand its existing natural gas infrastructure in Waterbury up to the University Boulevard. Eversource estimated the project would require approximately $1 million for the 2.5 mile expansion onto the campus, and another $500,000 for the remaining one mile of service and necessary building conversions.

From a cost standpoint, the price of fuel oil has dropped substantially, yet is still more costly per unit than natural gas. Based on FY 14 and FY 15, the unit price of fuel oil on an MMBTU basis approximately halved while the cost of natural gas increased. Annual savings based on FY 2015 natural gas unit costs are approximately $245,000 (see Table 2.2).

Fiscal Year	2014	2015
Fiuel Oil Use (MMBTU)	36,804	44,121
$/MMBTU	$ 33.62	$ 16.78
Total Cost	$ 1,142,794	$ 684,880
Savings based on Fiscal Year Natural Gas Cost	$ 927,093 ($8.43/MMBTU)	$ 244,872 ($11.23/MMBTU)

TABLE 2.2: FY 14 and FY 15 Western Fuel Oil Costs; Projected Savings

Consideration of this investment depends on future oil and gas prices, and cannot be determined with certainty. The U.S. Energy Information Administration (EIA) provides short-term, with the most current analysis projecting until 2017, and long term price projections.

In the latest 2016 Annual outlook, EIA projects prices out to 2040. Figure 2.3 represents expected pricing trends for natural gas and oil based on long-term commercial costs. In the reference case, the figure demonstrates an increasing price gap between natural gas and fuel oil into the long-term. As is the case with Western, while fuel oil prices did see a significant drop in the past year, fuel oil prices are expected to rebound. By the end of 2040, commercial New England natural gas prices are projected to increase by an annual average of 0.7%, while distillate commercial oil prices are projected to experience an annual average 2.4% price increase.

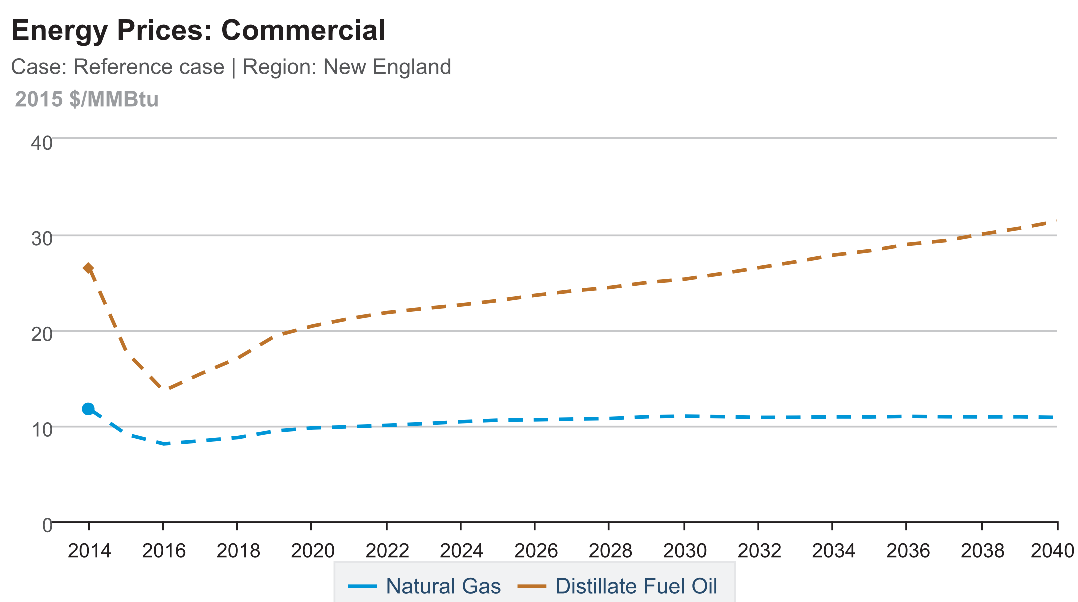

FIGURE 2.3: Projected New England Fuel Prices Over Time Based EIA Reference Case

*Western is part of a Connecticut open contract for fuel oil and propane, therefore vendors often change depending on contract.

EIA project pricing is based on geopolitical scenarios, supply and demand, technology developments, policy changes and numerous other scenarios. As Figure 2.4 demonstrates, even in the low fuel oil cost reference case, the cost of fuel oil still surpasses natural gas by at least $3/MMBTU. The scenario reflects a case in which there is slower economic growth, less consumption, less travel and other factors resulting in lower demand for liquid fuels and a higher supply.

In all cases of the Annual Outlook natural gas prices are lower than oil prices.

Given the price disparity, it is likely that by switching to natural gas, Western could continue to see energy savings.

For the simple payback calculation and to reflect potential changes in prices greater than a one-year short term outlook, the EIA Reference case is used for savings. The percent changes in price in the reference case is applied to the FY15 average fuel oil price for the Westside campus and the FY 15 natural gas use. Based on the data, the simple payback is approximately 3.5 years (See Table 2.3).

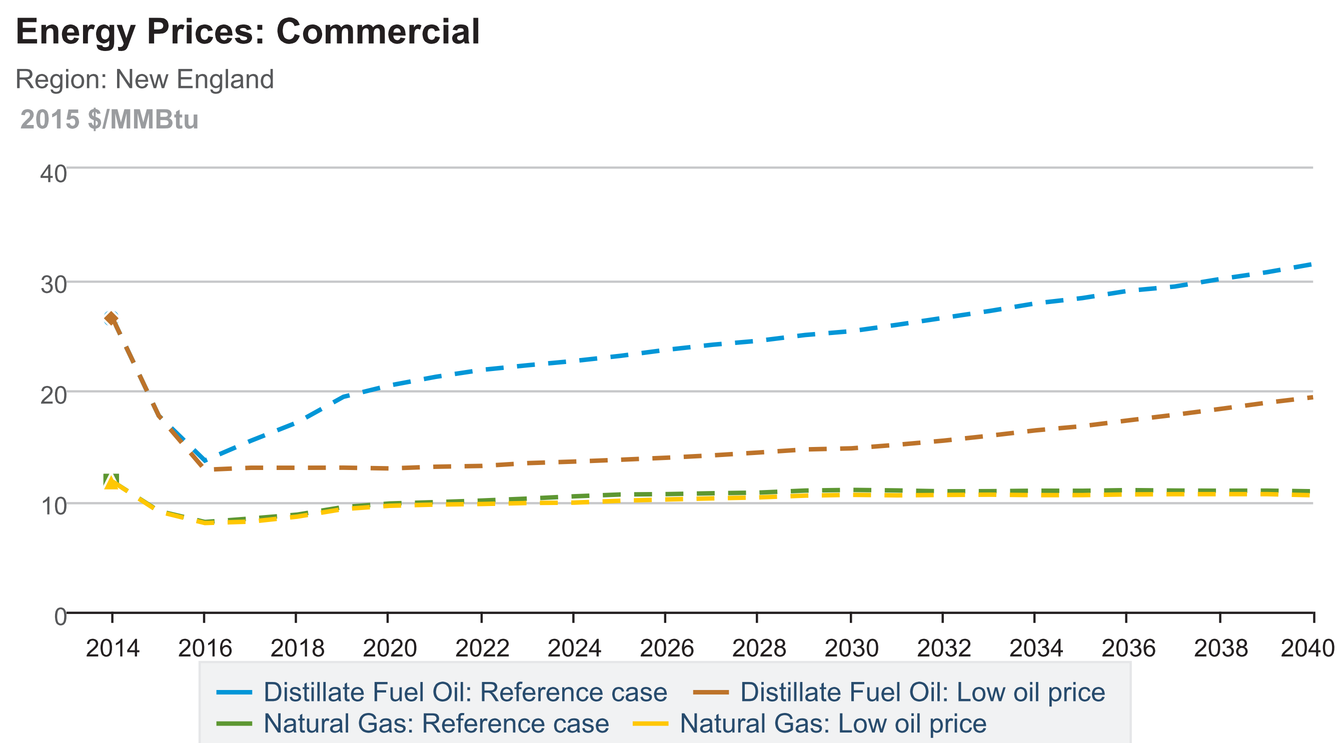

FIGURE 2.4: Comparison of New England Projected Fuel Oil Prices Based on EIA Reference Case and Low Oil Price Scenario

Item	Year	2016	2017	2018	2019	2020	2021
Capital Cost	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
Approximate Savings per Year		$ 329,385	$ 398,804	$ 483,861	$ 520,629	$ 556,053	$ 581,847
Savings to Date/Cash Flow		$ 329,385	$ 728,189	$ 1,212,050	$ 1,732,679	$ 2,288,732	$ 2,870,579
Cumulative Cash flow	$ (1,500,000)	$ (1,170,615)	$ (771,811)	$ (287,950)	$ 232,679	$ 788,732	$ 1,370,579

Payback	3.55

TABLE 2.3: Natural Gas Project Payback with New England EIA Reference Case Prices

Using the low oil price case (the scenario with the lowest cost of fuel oil), payback increases to approximately 6.5 years.

Item	Year	2016	2017	2018	2019	2020	2021	2022	2023
Capital Cost	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000	$ 1,500,000
Approximate Savings per Year		$ 252,365	$ 223,848	$ 181,282	$ 158,555	$ 160,771	$ 161,654	$ 593,945	$ 602,434
Savings to Date/Cash Flow		$ 252,365	$ 476,212	$ 657,494	$ 816,049	$ 976,820	$ 1,138,474	$ 1,732,419	$ 2,334,853
Cumulative Cash flow	$ (1,500,000)	$ (1,247,635)	$ (1,023,788)	$ (842,506)	$ (683,951)	$ (523,180)	$ (361,526)	$ 232,419	$ 834,853

Payback	6.61

TABLE 2.4: Natural Gas Project Payback with Low Oil Reference Case Prices

Despite multiple fuel scenarios that EIA presents, natural gas prices are still expected to remain lower than fuel oil. Therefore, the sooner Western switches to natural gas, the more savings the campus is likely to see.

2.3 ENERGY PROCUREMENT

Western is part of the CSCU's 2013 electric supply procurement contract with Direct Energy, formerly Hess Energy, detailed further in the Energy Master Plan. In FY13 Hess Energy was also the natural gas supplier. The local distribution company, Eversource, became Western's supplier in FY14.

Western purchases propane and fuel oil through Connecticut's Department of Administrative Services (DAS) open contract. The contract aids in bundling fuel delivery and lowering unit costs. Section 2.2 documents Western's current vendors for fuel oil and propane, but the vendor often changes depending on the contract.

2.4 OPERATIONAL AND ENERGY MANAGEMENT PRACTICES

2.4.1 CURRENT CONDITIONS

Western's infrastructure maintenance, improvement, and utility operations are completed under the umbrella of the Division of Facilities Services (Facilities). The Division consists of Environmental Health & Safety (EHS), Facilities Operations, Facilities Planning & Engineering, Facilities Scheduling and Promotion, and the WestConnect Card Office. Maintenance Trades and Minor Capital Projects in the Facilities Operations Department manage minor capital projects and building maintenance, while Facilities Planning & Engineering oversees large construction projects.

Western's campuses are occupied year round, with the exception of Winter Break. The campuses operate on a two semester a year schedule, with three to four summer sessions, campus and other programs during the summer. Facilities does not currently have the ability to schedule routine building shut downs. During Winter break there are no classes scheduled, but one or two faculty members may use their campus offices or labs. During the winter period, Facilities manages energy by adjusting setbacks and lowering temperatures, but does not shut the buildings down. The heating season begins October 15th and ends April 15th. When the heating season has ended, all heating systems in all buildings are turned off to eliminate standby losses and save energy.

Occupancy greatly fluctuates throughout the week and buildings are not always effectively utilized. An estimated 80% of classrooms are used in a three-day period, rather than all five days of the school week. In particular, students and faculty often use the labs in the science buildings only twice a week. In terms of energy intensity, the Science Building has a low EUI based on utility bills, since the fuel cell covers a large portion of heating and electricity costs. Part of the campus Master planning effort, includes the identification of ways to better utilize existing space.

Western does not have a designated temperature policy, yet tends to keep baseline temperatures between 68-72 °F. Humidity control in particular can be an energy intensive effort and has a large impact on what occupants feel as comfortable in relation to temperature.

ENERGY USE INFORMATION MANAGEMENT SYSTEMS

The Facilities Division monitors and manages energy use and infrastructure improvement through several management systems. Facilities implements a work-order management system, Maintenance Direct, which allows University faculty and staff to request and track maintenance work. Most buildings have some controls through the campuses' BAS, Johnson Controls. New buildings have full BAS coverage.

For energy data tracking, most buildings at Western are individually metered. Each building account is linked through a SchoolDude UtilityDirect module. The module contains reporting features to filter by energy type as well as track all utility costs and consumption, and present data based on cost per square foot, building totals, cost budgets and multiple other features. In this way, Western's Facility staff are generally apprised of energy consumption and spending.

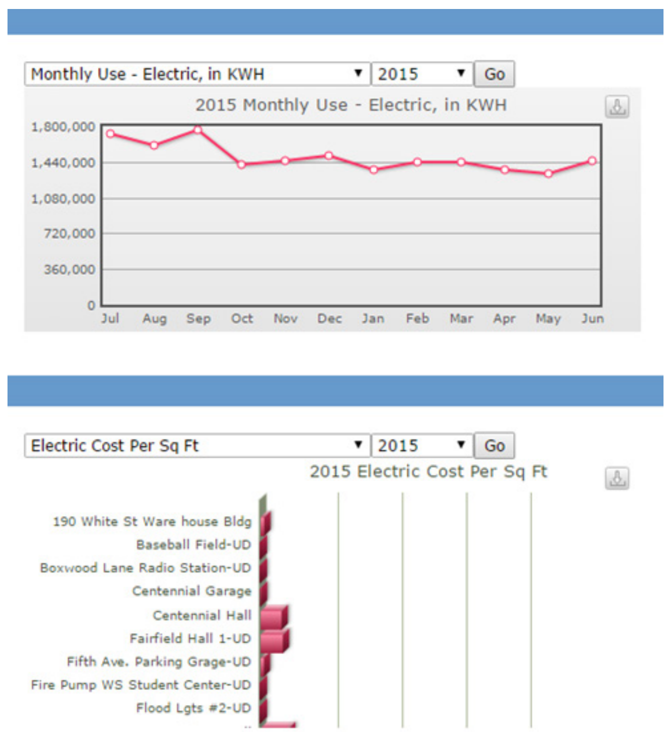

FIGURE 2.5: UtilityDirect Dashboard

From 2004 until the beginning of January 2016, Western had a partnership with EnerNOC for energy scheduling, work order management, and daily monitoring. Western used EnerNOC's PowerTrack platform for 15 buildings. More information about the partnership and results are presented in the Collaboration/ Partnerships section.

EnerNOC had controllers on the JCI infrastructure, drawing all data and reading it. Some buildings which still use pneumatics are unable to benefit from the advantages including monitoring and controling the BMS with DDC provide.

2.4.2 RECOMMENDATIONS

Western does a good job of staying apprised of building data and needs through the use of several energy and infrastructure software platforms. To the extent possible, Facilities should consider executing set backs and building shut downs during Winter break. Conversations may want to be broached with administration to consolidate faculty members in need of office space during the winter break. Now that EnerNOC is no longer viewing daily energy use, a current staff member or outside resource should to be tasked with monitoring and tracking consumption of various buildings using Utility Direct.

As part of the CSCU Energy Master Plan recommendations in Section 5.2.2, the System Office should create a template for energy tracking applicable to all campuses. Western should use this template to track energy over time rather than viewing energy use through bills only.

ASHRAE 90.1 is an excellent resource to reference for standards relating to design and operation. Alongside 90.1, ASHRAE 62.2 for IAQ should also be referenced. Always reference the most up-to-date edition as research is updating recommended ventilation flow rates and practices with each release.

2.5 EXISTING BUILDING COMMISSIONING

2.5.1 CURRENT CONDITIONS

Western implemented numerous continuing commissioning through EnerNOC. In 2008, the Association of Energy Engineers honored Western with an Energy Project Award for Innovative Retrocommissioning. Over the four-year period, the campuses' 14 identified energy efficiency measures resulted in natural gas and electricity costs savings in excess of $90,000* . As of 2016, Western secured an estimated $598,000 in annualized cost savings resulting from calibration, controls, scheduling and mechanical-related energy efficiency measures. (See Table 2.5) With most low-hanging energy opportunities tackled, recent efforts with EnerNOC have seen diminishing or limited returns and therefore the partnership has been discontinued.

	Count of Equipment	Sum of Annualized Electricity Savings 9kWh)	Sum of Annualized Thermal Energy Savings (100,000 BTU)	Sum of Annualized Cost Savings	Sum of Savings to Date
Calibration	35	25,219	-	$ 4,035	$ 19,203
Control	139	419,819	103,887	$ 193,913	$ 412,017
Mech.	44	548,168	15,172	$ 112,358	$ 463,231
Schedule	34	845,686	125,415	$ 288,345	$ 2,152,625
Total	252	1,839,074	244,473	$ 598,651	$ 3,047,076

TABLE 2.5: Western Past Projects and Associated Savings

A summary of the past projects and savings associated are shown in Table 2.5.

2.5.2 RECOMMENDATIONS

Buildings with BMS with measurable points stand to benefit the most from recommissioning. For the buildings that do not have a BMS, Western may benefit from manually checking all systems, especially actuators and pneumatic valves, to ensure they operate as intended. As a general rule of thumb, retrocommissioning existing building systems should occur every 3-5 years.

2.6 MECHANICAL SYSTEMS

2.6.1 CURRENT CONDITIONS

Western has two completely independent campuses, each with its own unique energy systems. A summary of the heating and cooling systems for both campuses is provided in Table 2.6..

WESTSIDE CAMPUS

The Westside campus is limited to fuel oil or electricity as a source of heat, although most of the existing boilers are setup for dual fuel should there be a future natural gas connection. Dual fuel boilers are usually not designed for condensing operation and therefore achieve efficiencies in the 80-88% range. Each building has its own independent heating system with no district heating loop in place.

Cooling is supported by a combination of chilled water (CHW) systems, direct expansion (DX) coolers, or less efficient window mounted AC units. There is also no district cooling loop.

*Energy Vortex "Western Connecticut State University Receives Energy Project Award for Innovative RetroComissioining," 2008. Web. Western Award for Innovative RetroCommissioning - EnergyVortex.pdf

Campus	Name	Gross S.F.	Fuel EUI (Btu/GSF)	Heating				Cooling				Heat Pump
				Heating Plant Steam	Local Heating System	Electric Heat	None	CHW System	DX System	Window AC Units	None	
Midtown Campus	Berkshire Hall	84,796		■		■			■	■		
Midtown Campus	Boiler House	10,773		■					■			
Midtown Campus	Ruth Haas Library	113,021		■				■				
Midtown Campus	Higgins Hall	85,674		■					■			
Midtown Campus	Honors House	8,434	43		■				■			
Midtown Campus	Old Main Administration Building	42,207		■					■			
Midtown Campus	Science Center	111,542		■				■				
Midtown Campus	Midtown Student Center	71,880	41	■					■			
Midtown Campus	University Hall	20,302	6		■				■			
Midtown Campus	Warner Hall	34,078		■				■				
Midtown Campus	White Hall	133,869		■				■				
Midtown Campus	190 White St. Warehouse	56,732	25				■				■	
Midtown Campus	Fairfield Hall	45,231		■								
Midtown Campus	Litchfield Hall	53,357		■					■			
Midtown Campus	Newbury Hall	60,158		■				■				
Midtown Campus	White St. Parking Garage	257,500					■				■	
Midtown Campus	Midtown/5th St/Student Parking Garage	215,421					■				■	
Westside Campus	Western Athletic Complex	18,273			■				■			
Westside Campus	Westside Campus Center	49,074			■			■				
Westside Campus	Westside Classroom Building	96,110	133		■			■				
Westside Campus	O'Neill Center Field House	167,581	38		■			■				
Westside Campus	Visual and Performing Arts Center	137,330			■			■				
Westside Campus	Observatory	2,694					■				■	
Westside Campus	Westside Maintenance Facility	2,566					■				■	
Westside Campus	Centennial Hall	131,038	43		■			■				
Westside Campus	Ella Grasso Dormitory	78,811	42		■			■				■
Westside Campus	Pinney Hall	193,772	45		■					■		
Westside Campus	Centennial Parking Garage	138,215			■					■		

TABLE 2.6: Western Existing Building Systems Summary

MIDTOWN CAMPUS

The Midtown campus has a central plant, known as the Boiler House, which produces 80-100 psig steam. The Boiler House has two (2) dual fuel 500 HP boilers, installed in the Fall 2012, to replace boilers which were fifty-years old. One original Bigelow 525HP boiler remains as only a backup. Maintenance Direct lists seven boiler rooms in total. Six of the boiler rooms are located at the Midtown campus and the last is at the Danbury Armory. It is unknown why all boilers do not appear in Maintenance Direct.

The steam from the boilers is converted to hot water in most buildings through heat exchangers. Some buildings use the high pressure steam directly. Recent reports indicate only 80% of the steam mass leaving the boilers returns as condensate. While some steam is used for humidification, a higher return rate is expected with losses due to blow down and venting which should only be a few percent. Steam traps are common maintenance challenges where in-house maintenance staff are responsible. The domestic hot water system is a stand-alone loop. All underground piping is direct burial.

Cooling is supported by a combination of CHW, DX, and window AC units with no central chiller for district cooling. In 2013, a fuel cell was installed which provides electricity and heat for the Science Building at the Midtown campus.

2.6.2 RECOMMENDATIONS

The following recommendations would aid in optimizing efficiency and reducing energy consumption.

BOILER SYSTEMS

- Move forward with connecting the Westside campus to natural gas. For any new construction, consider installing condensing natural gas boilers which can achieve efficiencies greater than 90%, as compared to oil boilers which do not often exceed 85%.
- Include boilers systems in recommissioning efforts. Temperature resets and hot water flow rates should all be considered and lowered as much as possible while still meeting building heating and domestic hot water needs, and manufacturers minimum return temperatures for hydronic systems.
- Include all valves and fittings when insulating, with priority for hotter, larger piping.
- Implement a steam trap maintenance program, either automatic such as Armstrong Steam-Eye, or perform at least an annual survey of all steam traps using ultrasonic or other means of detecting failed traps. Steam traps may fail open or closed, either wasting thousands of pounds of steam per month, or rendering steam coils inefficient or ineffective.

a. This EEM often has the most rapid return on investment, even without utility incentives. With the incentives, the cost of the steam trap survey can be 100% covered. The repair of traps can also be substantially covered by the rebate program.

- Install individual radiator thermostats. These can be installed for less than a few hundred dollars each and typically provide 9-15% savings according to a 1995 study paid for by NYSERDA.

FUME HOODS

- Implement a fume hood sash management program to ensure hoods are closed and turned off when not in use.

2.7 LIGHTING

2.7.1 CURRENT CONDITIONS

As a standard practice, Western adds LED fixtures and occupancy sensors in conjunction with renovations. The campuses generally lack BMS controlled lighting.

2.7.2 RECOMMENDATIONS

All lighting upgrades should be coordinated with Eversource to help maximize the return on investment. Western should consider the following recommendations:

- Conduct a lighting and controls audit.
- Continue to add occupancy based lighting (and ventilation) controls during renovations. Prioritize upgrades outside of capital planning when funding is available.
- All exterior lighting should be replaced with LED and have photo sensors installed to replace timers.

2.8 BUILDING ENVELOPE

2.8.1 CURRENT CONDITIONS

Western's Midtown campus has eight buildings that are over 50 years old and listed on the State Register of Historic Places. These buildings include:

- Old Main Administration Building
- White Hall
- Fairfield Hall
- Higgins Hall
- Berkshire Hall
- Boiler Plant (has been since updated)
- Midtown Student Center
- Honors House

In 1979, Connecticut legislated its first energy-related state wide standards for buildings, with 1981 as its implementation year. Therefore, for buildings constructed prior to 1981, it is assumed there is limited insulation, air sealing and other energy-related building envelope features that are now standard practice.

2.8.2 RECOMMENDATIONS

Western should insulate wood frame residential-style construction building that were constructed prior to 1981 as they are assumed to not have had to abide by stricter building codes. The following sections provide best practices for building envelopes that can be considered by Western, particularly for the buildings constructed prior to 1981.

- Review and ensure ventilation set points are not excessive per the latest edition of ASHRAE 90.1
- Address air infiltration issues by sealing doors and windows
- Insulate heated garage spaces
- Conduct a thermography study using ASTM C1060 or ISO 6781 of buildings built prior to 1980 to identify where there are defects or a lack of insulation.
- Hire a certified consultant to commission the building envelope for new construction using the National Institute of Building Sciences (NIBS) Guideline 3-2012 to include:

  a. Design & construction document review

  b. Laboratory and/or on site performance verification tests

  c. Construction visual QA/QC Inspections

    1. Air, water, water vapor, and thermal barriers

- Include building envelope in recommissioning activities.

2.9 DISTRICT ENERGY / COGENERATION

2.9.1 CURRENT CONDITIONS

The Boiler House at the Midtown campus is connected to the only district steam loop. The Science Building, originally supplied by the Boiler House, has a 400 kW fuel cell, which now provides a majority of the thermal energy needed by the building.

Both Western and Eastern have similar contract terms for their fuel cell.

In March 2012, Western entered into a power purchase agreement (PPA) with Doosan Fuel Cell America (Doosan), formerly UTC Power, for a PureCell Model 400 fuel cell located at the Science Center. A similar contract was provided for Eastern Connecticut State University's 400 kW fuel cell. Under the 10-year term contract, Western pays a fixed monthly payment of $24,834.

FIGURE 2.6: Western 400 kW Fuel Cell

Contract terms and structuring notes include:

- University personnel are trained and responsible for visually inspecting equipment each day, from outside the fence.
- Doosan will provide information to the University on the fuel cell for educational purposes.
- Doosan provides a guaranteed minimum output (GMO) (Mwh) during the 10-year term as well as a consumption guarantee
- If the kwh output for the year does not meet the total guaranteed minimum output (GMO), Doosan will credit the University one percent of the annual payment for each one percent under delivered. Only a credit will be applied if the lack of output is directly related to the system. If the output surpasses the GMO, the University must then compensate Doosan using the same structure.
- Doosan is responsible for providing Western with a usage report at the end of each calendar year, and Western also has access to usage data online.
- Two days of notice are given prior to maintenance
- The system is set up for net-metering mode

Based on the contract payment details outlined in the CSCU Energy Master Plan, the approximate normalized electrical cost for operation of the fuel cell is $0.158/kWh without the capture of Renewable Energy Credits (RECs). The normalized cost is inclusive of fuel input required, using the guaranteed maximum fuel consumption of 425,790 MMBtu over the term, as well as the minimum electric guarantee. Western's fuel cell has been operating well and with consistent electricity output. It is unclear if the campus is currently receiving RECs.

2.9.2 RECOMMENDATIONS

While the heating season (October 15-April 15) could support up to a 600 kW CHP base load to provide 19,000 therm/month, the lack of any thermal demand for the remainder of the year greatly extends the return on investment of an CHP system. (See Appendix B for more detail on the high-level screening). A second CHP system should not be considered again until the existing fuel cell is near it's end-of-life.

Meanwhile, recommendations for maximizing savings from the existing fuel cell CHP system consist of the following:

- Ensure REC payments are being recovered by Western

  a. Consider domestic hot water, makeup air, or feedwater preheating with excess energy to increase the efficiency.

  b. Based on the contract terms, Doosan is responsible for selling the RECs and retains 5% of the revenue

  c. 1 MWh of electric output is equivalent to one REC in Connecticut. 2016 market prices for a Class I REC are approximately $32.

While CHP may not be feasible given the limited thermal load, there have been advancements in fuel cell technology to produce electricity without a thermal sink.

2.10 DEMAND RESPONSE

Western was the first state agency in Connecticut to implement a demand response program. The campus reduced building loads for 14 of its biggest energy users, totaling 2.1 MW when demand response days were called.

2.10.1 CURRENT CONDITIONS

In anticipation of hot weather and high humidity days, Western should continue to enact demand response measures, such as equipment shut downs and involve the campuses in these events. As part of EPA's regulations, in order to participate in real time demand response, generators must meet EPA's Tier IV emissions requirements. The requirements place stricter emission guidelines on particulate matter and nitrogen oxides. Western should purchase Tier IV compliant systems for any future generators intended to be used for demand response.

2.11 RENEWABLE ENERGY

2.11.1 CURRENT CONDITIONS

Western does not currently have any renewable energy systems on campus. However, Western has been involved in a solar RFP for a 60 kW solar array, which went out to bid multiple times. Results in the past were not favorable. As of 2016, Western is involved in a joint RFP with Middlesex in the hopes of generating more interest for the Connecticut small LREC program. According to the campus, there is preference for purchasing an array rather than leasing, given past unfavorable electricity pricing.

2.11.2 RECOMMENDATIONS

There are several potential opportunities for rooftop solar PV on campus depending on roof age, plans for renovations, and availability of space not encumbered by mechanical equipment. In general, there are opportunities for small sites of less than 200 kW. For ground-mount solar, most of the available land is either tree covered or used for recreational purposes. Tree removal may provide additional opportunities for ground-mount. Solar PV should be incorporated into future capital planning building design.

Table 2.7 provides an overview of the buildings that may be considered for solar PV in the future. Following the table are images of each of the sites.

Building Name	Year Built [Renovated]	GSF [FY 2015]	Building Roof sq. ft.	Roof Install/ Replacement Date	Roof Type	Array Size Potential (kW DC)[1]	Annual Generation Potential (MWh)[2]	Solar Suitability Comments
HIGHER PRIORITY PROJECTS								
Litchfield Hall	1964-1966	53,357	17,786	Planned 2017	Built Up	65-85	85-110	Clear flat roof, about to get a new roof
O'Neill Center (Gymnasium Roof)	1994	167,581	52,100	2014	Membrane	192-250	250-321	Perfect candidate. New roof. PV over gym and pool. Not over lobby bar
Pinney Hall	1999	193,772	32,295	1999	EPDM	119-155	155-199	Ballasted roof needs replacement. Pinney Hall lower parking lot is a possible condidate for PV canopy. (Not the lot adjacent to bldg.)
Westside Campus Center	2007	49,074	24,537	2007	Membrane (25 year life)	90-118	118-151	A good condidate over ballroom. Not over the east end roof
Westside Maintenance Facility	1998	2,566	2,566	N/A	N/A	9-12	12-16	Good candidate but older roof needs replacing
Subtotal		466,350	129,284			475-620	620-797	
POTENTIAL/LOWER PRIORITY PROJECTS / TO BE DETERMINED								
Berkshire Hall	1958	84,796	42,398	1971	Built Up	156-204	204-261	Roof near end of life
Centennial Hall	2004	131,038	26,208	2004	Standing seam metal roof	96-126	126-161	Azimuth of roofs not ideal and would cause a 2-5% reduction in output. Standing seam metal roofs can be an advantage in that no roof penetrations are necessary for fastening. However, FM Global must approve.
Ella Grasso Dormitory	1983	78811	15762	2016	Rubber	58-76	76-97	Building has new roof, but many roof prostrisions.
Higging Hall	1950	85,674	28,558		Membrane	TBD		Higgins Annex: Roof needs to be replaced. TBD what the new eqipment will be. Higgins: A lower priority from roof obstructions
Midtown Student Center	1959 [1998]	71,880	25,980			60-78	78-100	The previous solar RFP did not sufficient bidders. Feasible in scale if paired with other roofs.
Midtown /5th Street/Student parking Garage	2006	257,500	67,209			247-323	232-414	TBD if structural capacity; aesthetics OK
Newbury Hall	1969	60,158	12,032	2012/2013	Built Up	44-58	58-74	Scheduled for renovation in approximately 3 years
Ruth Haas Library	1969 [2000]	113,021	18,837	N/A	Built Up / Ballast ED	69-90	90-116	Low priority. Building has multiple levels, and lower levels are in shade
Science Building	2005	111,542	8,316			38-50	50-64	Available area includes only south portion of the building.
University Hall	1984	20,302	5,076		Built Up	19-24	24-31	Low priority. Very small
Warner Hall	1999 [2006]	24,078	11,359		Membrane	42-55	55-70	Low priority. Switchgear on lower floor, little usable roof area for PV
White hall	1925	133,869	30,153	1996 (20+ years)	Built Up	55-72	72-93	Low priority. Flat roof, but many protrusions. Array size factors 40% of total roof area.
White Street parking Garage	1996	215,421	86,132			317-413	413-531	Sized for extra levels, so the load is acceptable.
Subtotal		157,554				1201-1569	1569-2012	
Total		623,904				1676-2189	2189-2809	

TABLE 2.7: Western PV Potential

FIGURE 2.7: Western Westside Campus Potential Areas for Solar PV

[1] Default assumption is that 80% of roof area is available for solar PV, or if total PV available space is used then 100% of area is assumed. Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Also assumes that each sf of panels can generate between 4.6 and 6 Watts DC (about a third of the PVWatt Output Assumptions). Actual generation values would be calculated if a solar PV study was performed.
[2] Assumes that 80% of roof area is available for solar PV and that each sf of panels can generate between 6 and 7.7 kWh annually (about a third of the PVWatt Output Assumptions). Buildings with mechanical equipment and other structures located on the roof will have less than 80% available space. Actual generation values would be calculated if a solar PV study was performed

FIGURE 2.8: Western Midtown Campus Potential Areas for Solar PV

WIND POTENTIAL

There may be an opportunity for building-integrated wind at Western. Generally, larger wind installations require wind speeds upwards of 6.5 m/s at heights of 80 m. Residential or microwind applications can create power over 4 m/s. The map below shows average annual wind speed at 30 m in Connecticut. Locations along the shoreline are considered the most suitable conditions for wind power at that height. The Westside campus is the only location believed to have sufficiently consistent winds to merit a feasibility study, with winds around 4 m/s.

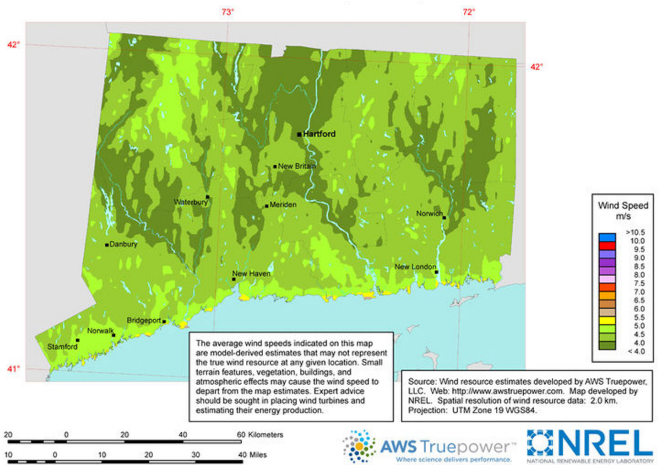

FIGURE 2.9: Connecticut Annual Average Wind Speed at 30m

An example micro turbine is UGE's 1kW Visionair 3, shown below. Based on 4 m/s, a mid-range potential annual output is around 500 kWh. (See Figure 2.11)

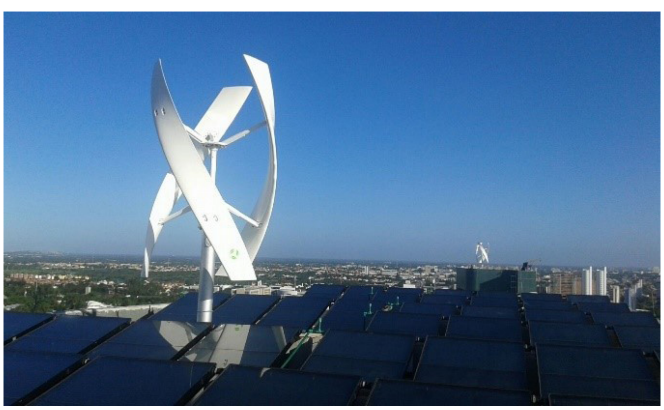

FIGURE 2.10: Building Integrated Microturbine

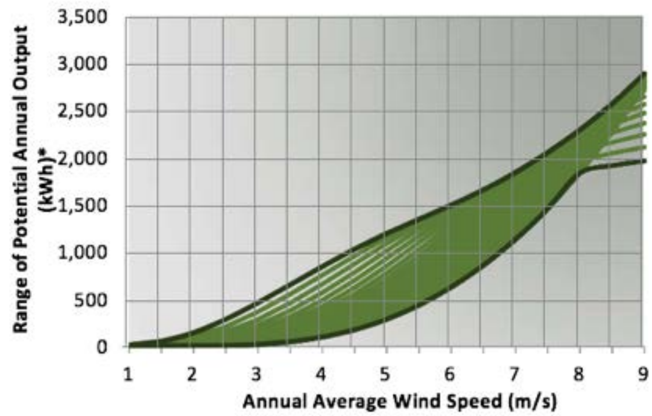

FIGURE 2.11: UGE Visionair3 Potential Annual Output based on Average Annual Wind Speed

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

- Wind turbine systems do not typically have a worthwhile ROI. An estimated cost for the UGE Visionaire3 is approximately $18,000- $21,000, inclusive of a ground-mount tower.
- Maintenance costs need to be considered.
- Consider wind turbines if integrated into building design or 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, 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.
- Need to factor zoning regulations.

2.12 CAPITAL PLANNING

2.12.1 CURRENT CONDITIONS

The Facilities Planning and Engineering department of Western's Facilities Services manages capital planning responsibilities, including project financing, master planning, compliance with state standards and construction of capital projects. The Department is guided by the Campus Master Plans which align with Western's overall vision and strategic goals. The Master Plans provide specific recommendations on space planning and utilization, outside the scope of this project. Western's latest Master Plan update will be completed in early 2017.

On an annual basis, Facilities Services publishes a report on completed Facilities projects, goals and general observations.* The report serves as a reflection on the prior year, and provides a path for improvement for the department. Based on the report, the division has numerous successes including managing over 30 capital projects with budgets totaling $70 million. The department faces challenges stemming from diminishing funds for deferred maintenance, valued at $200 million. While new infrastructure is added, is important that existing energy infrastructure is properly maintained. Despite the shortfall, a capital investment study indicated Western completed maintenance activities at or above peer schools at a lower cost.

Western has expanded its campus significantly in the last few years with the creation of the 137,330 GSF state-of-the-art Visual and Performing Arts Center (VPA) completed in 2014.** The VPA provides a collective space for Western's art, music, and theater arts program. According to the Environmental and Facilities Services Department focus was placed on increasing energy efficiency around Western, allowing the university to absorb energy consumption of the newest VPA building without additional energy cost.

FIGURE 2.12: Western Visual and Performing Arts Center

In fiscal year 2015, Western completed many capital and energy related projects such as the upgrade of the Alumni boiler and Student Center heat exchange rooftop unit, maintenance for Centennial Hall boiler, renovation of the Registrar's Office, Newbury Hall Energy Conservation Project and numerous others.

To accomplish its energy infrastructure goals, Western relies on financing and funding from the System Office and the State. The System Office provides annual code compliance and infrastructure funds. Larger capital projects are also funded under CSCU 2020, as of FY 2015. The State Legislature's Connecticut Health and Educational Facilities Authority (CHEFA) allocates bonds for campus improvement projects.

More information on campus expansion projects is found in Section 3.1

2.12.2 RECOMMENDATIONS

Western does an excellent job of documenting past projects and the status of the Department. In light of decreasing budgets, Western should collaborate with Eversource more heavily for major building renovations, plumbing, electrical, mechanical and new construction.

2.13 COLLABORATION / PARTNERSHIP

2.13.1 CURRENT CONDITIONS

Western has facilitated the implementation of numerous energy projects through strategic partnerships. Western worked with EnerNOC for accomplishing recommissioning and demand response outcomes. Based on the partnership, EnerNOC's tracking estimates over $3 million dollars in savings for the campus.

Western has also worked with Eversource. Western recently initiated a $65,000 steam trap maintenance project including a survey and implementation of recommendations. Eversource is funding approximately 80% of the costs.

For capital projects, Western collaborates with CSCU, the Department of Construction Services and multiple other state agencies to ensure compliance.

2.13.2 RECOMMENDATIONS

Western should continue to work with Eversource to take advantage of Utility Incentives for the EEMs presented in this plan. Incentives structures range and vary by program, but Eversource has offered incentives of up to 80% of project costs in the past.

2.14 SUMMARY OF RECOMMENDED ENERGY EFFICIENCY OPPORTUNITUES

As a result of the campus walk through energy assessment, and interviews with campus staff, a list of potential Energy Efficiency Measures (EEMs) is presented in Table 2.8. These projects represent low cost, immediate action measures, as well as projects that may require larger capital and therefore be longer-term.

Many energy-related projects are incentivized through utility rebates. Both of Western's utilities are through Eversource. This places the campus in a prime position to maximize incentives by combining multiple energy saving opportunities in what is known as a "Comprehensive Project." The primary advantage of a Comprehensive Project is the maximum incentive cap is

* Western Connecticut State University. Facilities Annual Report 2014-2015, 2015.
** Western Connecticut State University. Western's Newest Jewel: the Visual & Performing Arts Center (VPAC). Accessed December 7, 2015. http://www.wcsu.edu/svpa/svpa-center.asp

normally raised from 40% to 50%. Eversource has maximized these incentives in the past, and may also in the future, in the following ways:

- The comprehensive cost cap was increased from 50% to 80% of total cost.
- The incentive was increased from $0.30/kwh or $3.50/CCF (with 40% cost cap) to $0.40/kwh or $4.00/CCF (with 60% cost cap).

Since incentives are based on incremental energy savings; further analysis and collaboration with Eversource will be required to determine rebate amounts for each opportunity. To help Western navigate and prioritize the energy opportunities identified, a summary of opportunities is listed in Table 2.8. Immediate action should be taken to consider priority one and two opportunities with the goal of combining multiple opportunities into a Comprehensive Project. The simple payback in most cases cannot be reasonably estimated without detailed building models and/or more operating data. The payback periods provided are based upon the performance of past similar projects and are not necessarily indicative of future results.

Opportunity ID	Energy Conservation or Efficiency Opportunity	Associated Building if Applicable	App. Cost (Before Rebate)	Payback w/rebate (Years)	Priority
WCSU-1	Optimize fuel cell operations and ensure REC payments are received.	Fuel Cell	Engineering/ Administration Time	Instantaneous	1
WCSU-2	Continue to pursue connecting the Westside Campus to Natural gas.	Westside	$1.5 Million	3.5	1
WCSU-3	Pursue Solar PV PPA	Multiple, presented in Renewable Energy Section	PPA	PPA	1
WCSU-4	Continue to recommission existing buildings every 3-5 years. (Consult with Eversource). Focus on buildings using a strategy identified in the Energy Master Plan.	All	$0.50 - $3.50 / sf	Varies	Varies
WCSU-5	Program energy submetering historian to store at least one year's data from district steam loop so total building energy use can be calculated and archive annually after review. Existing JCI EMS can be used.	Midtown	Minimal	Varies	1
WCSU-6	Retrocommission Boiler House to manage flow and/or return temperatures, adding or tuning temperature resets.	Central Plant	Varies	<1 - 3	1
WCSU-7	Continue to coordinate operations scheduling with consolidating building occupants.	All	Varies	Varies	1
WCSU-8	Explore reducing boiler system pressure further from 80 psi based on outdoor air temperature. Refer to the DOE Best Practices Steam Technical Brief http://www.nrel.gov/docs/fy06osti/37853.pdf	Midtown	Minimal	Instantaneous	1
WCSU-9	Further insulate piping, focusing first on steam, including fittings and valves.	Midtown	$ 65,000	<1 - 3	1
WCSU-10	Explore a steam trap maintenance program, either automatic, such as Armstrong Steam-Eye, or perform at least an annual survey of all steam traps using ultrasonic or other means of detecting failed traps. (Consult with Eversource for a free/heavily subsidized audit)	Midtown	Minimal	<1 - 2	1
WCSU-11	Consult with Eversource to update lighting in Garage to LED.	White Street Parking Garage	$50,000 - $150,000	1.2 - 2.5	1
WCSU-12	Conduct a comprehensive lighting audit.	Campus-Wide	Varies (Possibly Free)	1 - 3	2

WCSU-13	Install individual thermostats on steam radiators.	Old Main, Higgins Hall	$160 - $315 per thermostat	1 - 5	2
WCSU-14	Insulation: Conduct EBCx for building envelope on buildings built before 1980, or for buildings with obvious deficiencies such as ice dams and drafts. Insulation should exceed latest building code or ASHRAE 90.1 standard.	White Hall	Varies	Varies	2
WCSU-15	Convert pneumatic controlled HVAC systems to DDC.	Old Main, Higgins, White Hall, Berkshire Hall, Westside Building, Ella Grasso Dormitory	$2.50 - $5 /sf	Varies	2
WCSU-16	Investigate alternative energy system such as district ground source geothermal system (closed loop).	Westside	Varies	Varies	3
WCSU-17	Monitor wind incentive programs for Westside Campus.	Westside	-	-	3
WCSU-18	Monitor Fuel Cells/CHP for Westside Campus (certain fuel cells may not need a thermal load).	Westside Campus	-	-	3

TABLE 2.8: Western Energy Efficiency Measures

ENERGY NEEDS

3.1 FUTURE DEVELOPMENT

Overall energy use may be impacted by campus expansions and renovations. Western's Master Plans are used to inform future development strategies. The focus of the Master Plan Update, to be finalized in early 2017, is on renovations of existing buildings, rather than purely the creation of additional space, which was an obj ective of the previous 2007 Master Plan. The campus is preparing for multiple potential future capital investments, including:

- **Litchfield Hall renovations** –The 1960 Midtown Campus residence hall is slated for needed upgrades. Renovations will incorporate redesign of common spaces and dorm rooms. The project is intended to meet LEED Silver Certifications. Plans include a requirement for a standby generator and evaluation of life safety system upgrades. The project is in the design phase.

FIGURE 3.1: Litchfield Hall

- **Midtown Campus Police Station** – The current police station is located in the boiler house in an approximately 1,150 square foot addition. The new facility will create a much larger footprint of approximately 8,100 sq. feet. The space will feature multiple office spaces, evidence receiving room, interview rooms, and other facilities imperative to the operation of a police force. The building is projected to meet LEED Silver Certification
- **Higgins Hall Renovation** – The building's current academic spaces and faculty offices are proposed to be reconfigured to meet additional space needs. The renovation will include the addition of a new Academic Success Center. The building will also feature new building systems, including plumbing, HVAC and electrical. An architect has been selected for the work.

There are additional projects in the discussion and planning phases, including a space allocation study for an education/nursing/business school, a potential new 500-car parking garage, and other renovations. Western has a history of incorporating energy efficient design into planning efforts and should continue to incorporate energy efficient building design into capital planning.

The updated Master Plan will include further objectives for providing the best resources for students; initial long-term project ideas by campus, include:

Midtown Campus

- Boiler House facility equipment renovations and upgrades
- Berkshire Hall demolition of approximately 45,000 GSF and expansion of 97,600 GSF
- New 86,000 GSF Academic Building

Westside Campus

- New 103,000 GSF Academic Building
- New Visual Arts/Academic Building
- O'Neill Center Expansion
- Westside Athletic Complex Expansion
- Westside Campus Center Expansion
- Demolition of the Westside Classroom Building

Please note that these plans are likely to take in excess of 10 years to complete.

As the campuses grow, it is important to be able to support electric and thermal needs of new, as well as existing, buildings. According to a recent infrastructure analysis, the Boiler House is close to capacity. The study projected that additional buildings without expansion of the Boiler House would reduce the redundancy of the plant to lower than the current 75%. Thus, an increase in capacity of the Boiler House is suggested with expansions. Specifically an additional boiler at the Midtown Campus is recommended.

The Westside Campus does not currently have a central plant or natural gas. As a result, with building expansions or new construction, energy efficient local heating and cooling systems are recommended on a local basis.

Ensuring energy reliability through campus expansions is another need. The campus has cited a lack of emergency generator capabilities to run critical equipment on both campuses. As of the FY15 Annual Report, there were plans to purchase Student Center generators.

The Westside Classroom Building has a 1982 365 kW generator that can power only analog systems, and not the necessary power to run electronic systems. A total of eight buildings on campus have generator capabilities:

- Boiler House
- Campus Center
- Fairfield Hall
- Old Main
- Science Center
- Student Center
- University Hall
- Warner Hall

Western should expand its generator capabilities, expand natural gas into the Westside campus, and study the need for additional infrastructure given the numerous additions planned for the campus. With purchases of new generators, Western should pursue Tier IV to be able to use the generators for ISO New England's demand response programs.

Connecticut's Department of Energy & Environmental Protection (DEEP) offers a $10 million microgrid grant program for entities other than municipalities. Western may want consider this program for the future in connection to the fuel cell.

3.2 ENERGY RESILIENCY RECOMMENDATIONS

In 2015, Western participated in the CSCU Multi-Campus Hazard Mitigation Plan. The CSCU Multi-Campus Hazard Mitigation Plan provided recommendations surrounding energy resiliency that are also applicable for the Energy Master Plan. Recommendations from the hazard mitigation plan for improving the energy reliability and resiliency of the campus, include:

- Study and implement hardening of electrical feed on the Westside Campus from Middle River feed.
- Add a redundant fuel source on the Westside Campus (i.e., natural gas).
- Install an emergency generator to power the IT closets on campus to support VOIP.
- Add emergency generator capacity for essential systems (security, air handling, IT, repeaters, residence halls, etc.)
- Work with the utility to evaluate options for electrical service on the Westside Campus (isolate Westside Campus)
- Upgrade emergency generator on the West campus to enable distribution to digital systems.
- Evaluate and identify site for temporary boilers in case of emergency.
- Evaluate HVAC systems and upgrade vulnerable spaces (IT closets, computer labs).
- Retrofit and add insulation to select buildings to prevent burst pipes and other winter-related impacts.

CONCLUSION / NEXT STEPS

Western has focused on reducing energy use throughout the years, and securing significant savings with recommissioning programs, BMS upgrades and general energy management. Energy opportunities include lighting audits and upgrades, steam trap maintenance and building envelope upgrades. Challenges for the campuses include preventative maintenance and HVAC repairs, especially given budget recessions.

Top priorities for Western include:

- *Investigation of fuel switching:* Based on projected future fuel oil and gas prices and preliminary findings, it is likely in Western's best interest to consider switching the Westside campus heating fuel from oil to gas. This change could help decrease carbon emissions and save on operating and energy costs, to devote the additional savings to other imperative energy projects.
- *Management:* Review existing energy data on a more frequent basis, with an eye for outliers and energy intensive buildings by month. If resources are not available for an existing staff member to continuously monitor data, investigate opportunities for external support. Facilities should be routinely apprised of total energy spending.
- *Alternative Energy:* Investigate if Western is receiving RECs, and if not follow up with the fuel cell operator to ensure RECs are being generated. Western may consider monitoring incentives related to wind turbines, and a further study on wind potential on the Westside campus.
- *Renewable Energy:* Explore PPAs for rooftop solar, and bundle multiple solar sites.
- *Utility Incentives/ Develop Plan for EEMs:* Western should maximize incentive funding for EEMs by working with Eversource, and combining multiple energy saving opportunities in what is known as a "Comprehensive Project." Further analysis and collaboration with Eversource is required to determine rebate amounts for each opportunity.

A summary of further projects and priorities for the campus are listed in Table 2.8. Western has the opportunity to further optimize systems, save on energy spending and increase energy reliability and sustainability.

4.1 CONTACT INFORMATION FOR KEY STAKEHOLDERS

Collecting all the necessary information for this planning effort required a collaborative effort. Below are the stakeholders that were active in providing their expertise about campus current conditions and future needs, and energy related decisions.

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EVERSOURCE

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APPENDIX A: WESTERN DATA, METHODOLOGY, ASSUMPTIONS AND NOTES

The following are the data, methodology and assumptions that were used when analyzing and benchmarking data for Western:

- There is no information to indicate that the campus uses purchased chilled water or steam

Electricity: Utility Direct (FY13,14,15), Fuel Cell Estimated Generation

- Western indicated the Old Main Administration Building shares its account with 8 other buildings, the specific buildings were not identified.
- The campus EUI will increase if these buildings do not share accounts with existing buildings.

  1. Berkshire Hall
  2 Boiler Plant
  3. Higgins Hall
  4. Ives Concert Hall
  5. Litchfield Hall
  6. Midtown Student Center
  7. Newbury Hall
  8. Warner Hall
  9. Western Athletic Complex
  10. White Hall

- Multiple accounts in Utility Direct were excluded from the EUI calculations such as street lights and buildings that were not a part of the study.
- Fuel cell output was estimated to be 3,000,000 kWh/year based on fuel cell size and electrical efficiency.
- The Western Athletic Complex did not have an associated fuel account or consumption available, and is also not on the steam loop.

Natural Gas: Utility Direct (FY13,14,15)

- BTU submetering was not available for the Midtown Campus steam loop. Building-level EUIs cannot be calculated for any buildings in the Midtown campus at this time.
- Westside campus has oil only.

Propane: Utility Direct (FY15)

- The campus level site EUI cannot be calculated correctly with FY14 data missing.

Fuel Oil: Utility Direct (FY13,14,15)

General Assumptions

- Assumed that the building called Ives Concert Hall was neither the performance space within White Hall, nor the Concert Park, which the campus leases to the town. It is likely the storage shed or a Gazeebo near the Concert Park based on its GSF. Its exact consumption is unknown.

APPENDIX B: WESTERN CONNECTICUT STATE UNIVERSITY (WESTERN) CHP SCREENING

INTRODUCTION

The intent of this assessment is to provide a high-level review of Western Connecticut State University (Western)'s Boiler House and the potential for a cogeneration/combined heat and power (CHP) application on campus. The resulting conclusions are based on data review and discussion with campus plant personnel. The Boiler House on the Midtown Campus is being examined as the potential location for cogeneration. The Westside Campus is not being considered for siting CHP due to there being no natural gas service at that campus. The Midtown Campus already employs a form of cogeneration with its existing 400 kW fuel cell located at the Science Building. The Midtown Boiler House would serve as the potential location for a CHP at the end of the existing fuel cell's useful life.

EXISTING INFRASTRUCTURE

The Midtown Campus Boiler House includes two dual fuel 500 HP boilers installed around 2013 and an older Bigelow boiler as backup. The boilers are connected to an 80 to 100 psi steam distribution loop which supplies the Midtown Campus buildings with steam for heating. The domestic hot water system is a stand-alone loop. All underground piping is direct burial.

Thermal: Western's dual fuel boilers are used to provide steam through a distribution loop to several of the Midtown Campus buildings. The Science Building, originally supplied by the Boiler House, has a 400 kW fuel cell, which now provides a majority of the thermal energy needed by the building.

The Midtown Campus is on an interruptible natural gas contract and occasionally needs to switch to oil. The Westside campus currently does not have access to natural gas and would not support CHP at this time.

Electrical: Through an inventory of Western's electric accounts, 19 electric meters were accounted for, with the top five consuming approximately 72% of the total electrical energy use. Excluding the Science Building, the remaining top five accounts contribute to about 63% of the total.

The "Old Main Administration Building" meter is the largest electrical consumer at over 5,000,000 kWh and includes several buildings on the Midtown campus. The next largest electrical consumers are the Westside Classroom Building, O'Neill Center Field House, and Pinney Hall which are on the Westside campus. Even though these accounts are on the Westside campus, it is anticipated these accounts can be included through virtual net metering, explained later in this screening.

EXISTING CONSUMPTION

Evaluated Datasets: Utility:

Direct energy use reports for fiscal year (FY) 2014 and 2015 were used for this screening, including:

- Boiler House Natural Gas and Fuel Oil consumption monthly totals
- Electrical consumption monthly totals for each service at the Midtown and Westside campus

Based on the average of FY 2014 and 2015 natural gas consumption, the base thermal load during summer months, was found to be substantially less than during the colder months of the year. This trend is depicted in Figure A.

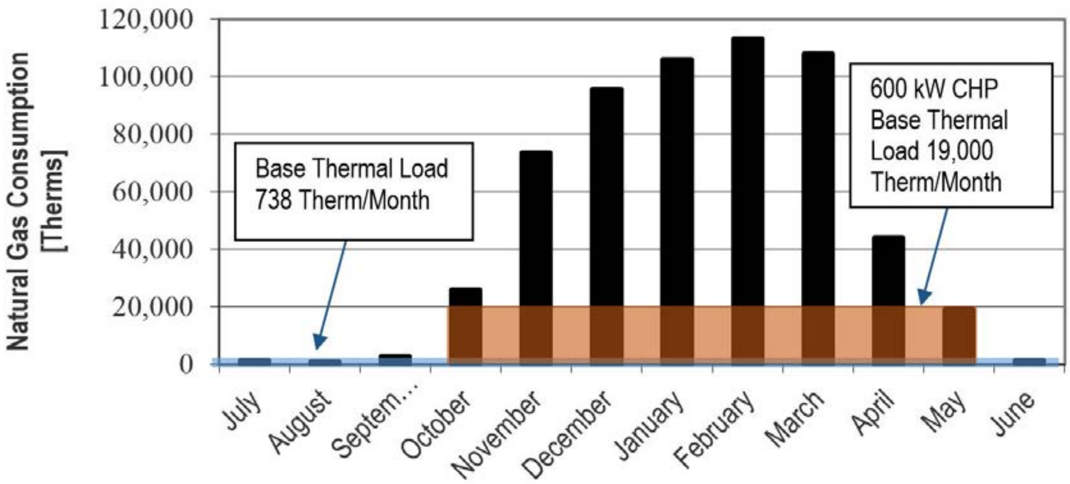

FIGURE A: Midtown Boiler House Thermal Load Profile

The base thermal load is indicative of the size CHP unit that would be best suited for the campus in order to maximize run time and efficiency. A simple hourly average of the base thermal load in the summer months would not support cogeneration while the thermal load from October through May could. The minimum hourly simple average for October through May is approximately 25 therms per hour.

OPPORTUNITY, CONCLUSIONS AND NEXT STEPS

The existing infrastructure at Western could potentially support a 600 kW CHP installation for part of the year. CHP systems are classified as a Class III alternative energy in Connecticut and are therefore eligible for virtual net metering, given that they meet a minimum 50% overall efficiency. Virtual net metering would allow up to five electrical services to benefit from the excess generation on one service. In theory, excess generation at the Midtown campus could offset use at the Westside even though they are not physically connected. The utility would need to be consulted to confirm eligibility and specifics. Virtual net-metering with up to five accounts and an existing steam loop at the Midtown campus would allow the CHP to run at design load eight months of the year. An additional absorption chiller and distribution would need to be added to support the CHP through the remainder of the year.

The Potential Utilities Report attached shows how a 600 kW internal combustion CHP would provide a baseload of thermal energy from May through October. The report also demonstrates the estimated effect of a 600 kW CHP on the Boiler House's natural gas consumption and its top five electric meters. The top five electric meters are used assuming virtual net metering is implemented, since the single largest meter would not have a high enough electrical demand to support 100% generation behind the meter.

Assuming a CHP system installation cost at $3,250 per kW, electrical energy rate of $0.1304 per kWh, and natural gas energy rate of $0.984 per MMBtu, a simple payback near 7.2 years could be expected before incentives with no additional infrastructure upgrades and where the CHP only operated eight months of the year.

The thermal and electric loads at Western indicate a moderate CHP potential for additional cogeneration. However, the effectiveness of the system without the need for heat year round reduces the efficiency of the system if oversized beyond the minimum thermal load. Thermally driven (absorption) chillers can increase the summer heat load, but without a chiller loop on campus this is an unlikely scenario. It is recommended that electrical and thermal data continue to be collected for future cogeneration analysis. New onsite generation should be evaluated at the end of the existing 400kW fuel cell's cost effective life.