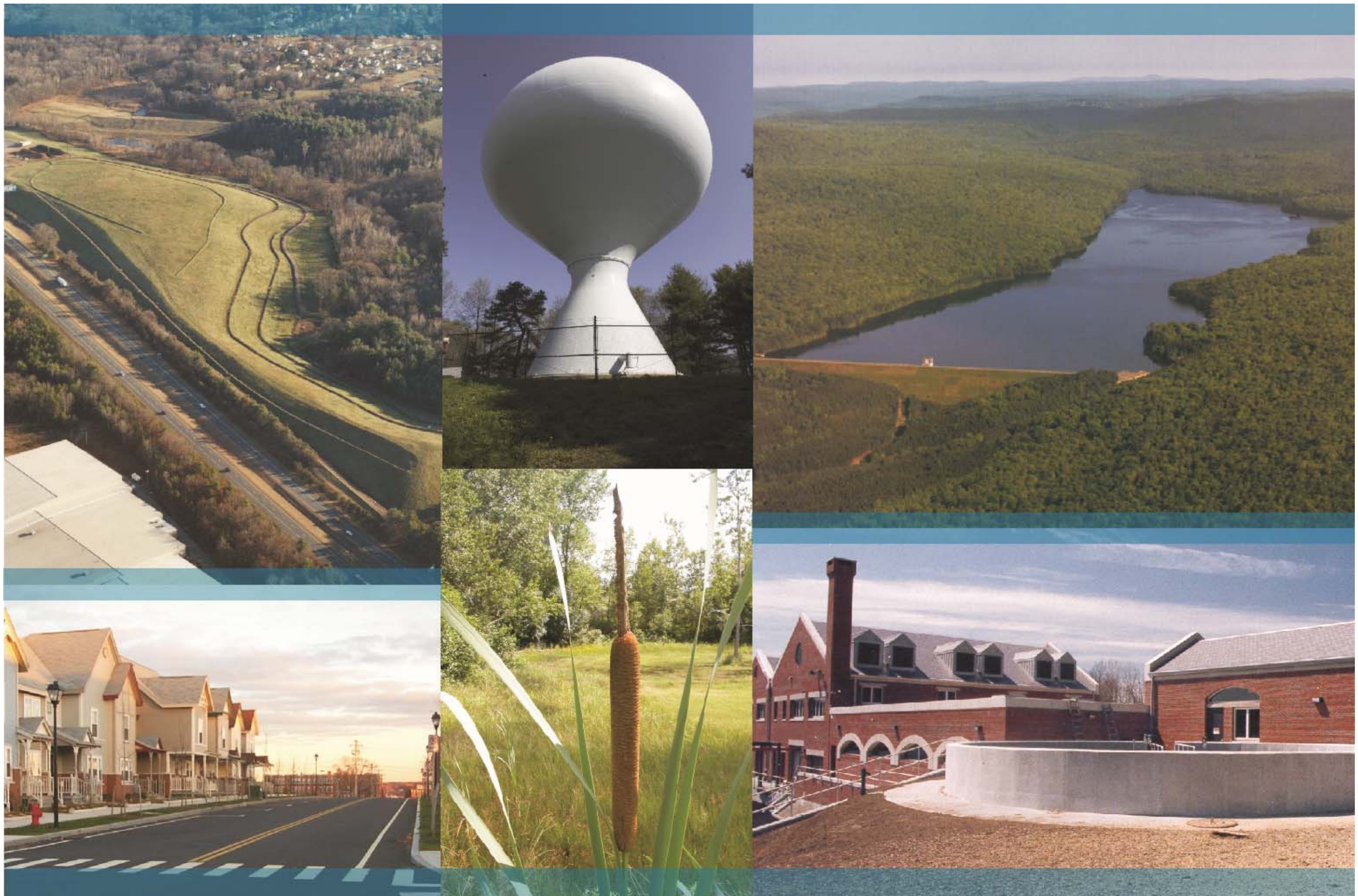

2015 Greenhouse Gas Reporting

Prepared For:

Worcester Polytechnic Institute
Worcester, Massachusetts

April 2016

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Section 1
Introduction

In August 2008, Massachusetts enacted into law the Global Warming Solutions Act (GWSA). The Act requires an 80 percent reduction of greenhouse gas (GHG) emissions economy-wide by 2050, with a 2020 target to be set between 10 and 25 percent below 1990 levels. As part of the GWSA, Massachusetts promulgated greenhouse gas reporting regulations in July 2009 that affect approximately 300 facilities in the state.

1.1 Applicability

In July of 2009, the Massachusetts Department of Environmental Protection (MADEP) promulgated greenhouse gas emissions reporting (310 CMR 7.71). In accordance with 310 CMR 7.71, the following facilities are subject to the reporting requirements:

- All facilities that are regulated under Title V of the U.S. Clean Air Act and 310 CMR 7.0, Appendix C
- Facilities that emit more than 5,000 tons per year of carbon dioxide equivalent emissions
- Retail sellers of electricity

GHG Emissions Reporting for facilities subject to the requirements of 310 CMR 7.71 commenced in 2010 for calendar year 2009. Reporting of 2009 emissions was due by June 15, 2010 and only included carbon dioxide emissions from stationary and mobile fuel combustion sources. Beginning in 2011, for emissions that occur in 2010, and each year thereafter, facilities are required to report emissions of all greenhouse gases by April 15 in carbon dioxide equivalent. The additional gasses include methane, nitrous oxide, sulfur hexafluoride, hydroflourocarbons and perflourocarbons.

Worcester Polytechnic Institute (WPI) is applicable to the GHG reporting requirements of 310 CMR 7.71 because the carbon dioxide equivalent emission from the site in 2015 exceeded the 5,000 tons threshold. Therefore, this facility is required to report GHG emissions to the MADEP.

1.2 Emissions Reporting

The MADEP has adopted the General Reporting Protocol (GRP) established by The Climate Registry, a nonprofit collaboration, to record and track the greenhouse gas emissions of businesses, municipalities and other organizations. Reporters are required to refer to 310 CMR 7.71 to determine which emissions sources should be reported and then use methodologies included in the GRP to quantify emissions from those sources. The relevant sections of the GRP are the methodologies that explain how to quantify emissions from particular source categories (e.g., boilers, refrigeration units, vehicle fleets, etc.), and facilities are required to use these methodologies to quantify emissions for reporting to MADEP.

As described in the GRP, the reporting of the six greenhouse gases from applicable sources at a facility is required. Facilities emitting greater than 5,000 tons of carbon dioxide equivalent (CO2e) are required to include carbon dioxide emissions from on-road vehicles. Title V facilities emitting less than 5,000 tons of carbon dioxide equivalent emissions are not required to report emissions from motor vehicles, while all facilities emitting greater than 5,000 tons of carbon dioxide are required to report emissions from all vehicles operated by the facility.

Facilities subject to the Massachusetts GHG Reporting Program are required to electronically report their greenhouse gas emissions using a regional electronic reporting system. The MADEP contracted with The Climate Registry to develop the Massachusetts Greenhouse Gas Registry which is built off of The Climate Registry's Climate Registry Information System (CRIS) software platform. The MA GHG Registry allows subject facilities to calculate and report GHG emissions per the requirements of the MA GHG Reporting Regulation and the quantification methodologies of The Climate Registry's General Reporting Protocol. This comprehensive reporting tool is used by Massachusetts facility reporters, the MADEP, and the general public.

A total facility emissions report for WPI using the MA GHG Reporting Program is included in Appendix A of this report.

1.3 Grouping Emission Sources

In accordance with Chapter 11 of The Climate Registry General Reporting Protocol, facilities with a large number of small emissions sources are required to report GHG emissions from these units, regardless of unit size. However, small emission units such as space heaters and welding tools can be accounted for by using simplified estimation methods to quantify emissions, as long as the total amount of emissions quantified in accordance with simplified emissions methods does not exceed 1,000 short tons. Simplified estimation methods allow for the aggregation of smaller emission units and provide a credible estimate of emissions while minimizing the reporting burden on a facility.

1.4 Methodology

The MADEP requires emission quantification based upon The Climate Registry General Reporting Protocol. The following subsections identify the prescribed methodologies.

1.4.1 Calculation-Based Methodologies

Calculation-based methodologies involve the calculation of emissions based on activity data and emission factors. Activity data can include data on fuel consumption, input material flow, or product output. Emission factors are determined by means of direct measurement and laboratory analyses or by using generalized default factors.

Default emission factors sometimes change over time as the components of energy (electricity, fuel, etc.) change and as emission factor quantification methods are refined. The Registry updates emission factors on an annual basis in January to reflect the most up-to-date knowledge. In most cases, facilities reporting emissions data from previous years can use the most up to date emission factors available when the inventory is being reported. In the case of default emission factors for electricity use, facilities must use the emission factor closest to the emissions year reported that do not post-date the emissions year.

Facilities with access to high-quality site specific emission factors are encouraged to use those factors. Activity data and calculations should be reported in appropriately accurate detail.

1.4.2 Measurement-Based Methodologies

Measurement-based methodologies determine emissions by means of continuous measurement of the exhaust stream and the concentration of the relevant GHG(s) in the flue gas. Direct measurement will only be relevant to entities with facilities using existing continuous emission monitoring systems (CEMS), such as power plants or industrial facilities with large stationary combustion units. Facilities without existing monitoring systems will not need to install new monitoring equipment to comply with The Registry's quantification requirements.

1.4.3 Mandatory Methodologies

The Registry accepts all GHG emission calculation methodologies mandated by a state, provincial, or federal GHG Regulatory reporting program. Like all information publically reported through The Registry, data calculated using mandatory methodologies must be included in the Verification Body's risk assessment in accordance with the guidelines of the General Verification Protocol.

Although it is encouraged, Facilities are not required to use mandatory calculation methods. Facilities may also elect to use some mandatory calculation methods for select sources or gasses and other Registry-approved methods for others. Please note, where mandatory requirements exclude certain emission sources, Facilities are still required to quantify emissions from those sources in accordance with The Registry's reporting requirements.

1.4.4 Simplified Emissions

Facilities are encouraged to use the Climate Registry's approved methodologies described in the paragraph above. However, the Registry understands that in some cases these methodologies are not feasible for a facility within their organizational boundaries. In these cases, facilities are allowed to use alternative, simplified estimation methods for any combination of emission sources or gases, provided that the emissions from these sources and/or gases are less than 5% of the facility's total emissions.

Methodologies used for specific emission sources and gases are detailed in Section 2.2.

1.5 Carbon Dioxide Equivalents

Beginning in RY 2010, facilities are required to report emissions from additional GHGs, as described in Section 1.1. In order to report emissions of non CO_2 gases, facilities must convert the emissions to CO_2 equivalents, calculated on the basis of each GHGs Global Warming Potential (GWP). GWPs represent the ratio of the heat trapping ability of each green-house gas relative to that of CO_2. For this report, the emissions of non-CO_2 gases are converted to units of CO_2 equivalent by using the following GWPs:

TABLE 1-1
Global Warming Potentials

Common Name	Formula	GWP
Carbon Dioxide	CO2	1
Methane	CH4	21
Nitrous Oxide	N2O	310
Sulfur Hexafluoride	SF6	23,900
HFCs/PFCs	Varies	Varies (150-11,700)

Section 2
Project Scope

WPI is located at 100 Institute Road in Worcester, Massachusetts and is a technological university. WPI Campus comprises 35 major buildings. The off-campus buildings including Lee Street and Gateway Park are also included in this report.

WPI is applicable to the Greenhouse Gas reporting requirements of 310 CMR 7.71 as an emitter of greater than 5,000 tons/year CO_2e during the calendar year 2013 as stated in 310 CMR 7.71(2).

This report includes all applicable GHG emissions, including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perflouorocarbons and sulfur hexafluoride in tons of CO_2e.

2.1 Inventory

WPI has the following emission sources subject to GHG emissions inventory:

- Founders Equip. Boiler # 4
- Generator # 1 Daniels Hall, Kohler
- Generator # 2 Founders Hall, CPI
- Generator # 3 Harrington, Onan
- Generator # 4 Salisbury, Olympian
- Generator # 5 Fuller #1 Roof, Superior
- Generator # 6 Fuller #2 Caterpillar
- Generator # 9 Power Plant, SR-4 Caterpillar
- Generator #7 Gateway, Kohler
- Generator #10 East Hall, Kohler
- Generator # 11 Goddard, Olympian
- Generator #8 Gateway Garage, Caterpillar
- Generator #13 Gateway 2 Generator
- Generator #12 Rec Center Generator
- Generator #14 Faraday Generator
- Generator #15 Drury Lane
- Power House New Boiler #1
- Power House New Boiler #2
- Power House New Boiler #3
- Off Campus Residences (group)
- On-Campus Miscell. 1st set (group)
- On-Campus Miscell. 2nd set (group)

- On-Campus Miscell. 3rd set (group)
- Gateway Cleaver Brooks Boilers (2)
- Gateway Lattern Boilers (2)
- Salisbury Estates Heating
- HVAC units
- Vehicle Air Conditioning units
- Refrigeration units
- Non-highway Motor units
- Tier 1 1998-2003 Light Trucks
- Tier 2 2004-2009 Light Trucks
- Tier 2 Passenger Cars

WPI uses ABC, K, K-CL, Halon, CL-D and CO_2 type fire extinguishers. WPI contracts the services of Bob O'Connell Fire Protection from Worcester, MA to maintain the fire extinguishers. Therefore, WPI is not including the emission from fire extinguishers that were used in 2015 in its GHG report.

WPI uses and maintains multiple refrigeration units that mainly include R404A, R410A and R134A as a heat transfer medium. The emissions reported were calculated based on available purchase records, maintenance inventory records and available capacity data provided by WPI personnel.

WPI uses AC window units that contain only R-22. WPI uses a variety of refrigerators that contain R134A. It was estimated that WPI used 250 G.E. units model GTH21KBAWN that contained 4.23 ounces of R134A each. WPI uses a number of vehicles that are equipped with air conditioning. The refrigerator and mobile air conditioning emissions were calculated using the operation emission factor from GRP Table 16.3.

2.2 Methodology

For 2015, WPI has chosen to utilize Calculation-based methodologies. Default emission factors are found in the GRP's 2013 update to Table 12.1 – Default Factors for Calculating CO_2 Emissions from Fossil Fuel Combustion.

The selection of the calculation-based methodology is due to the technical constraints and excessive costs of data collection per unit of emission. As shown in the CRIS emission report included in Appendix A of this report, fuel combustion at the WPI facility resulted in the generation of approximately 9,613 metric tons. Informal research identified the costs associated with the purchase of a Continuous Emissions Monitoring (CEM) system at approximately $30,000. The additional costs of installing, operating and maintain such a system would be in excess of this amount. It should be noted that a CEM would be needed it for each emission source. A CEM system quote is included in Appendix B

The specific heat and carbon contents of the fuels combusted at the facility are unknown. Therefore, WPI has utilized the emission factors in Tables 12.1 and 12.2 of the Climate Registry General Reporting Protocol. These tables are included in Appendix B of this report.

In addition, WPI has chosen to utilize the Simplified Method for the calculation of HFC emissions utilizing default emission factors found in the GRP's update to Table 16.3 – Default Emission Factors for Refrigeration/Air Conditioning Equipment. Equation 16e was used to estimate emissions from each type of refrigerant. This methodology was chosen because it is not feasible for WPI to determine a base inventory for each refrigerant used at the facility, which is required for use of Tier A. However, WPI was able to conduct an inventory, identifying the refrigeration unit and the capacity and type of refrigerant for the larger units, allowing them to use a more accurate version of the Screening Method. Additionally, records of maintenance to refrigeration units, which is required for use of Tier B were used. Where specific capacity was not available, the most conservative value from Table 13.6 was used. It should be noted that the refrigerant's emissions calculated using the Screening Method is less than 1,000 short tons.

2.3 Combined Reporting Units

Stationary emission units are grouped in the same manner as reported in the Source Registration Emission Statement. Mobile sources are grouped by type of fuel and EPA EPA Tier classification as follows: Tier 1 for years 1998-2003; and Tier 2 for vehicles years 2004-2012. A summary of the vehicles grouped under each Tier is included in Appendix B. Also, refrigerant units were grouped by type of refrigerant as indicated in Section 2.2.

2.4 Data Collection

The data used to calculate emissions at WPI was provided by WPI personnel and was taken directly from fuel consumption, operating, maintenance and purchase records.

Section 3
Report Summary

3.1 Reporting Year 2015

In calendar year 2015, WPI generated 10,787 short tons (9,786 metric tons) of CO_2e. Table 3-1 below provides source specific emissions data. Additionally, Appendix A of this report includes the Climate Registry Information System (CRIS) Report submitted to the Climate Registry and MADEP.

TABLE 3-1
Emissions Report Summary

Emission Source	Methodology	Fuel	Carbon Dioxide Equivalent Emissions (metric tons)
Founders Equip. Boiler # 4	Calculations-Based	N.G.	209.5413
Generator # 1 Daniels Hall, Kohler	Calculations-Based	N.G.	2.3570
Generator # 2 Founders Hall, CPI	Calculations-Based	N.G.	2.0431
Generator # 3 Harrington, Onan	Calculations-Based	N.G.	0.3632
Generator # 4 Salisbury, Olympian	Calculations-Based	N.G.	2.2579
Generator # 5 Fuller #1 Roof, Superior	Calculations-Based	diesel	1.1946
Generator # 6 Fuller #2 Caterpillar	Calculations-Based	diesel	4.2475
Generator # 9 Power Plant, Caterpillar	Calculations-Based	Diesel	13.2328
Generator #7 Gateway, Kohler	Calculations-Based	diesel	19.6960
Generator #10 East Hall, Kohler	Calculations-Based	diesel	3.4307
Generator # 11 Goddard, Olympian	Calculations-Based	N.G.	0.0820
Generator #8 Gateway Garage, Caterpillar	Calculations-Based	diesel	1.3110
Generator #13 Gateway 2 Generator	Calculations-Based	diesel	5.8628
Generator #12 Rec Center Generator	Calculations-Based	diesel	0.7392
Generator #14 Faraday Olympian	Calculations-Based	N.G.	39.4884
Generator #15 Drury Lane	Calculations-Based	N.G.	0.4184

TABLE 3-1
Emissions Report Summary

Emission Source	Methodology	Fuel	Carbon Dioxide Equivalent Emissions (metric tons)
Power House New Boiler #1	Calculations-Based	N.G./diesel	1,594.0416
Power House New Boiler #2	Calculations-Based	N.G.	1,831.8328
Power House New Boiler #3	Calculations-Based	N.G./diesel	1,848.3834
Off Campus Residences	Calculations-Based	N.G.	1,189.5314
On-Campus Miscell. 1st set	Calculations-Based	N.G.	393.0077
On-Campus Miscell. 2nd set	Calculations-Based	N.G.	317.5819
On-Campus Miscell. 3rd set	Calculations-Based	N.G.	305.5233
Gateway Cleaver Brooks Boilers (2)	Calculations-Based	N.G.	748.5961
Gateway Lattern Boilers (2)	Calculations-Based	N.G.	208.9857
Salisbury Estates Heating	Calculations-Based	N.G.	683.0109
Refrigeration units	Calculations-Based /Simplified	R134A/R404A/R410A	0.102
Non-highway Motor units	Calculations-Based	diesel	11.4230
Tier 1 1998-2003 Light Trucks	Calculations-Based	gasoline	11.7607
Tier 2 2004-2009 Light Trucks	Calculations-Based	gasoline	92.3527
Tier 2 Passenger Cars	Calculations-Based	gasoline	9.2218
Vehicle Refrigeration	Calculations-Based	R134A	0.0076
TOTAL			**9,786**

3.2 Data Retention

WPI will maintain GHG emission documentation on site for at least 5 years from the date of submittal to the climate registry as required by 310 CMR 7.71.

Appendix A
Climate Registry Submittal

Massachusetts Greenhouse Gas Emissions Reporting Program

Total Facility Emissions Report

WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ID: 1180127]

WORCESTER, United States

MA Facility AQ Id 1180127

4/15/2016 8:38:55

Facility Information

Facility Name	WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ..
Facility Category	Stationary source(e.g. power plants etc)
Facility Location	Massachusetts
Facility Address	100 INSTITUTE RD, WORCESTER, Massachusetts, 016090000, United States
Facility Contact	GRUDZINSKI, WILLIAM
Contact Email	WILLIAMG@WPI.EDU
Contact Phone	5088316406
NAIC Code	611310 - Colleges, Universities, and Professional Schools
Facility Description	

2015 Emissions Information

Report Status	Certified_Submitted
Reporting Protocol	The Climate Registry's General Reporting Protocol and associated updates and clarifications

ASSOCIATED ENTITIES

Entity Name	Consolidation Methodology	Equity Share	Operational Control	Financial Control
WORCESTER POLYTECHNIC INSTITUTE	Operational Control Only	Not Applicable	Yes	Not Applicable

Massachusetts Greenhouse Gas Emissions Reporting Program

Total Facility Emissions Report

WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ID: 1180127]

WORCESTER, United States

MA Facility AQ Id 1180127

4/15/2016 8:38:55

TOTAL EMISSIONS: WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ID: 1180127]

DIRECT EMISSIONS (Scope 1) Metric Tons	CO2e	CO2	CH4	N2O	HFCs	PFCs	SF6
Fugitive - Scope 1	172.375	0	0	0	0.1096	0	0
Mobile Combustion - Scope 1	126.22296	124.74738	0.0065	0.00432	0	0	0
Process - Scope 1	0	0	0	0	0	0	0
Stationary Combustion - Scope 1	9487.13166	9422.02863	0.75071	0.15914	0	0	0
TOTAL DIRECT EMISSIONS	9785.72962	9546.77601	0.75721	0.16346	0.1096	0	0

BIOGENIC EMISSIONS Metric Tons	CO2
Mobile Biomass Combustion - Biomass	0
Stationary Biomass Combustion - Biomass	0
TOTAL BIOGENIC EMISSIONS	0

Total Facility Emissions	
CO2e in metric ton (t)	9785.72962
CO2e in short ton (ton)	10786.92044

Massachusetts Greenhouse Gas Emissions Reporting Program

Total Facility Emissions Report

WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ID: 1180127]

WORCESTER, United States

MA Facility AQ Id 1180127

4/15/2016 8:38:55

DETAILED EMISSIONS

Emitting Activity Name	Emissions Category	Emitting Activity	Green House Gas	Amount (metric tons)	Total CO2e (metric tons)	Calculation Methodology	Factor Source	Fuel	Amount	Emission Factor	Heat Content	Oxidation Factor	Coefficient Perform	Efficiency Factor	Comment
BOILER #4 FOUNDERS -2 HB SMITH+2 PVI NATURAL GAS	Stationary Combustion - Scope 1	Boilers	CO2	209.53418	209.53418	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	3960.2 MMBtu	52.91 kg/MMBtu	1025 Btu/scf				
BOILER #4 FOUNDERS -2 HB SMITH+2 PVI NATURAL GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.00356	0.07485	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	3960.2 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
BOILER #4 FOUNDERS -2 HB SMITH+2 PVI NATURAL GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.00356	1.1049	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	3960.2 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - CLEAVER BROOKS - NAT GAS	Stationary Combustion - Scope 1	Boilers	CO2	748.57068	748.57068	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	14148 MMBtu	52.91 kg/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - CLEAVER BROOKS - NAT GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.01273	0.2674	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	14148 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - CLEAVER BROOKS - NAT GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.01273	3.94729	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	14148 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - LATTNER - NAT GAS	Stationary Combustion - Scope 1	Boilers	CO2	208.97863	208.97863	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	3949.7 MMBtu	52.91 kg/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - LATTNER - NAT GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.00355	0.07465	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	3949.7 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
BOILERS (2) GATEWAY - LATTNER - NAT GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.00355	1.10197	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	3949.7 MMBtu	0.9 g/MMBtu	1025 Btu/scf				
EMER GEN #1 - DANIELS HALL - KOHLER 80-R2-82 - NAT GAS - PWR HSE	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	2.32804	2.32804	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	44 MMBtu	52.91 kg/MMBtu	1025 Btu/scf				
EMER GEN #1 - DANIELS HALL - KOHLER 80-R2-82 - NAT GAS - PWR HSE	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.02895	0.60799	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	44 MMBtu	658 g/MMBtu	1025 Btu/scf				
EMER GEN #1 - DANIELS HALL - KOHLER 80-R2-82 - NAT GAS - PWR HSE	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	44 MMBtu						44 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #10 - EAST HALL - KOHLER 150	Stationary Combustion - Scope 1	Unspecified Technology	CO2	3.43056	3.43056	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	336 gal	10.21 kg/gal	0.138 MMBtu/gal				

Massachusetts Greenhouse Gas Emissions Reporting Program

Total Facility Emissions Report

WORCESTER POLYTECHNICAL INSTITUTE [Facility AQ ID: 1180127]

WORCESTER, United States

MA Facility AQ Id 1180127

4/15/2016 8:38:55

EMER GEN #10 - EAST HALL - KOHLER 150	Stationary Combustion - Scope 1	Unspecified Technology	CH4	0.00014	0.00292	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	336 gal	0.003 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #10 - EAST HALL - KOHLER 150	Stationary Combustion - Scope 1	Unspecified Technology	N2O	3e-005	0.00862	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	336 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #11 - GODDARD HALL OLYMPIAN G60F3 NAT GAS	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	0.7291	0.7291	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	13.78 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #11 - GODDARD HALL OLYMPIAN G60F3 NAT GAS	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.00907	0.19041	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	13.78 MMBtu	658 g/MMBtu	1025 Btu/scf	
EMER GEN #11 - GODDARD HALL OLYMPIAN G60F3 NAT GAS	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	13.78 MMBtu			13.78 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #12 - REC CENTER GENERATOR	Stationary Combustion - Scope 1	Unspecified Technology	CO2	0.7392	0.7392	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	72.4 gal	10.21 kg/gal	0.138 MMBtu/gal	
EMER GEN #12 - REC CENTER GENERATOR	Stationary Combustion - Scope 1	Unspecified Technology	CH4	3e-005	0.00063	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	72.4 gal	0.003 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #12 - REC CENTER GENERATOR	Stationary Combustion - Scope 1	Unspecified Technology	N2O	1e-005	0.00186	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	72.4 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #13 - GATEWAY 2 GENERATOR - CUMMINS	Stationary Combustion - Scope 1	Unspecified Technology	CO2	5.86258	5.86258	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	574.2 gal	10.21 kg/gal	0.138 MMBtu/gal	
EMER GEN #13 - GATEWAY 2 GENERATOR - CUMMINS	Stationary Combustion - Scope 1	Unspecified Technology	CH4	0.00024	0.00499	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	574.2 gal	0.003 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #13 - GATEWAY 2 GENERATOR - CUMMINS	Stationary Combustion - Scope 1	Unspecified Technology	N2O	5e-005	0.01474	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	574.2 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #14 - FARADAY OLYMPIAN	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	39.37933	39.37933	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	744.27 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #14 - FARADAY OLYMPIAN	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.48973	10.28432	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	744.27 MMBtu	658 g/MMBtu	1025 Btu/scf	
EMER GEN #14 - FARADAY OLYMPIAN	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0.0001	0.031	PreCalculated		1,000 - 1,025 Btu / SCF	744.27 MMBtu			744.27 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #15 - DRURY LANE GENERAC	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	0.41323	0.41323	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	7.81 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #15 - DRURY LANE	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke	CH4	0.00514	0.10792	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu	7.81 MMBtu	658 g/MMBtu	1025 Btu/scf	

GENERAC		Lean Burn)						/ SCF				
EMER GEN #15 - DRURY LANE GENERAC	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	7.81 MMBtu			7.81 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #2 - CPI 115G0 - NAT GAS - FOUNDERS HALL	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	2.01799	2.01799	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	38.14 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #2 - CPI 115G0 - NAT GAS - FOUNDERS HALL	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.0251	0.52702	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	38.14 MMBtu	658 g/MMBtu	1025 Btu/scf	
EMER GEN #2 - CPI 115G0 - NAT GAS - FOUNDERS HALL	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	38.14 MMBtu			38.14 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #3 - ONAN 15JC4R - NAT GAS - HARRINGTON	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	0.35873	0.35873	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	6.78 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #3 - ONAN 15JC4R - NAT GAS - HARRINGTON	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.00446	0.09369	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	6.78 MMBtu	658 g/MMBtu	1025 Btu/scf	
EMER GEN #3 - ONAN 15JC4R - NAT GAS - HARRINGTON	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	6.78 MMBtu			6.78 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #4 - OLYMPIAN 96A - NAT GAS- SALISBURY	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CO2	2.23016	2.23016	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	42.15 MMBtu	52.91 kg/MMBtu	1025 Btu/scf	
EMER GEN #4 - OLYMPIAN 96A - NAT GAS- SALISBURY	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	CH4	0.02773	0.58243	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	42.15 MMBtu	658 g/MMBtu	1025 Btu/scf	
EMER GEN #4 - OLYMPIAN 96A - NAT GAS- SALISBURY	Stationary Combustion - Scope 1	Reciprocating Engines (2-Stroke Lean Burn)	N2O	0	0	PreCalculated		1,000 - 1,025 Btu / SCF	42.15 MMBtu			42.15 MMBTU x 0.0001 Kg/MMBTU/10 ..
EMER GEN #5 - FULLER #1 ROOF, SUPERIOR	Stationary Combustion - Scope 1	Unspecified Technology	CO2	1.19457	1.19457	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	117 gal	10.21 kg/gal	0.138 MMBtu/gal	
EMER GEN #5 - FULLER #1 ROOF, SUPERIOR	Stationary Combustion - Scope 1	Unspecified Technology	CH4	5e-005	0.00102	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	117 gal	0.003 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #5 - FULLER #1 ROOF, SUPERIOR	Stationary Combustion - Scope 1	Unspecified Technology	N2O	1e-005	0.003	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	117 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal	
EMER GEN #6 - FULLER #2 CATERPILLAR #D200P4 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	CO2	4.24736	4.24736	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	416 gal	10.21 kg/gal	0.138 MMBtu/gal	
EMER GEN #6 - FULLER #2 CATERPILLAR #D200P4	Stationary Combustion - Scope 1	Unspecified Technology	CH4	0.00017	0.00362	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	416 gal	0.003 kg/MMBtu	0.138 MMBtu/gal	

DIESEL											
EMER GEN #6 - FULLER #2 CATERPILLAR #D200P4 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	N2O	3e-005	0.01068	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	416 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #7 - GATEWAY KOHLER 500	Stationary Combustion - Scope 1	Unspecified Technology	CO2	15.39668	15.39668	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	1508 gal	10.21 kg/gal	0.138 MMBtu/gal
EMER GEN #7 - GATEWAY KOHLER 500	Stationary Combustion - Scope 1	Unspecified Technology	CH4	0.00062	0.01311	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	1508 gal	0.003 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #7 - GATEWAY KOHLER 500	Stationary Combustion - Scope 1	Unspecified Technology	N2O	0.00012	0.03871	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	1508 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #8 GATEWAY GARAGE CAT D125-6 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	CO2	1.31096	1.31096	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	128.4 gal	10.21 kg/gal	0.138 MMBtu/gal
EMER GEN #8 GATEWAY GARAGE CAT D125-6 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	CH4	5e-005	0.00112	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	128.4 gal	0.003 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #8 GATEWAY GARAGE CAT D125-6 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	N2O	1e-005	0.0033	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	128.4 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #9 - POWER PLANT CATERPILLAR # SR-4 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	CO2	13.23216	13.23216	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	1296 gal	10.21 kg/gal	0.138 MMBtu/gal
EMER GEN #9 - POWER PLANT CATERPILLAR # SR-4 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	CH4	0.00054	0.01127	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	1296 gal	0.003 kg/MMBtu	0.138 MMBtu/gal
EMER GEN #9 - POWER PLANT CATERPILLAR # SR-4 DIESEL	Stationary Combustion - Scope 1	Unspecified Technology	N2O	0.00011	0.03327	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	1296 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
HVAC Units	Fugitive - Scope 1	Unspecified Technology	HFC-13 ..	0.075	97.5	PreCalculated		N/A	56 L		
Light truck Vehicles Tier 0	Mobile Combustion - Scope 1	EPA Tier 0	CO2	0	0	Emission Factor	2014 Default Emission Factors - Table #13.1	All	0 gal	8.78 kg/gal	5.25 MMBtu/bbl
Light truck Vehicles Tier 0	Mobile Combustion - Scope 1	EPA Tier 0	CH4	0	0	Emission Factor	2014 Default Emission Factors - Table #13.4	All	0 mi	0.0776 g/mi	
Light truck Vehicles Tier 0	Mobile Combustion - Scope 1	EPA Tier 0	N2O	0	0	Emission Factor	2014 Default Emission Factors - Table #13.4	All	0 mi	0.1056 g/mi	
Light truck vehicles Tier 1	Mobile Combustion - Scope 1	EPA Tier 1	CO2	11.75818	11.75818	Emission Factor	2014 Default Emission Factors - Table #13.1	All	1339.2 gal	8.78 kg/gal	5.25 MMBtu/bbl
Light truck vehicles Tier 1	Mobile Combustion - Scope 1	EPA Tier 1	CH4	0.00085	0.01776	Emission Factor	2014 Default Emission Factors - Table #13.4	All	18708 mi	0.0452 g/mi	

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Light truck vehicles Tier 1	Mobile Combustion - Scope 1	EPA Tier 1	N2O	0.00163	0.50513	Emission Factor	2014 Default Emission Factors - Table #13.4	All	18708 mi	0.0871 g/mi	
Light truck vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 2	CO2	92.34909	92.34909	Emission Factor	2014 Default Emission Factors - Table #13.1	All	10518.12 gal	8.78 kg/gal	5.25 MMBtu/bbl
Light truck vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 2	CH4	0.00256	0.05373	Emission Factor	2014 Default Emission Factors - Table #13.4	All	156954 mi	0.0163 g/mi	
Light truck vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 2	N2O	0.00104	0.32113	Emission Factor	2014 Default Emission Factors - Table #13.4	All	156954 mi	0.0066 g/mi	
Mobile Air Conditioning	Fugitive - Scope 1	Unspecified Technology	HFC-13 ..	0.0076	9.88	PreCalculated		N/A	6 L		
Motor Equipment	Mobile Combustion - Scope 1	Agricultural Equipment	CO2	11.42111	11.42111	Emission Factor	2014 Default Emission Factors - Table #13.1	All	1118.62 gal	10.21 kg/gal	5.8 MMBtu/bbl
Motor Equipment	Mobile Combustion - Scope 1	Agricultural Equipment	CH4	0.00161	0.03383	Emission Factor	2014 Default Emission Factors - Table #13.7	All	1118.62 gal	1.44 g/gal	5.8 MMBtu/bbl
Motor Equipment	Mobile Combustion - Scope 1	Agricultural Equipment	N2O	0.00029	0.09016	Emission Factor	2014 Default Emission Factors - Table #13.7	All	1118.62 gal	0.26 g/gal	5.8 MMBtu/bbl
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	CO2	1593.82909	1593.82909	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	30123.4 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	CH4	0.02711	0.56933	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	30123.4 MMBtu	0.9 g/MMBtu	1025 Btu/scf
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	N2O	0.02711	8.40443	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	30123.4 MMBtu	0.9 g/MMBtu	1025 Btu/scf
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	CO2	0.15826	0.15826	Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	15.5 gal	10.21 kg/gal	0.138 MMBtu/gal
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	CH4	1e-005	0.00013	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	15.5 gal	0.003 kg/MMBtu	0.138 MMBtu/gal
NEW BOILER #1-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	N2O	0	0.0004	Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	15.5 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
NEW BOILER #2-VICTORY ENERGY - NAT GAS	Stationary Combustion - Scope 1	Boilers	CO2	1831.20981	1831.20981	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	34609.9 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
NEW BOILER	Stationary Combustion - Scope 1	Boilers	CH4	0.03115	0.65413	Emission Factor	2014 Default Emission	1,000 -	34609.9	0.9 g/MMBtu	1025

#2-VICTORY ENERGY - NAT GAS						Factors - Table #12.7	1,025 Btu / SCF	MMBtu		Btu/scf
NEW BOILER #2-VICTORY ENERGY - NAT GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.03115	9.65616 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	34609.9 MMBtu	0.9 g/MMBtu	1025 Btu/scf
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	CO2	1848.16217	1848.16217 Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	34930.3 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	CH4	0.03144	0.66018 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	34930.3 MMBtu	0.9 g/MMBtu	1025 Btu/scf
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Boilers	N2O	0.03144	9.74555 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	34930.3 MMBtu	0.9 g/MMBtu	1025 Btu/scf
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	CO2	0.15826	0.15826 Emission Factor	2014 Default Emission Factors - Table #12.1	Distillate Fuel Oil No. 2	15.5 gal	10.21 kg/gal	0.138 MMBtu/gal
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	CH4	1e-005	0.00013 Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	15.5 gal	0.003 kg/MMBtu	0.138 MMBtu/gal
NEW BOILER #3-VICTORY ENERGY - NAT GAS / #2 OIL	Stationary Combustion - Scope 1	Unspecified Technology	N2O	0	0.0004 Emission Factor	2014 Default Emission Factors - Table #12.9	Distillate Fuel Oil No. 2	15.5 gal	0.0006 kg/MMBtu	0.138 MMBtu/gal
OFF-CAMPUS RESIDENCES - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CO2	1189.49087	1189.49087 Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	22481.4 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
OFF-CAMPUS RESIDENCES - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.02023	0.4249 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	22481.4 MMBtu	0.9 g/MMBtu	1025 Btu/scf
OFF-CAMPUS RESIDENCES - NAT. GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.02023	6.27231 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	22481.4 MMBtu	0.9 g/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 1ST SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CO2	392.99432	392.99432 Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	7427.6 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 1ST SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.00668	0.14038 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	7427.6 MMBtu	0.9 g/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 1ST SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.00668	2.0723 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	7427.6 MMBtu	0.9 g/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 2ND SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CO2	317.57111	317.57111 Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	6002.1 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 2ND SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.0054	0.11344 Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	6002.1 MMBtu	0.9 g/MMBtu	1025 Btu/scf
ON-CAMPUS	Stationary Combustion - Scope 1	Boilers	N2O	0.0054	1.67459 Emission Factor	2014 Default Emission	1,000 -	6002.1	0.9 g/MMBtu	1025

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MISCELLANEOUS SOURCES 2ND SET - NAT. GAS							Factors - Table #12.7	1,025 Btu / SCF	MMBtu		Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 3RD SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CO2	305.51292	305.51292	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	5774.2 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 3RD SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	CH4	0.0052	0.10913	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	5774.2 MMBtu	0.9 g/MMBtu	1025 Btu/scf
ON-CAMPUS MISCELLANEOUS SOURCES 3RD SET - NAT. GAS	Stationary Combustion - Scope 1	Boilers	N2O	0.0052	1.611	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	5774.2 MMBtu	0.9 g/MMBtu	1025 Btu/scf
Passenger Vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 0	CO2	9.219	9.219	Emission Factor	2014 Default Emission Factors - Table #13.1	All	1050 gal	8.78 kg/gal	5.25 MMBtu/bbl
Passenger Vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 0	CH4	0.00148	0.03116	Emission Factor	2014 Default Emission Factors - Table #13.4	All	21074 mi	0.0704 g/mi	
Passenger Vehicles Tier 2	Mobile Combustion - Scope 1	EPA Tier 0	N2O	0.00136	0.42268	Emission Factor	2014 Default Emission Factors - Table #13.4	All	21074 mi	0.0647 g/mi	
Refrigeration R404A	Fugitive - Scope 1	Unspecified Technology	R-404A	0.012	39.12	PreCalculated		N/A	9 L		
Refrigeration R410A	Fugitive - Scope 1	Unspecified Technology	R-410A	0.015	25.875	PreCalculated		N/A	11 L		
SALISBURY ESTATES HEATING	Stationary Combustion - Scope 1	Boilers	CO2	682.98768	682.98768	Emission Factor	2014 Default Emission Factors - Table #12.1	1,000 - 1,025 Btu / SCF	12908.48 MMBtu	52.91 kg/MMBtu	1025 Btu/scf
SALISBURY ESTATES HEATING	Stationary Combustion - Scope 1	Boilers	CH4	0.01162	0.24397	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	12908.48 MMBtu	0.9 g/MMBtu	1025 Btu/scf
SALISBURY ESTATES HEATING	Stationary Combustion - Scope 1	Boilers	N2O	0.01162	3.60147	Emission Factor	2014 Default Emission Factors - Table #12.7	1,000 - 1,025 Btu / SCF	12908.48 MMBtu	0.9 g/MMBtu	1025 Btu/scf

Appendix B
Supporting Documentation

Worcester Polytechnic Institute
Worcester, MA
Greenhouse Gas Emissions Report

Summary of Sources of GHG Emissions Operating in 2015

EU#	Emission Unit	Fuel	Quantity Used	Unit of Measure	Quantity Used	Unit of Measure	Emission Factor (EF)[1]	Unit of Measure	EF Source	Metric-Tons of CO2 Emitted[2]	Short-Tons of CO2 Emitted[3]
DIRECT EMISSIONS SCOPE 1											
Carbon Dioxide CO_2 - GWP 1											
Stationary Fuel Combustion											
EU # 4	Founders Equip. Boiler # 4	N. G.	39,602	Therms	3,960.20	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	209.53	230.970
EU # 7	Generator # 1 Daniels Hall, Kohler	N.G.	0.0428	MMCF	44.00	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	2.3280	2.566
EU # 8	Generator # 2 Founders Hall, CPI	N.G.	0.0371	MMCF	38.14	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	2.0179	2.224
EU # 9	Generator # 3 Harrington, Onan	N.G.	0.0066	MMCF	6.78	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	0.3590	0.396
EU # 10	Generator # 4 Salisbury, Olympian	N.G.	0.0410	MMCF	42.15	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	2.2301	2.458
EU # 11	Generator Security, Honda	N.G.	-	MMCF	0.00	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	0.0000	0.000
EU # 12	Generator #5 Fuller #1 Roof, Superior	diesel	0.1170	1000 gallons	117.00	gallons	10.21	kg/gallon	GRP Table 12.1	1.1946	1.317
EU # 13	Generator #6 Fuller #2 Caterpillar	diesel	0.4160	1000 gallons	416.00	gallons	10.21	kg/gallon	GRP Table 12.1	4.2474	4.682
EU # 14	Generator #9, Power Plant,SR-4 Caterpillar	diesel	1.2960	1000 gallons	1,296.00	gallons	10.21	kg/gallon	GRP Table 12.1	13.2322	14.586
EU # 28	Generator #7 Gateway, Kohler	diesel	1.5088	1000 gallons	1,508.80	gallons	10.21	kg/gallon	GRP Table 12.1	15.4048	16.981
EU # 29	Generator #10 East Hall, Kohler	diesel	0.3360	1000 gallons	336.00	gallons	10.21	kg/gallon	GRP Table 12.1	3.4306	3.782
EU # 30	Generator # 11 Goddard, Olympian	N.G.	0.0134	MMCF	13.78	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	0.7288	0.803
EU # 31	Generator #8 Gateway Garage, Caterpiller	diesel	0.1284	1000 gallons	128.40	gallons	10.21	kg/gallon	GRP Table 12.1	1.3110	1.445
33	Generator #13 Gateway 2 Generator	diesel	0.5742	1000 gallons	574.20	gallons	10.21	kg/gallon	GRP Table 12.1	5.8626	6.462
32	Generator #12 Rec Center Generator	diesel	0.0724	1000 gallons	72.40	gallons	10.21	kg/gallon	GRP Table 12.1	0.7392	0.815
34	Generator #14 Faraday Generator	N.G.	0.7240	MMCF	744.27	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	39.3794	43.408
35	Generator #15 Drury Lane	N.G.	0.0076	MMCF	7.81	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	0.4134	0.456
EU # 15	Power House New Boiler #1	N. G.	301,234	Therms	30,123.40	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	1,593.83	1,757
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	10.21	kg/gallon	GRP Table 12.1	0.1583	0.1744
EU # 16	Power House New Boiler #2	N.G.	346,099	Therms	34,609.90	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	1,831.21	2,019
EU # 17	Power House New Boiler #3	N.G.	349,303	Therms	34,930.30	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	1,848.16	2,037
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	10.21	kg/gallon	GRP Table 12.1	0.1583	0.1744
EU # 20	Off Campus Residences (group)	N.G.	224,814	Therms	22,481.40	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	1,189.49	1,311
EU # 21	On-Campus Miscell. 1st set	N.G.	74,276	Therms	7,427.60	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	392.99	433
EU # 22	On-Campus Miscell. 2nd set	N.G.	60,021	Therms	6,002.10	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	317.57	350
EU # 23	On-Campus Miscell. 3rd set	N.G.	57,742	Therms	5,774.20	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	305.51	337
EU # 24	Off-Campus Residences Oil	#2 Oil	-	1000 gallons	0.00	gallons	10.21	kg/gallon	GRP Table 12.1	0.00	0
EU # 27	Gateway Cleaver Brooks Boilers (2)	N.G.	141,480	Therms	14,148.00	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	748.57	825
EU # 26	Gateway Lattern Boilers (2)	N.G.	39,497	Therms	3,949.70	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	208.98	230
	Salisbury Estates Heating	N.G.	129,085	Therms	12,908.48	MMBTU	52.91	Kg CO2/MMBTU	GRP Table 12.1	682.99	753
Mobile Fuel Combustion											
	Non-Highway Motor Vehicles	diesel			1,118.62	gallons	10.21	Kg CO2/gallon	GRP Table 12.1	11.42	13
	Tier 1 - Light Trucks	gasoline			1,339.20	gallons	8.78	Kg CO2/gallon	GRP Table 12.1	11.76	13
	Tier 2 - Light Trucks	gasoline			10,518.12	gallons	8.78	Kg CO2/gallon	GRP Table 12.1	92.35	102
	Tier 2 - Passenger Cars	gasoline			1,050.00	gallons	8.78	Kg CO2/gallon	GRP Table 12.1	9.22	10

Summary of Sources of GHG Emissions Operating in 2015

EU#	Emission Unit	Fuel	Quantity Used	Unit of Measure	Quantity Used	Unit of Measure	Emission Factor (EF)[1]	Unit of Measure	EF Source	Metric-Tons of CO2 Emitted[2]	Short-Tons of CO2 Emitted[3]
Methane CH_4 - GWP 21											
Stationary Fuel Combustion											
EU # 4	Founders Equip. Boiler # 4	N. G.	39,602	Therms	3,960.20	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0036	0.0039
EU # 7	Generator # 1 Daniels Hall, Kohler	N.G.	0.0428	MMCF	44.00	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0290	0.0319
EU # 8	Generator # 2 Founders Hall, CPI	N.G.	0.0371	MMCF	38.14	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0251	0.0277
EU # 9	Generator # 3 Harrington, Onan	N.G.	0.0066	MMCF	6.78	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0045	0.0049
EU # 10	Generator # 4 Salisbury, Olympian	N.G.	0.0410	MMCF	42.15	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0277	0.0306
EU # 11	Generator Security, Honda	N.G.	-	MMCF	0.00	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 12	Generator #5 Fuller #1 Roof, Superior	diesel	0.1170	1000 gallons	117.00	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0000	0.0001
EU # 13	Generator #6 Fuller #2 Caterpillar	diesel	0.4160	1000 gallons	416.00	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0002	0.0002
EU # 14	Generator #9, Power Plant,SR-4 Caterpillar	diesel	1.2960	1000 gallons	1,296.00	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0005	0.0006
EU # 28	Generator #7 Gateway, Kohler	diesel	1.5088	1000 gallons	1,508.80	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0006	0.0007
EU # 29	Generator #10 East Hall, Kohler	diesel	0.3360	1000 gallons	336.00	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0001	0.0002
EU # 30	Generator # 11 Goddard, Olympian	N.G.	0.0134	MMCF	13.78	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0091	0.0100
EU # 31	Generator #8 Gateway Garage, Caterpiller	diesel	0.1284	1000 gallons	128.40	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0001	0.0001
	Generator #13 Gateway 2 Generator	diesel	0.5742	1000 gallons	574.20	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0002	0.0003
	Generator #12 Rec Center Generator	diesel	0.0724	1000 gallons	72.40	gallons	0.003	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
	Generator #14 Faraday Generator	N.G.	0.7240	MMCF	744.27	MMBTU	658	g/MMBTU	GRP Table 12.7	0.4897	0.5398
	Generator #15 Drury Lane	N.G.	0.0076	MMCF	7.81	MMBTU	658	g/MMBTU	GRP Table 12.7	0.0051	0.0057
EU # 15	Power House New Boiler #1	N. G.	301,234	Therms	30,123.40	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0271	0.0299
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	0.2	g/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 16	Power House New Boiler #2	N.G.	346,099	Therms	34,609.90	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0311	0.0343
EU # 17	Power House New Boiler #3	N.G.	349,303	Therms	34,930.30	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0314	0.0347
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	0.2	g/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 20	Off Campus Residences (group)	N.G.	224,814	Therms	22,481.40	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0202	0.0223
EU # 21	On-Campus Miscell. 1st set	N.G.	74,276	Therms	7,427.60	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0067	0.0074
EU # 22	On-Campus Miscell. 2nd set	N.G.	60,021	Therms	6,002.10	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0054	0.0060
EU # 23	On-Campus Miscell. 3rd set	N.G.	57,742	Therms	5,774.20	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0052	0.0057
EU # 24	Off-Campus Residences Oil	#2 Oil	-	1000 gallons	0.00	gallons	0.0030	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 27	Gateway Cleaver Brooks Boilers (2)	N.G.	141,480	Therms	14,148.00	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0127	0.0140
EU # 26	Gateway Lattern Boilers (2)	N.G.	39,497	Therms	3,949.70	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0036	0.0039
	Salisbury Estates Heating	N.G.	129,085	Therms	12,908.48	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0120	0.0132
Mobile Fuel Combustion											
	Non-Highway Motor Vehicles	diesel			1,118.62	gallons	1.44	g/gal	GRP Table 13.7	0.0016	0.0018
	Tier 1 - Light Trucks	gasoline			1,339.20	gallons	0.0452	g/mi	GRP Table 13.4	0.0008	0.0009
	Tier 2 - Light Trucks	gasoline			10,518.12	gallons	0.0163	g/mi	GRP Table 13.4	0.0026	0.0028
	Tier 2 - Passenger Cars	gasoline			1,050.00	gallons	0.0704	g/mi	GRP Table 13.4	0.0015	0.0016

Worcester Polytechnic Institute
Worcester, MA
Greenhouse Gas Emissions Report

Summary of Sources of GHG Emissions Operating in 2015

EU#	Emission Unit	Fuel	Quantity Used	Unit of Measure	Quantity Used	Unit of Measure	Emission Factor (EF)[1]	Unit of Measure	EF Source	Metric-Tons of CO2 Emitted[2]	Short-Tons of CO2 Emitted[3]
Nitrous Oxide N_2O - GWP 310											
Stationary Fuel Combustion											
EU # 4	Founders Equip. Boiler # 4	N. G.	39,602	Therms	3,960.20	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0036	0.0039
EU # 7	Generator # 1 Daniels Hall, Kohler	N.G.	0.0428	MMCF	44.00	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 8	Generator # 2 Founders Hall, CPI	N.G.	0.0371	MMCF	38.14	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 9	Generator # 3 Harrington, Onan	N.G.	0.0066	MMCF	6.78	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 10	Generator # 4 Salisbury, Olympian	N.G.	0.0410	MMCF	42.15	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 11	Generator Security, Honda	N.G.	-	MMCF	0.00	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 12	Generator #5 Fuller #1 Roof, Superior	diesel	0.1170	1000 gallons	117.00	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 13	Generator #6 Fuller #2 Caterpillar	diesel	0.4160	1000 gallons	416.00	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 14	Generator #9, Power Plant,SR-4 Caterpillar	diesel	1.2960	1000 gallons	1,296.00	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0001	0.0001
EU # 28	Generator #7 Gateway, Kohler	diesel	1.5088	1000 gallons	1,508.80	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0001	0.0001
EU # 29	Generator #10 East Hall, Kohler	diesel	0.3360	1000 gallons	336.00	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 30	Generator # 11 Goddard, Olympian	N.G.	0.0134	MMCF	13.78	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 31	Generator #8 Gateway Garage, Caterpiller	diesel	0.1284	1000 gallons	128.40	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
	Generator #13 Gateway 2 Generator	diesel	0.5742	1000 gallons	574.20	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
	Generator #12 Rec Center Generator	diesel	0.0724	1000 gallons	72.40	gallons	0.0006	Kg/MMBTU	GRP Table 12.9	0.0000	0.0000
	Generator #14 Faraday Generator	N.G.	0.7240	MMCF	744.27	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0001	0.0001
	Generator #15 Drury Lane	N.G.	0.0076	MMCF	7.81	MMBTU	0.0001	Kg/MMBTU	GRP Table 12.7	0.0000	0.0000
EU # 15	Power House New Boiler #1	N. G.	301,234	Therms	30,123.40	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0271	0.0299
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	0.4	g/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 16	Power House New Boiler #2	N.G.	346,099	Therms	34,609.90	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0311	0.0343
EU # 17	Power House New Boiler #3	N.G.	349,303	Therms	34,930.30	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0314	0.0347
		#2 Oil	0.0155	1000 gallons	15.5000	gallons	0.4	g/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 20	Off Campus Residences (group)	N.G.	224,814	Therms	22,481.40	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0202	0.0223
EU # 21	On-Campus Miscell. 1st set	N.G.	74,276	Therms	7,427.60	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0067	0.0074
EU # 22	On-Campus Miscell. 2nd set	N.G.	60,021	Therms	6,002.10	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0054	0.0060
EU # 23	On-Campus Miscell. 3rd set	N.G.	57,742	Therms	5,774.20	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0052	0.0057
EU # 24	Off-Campus Residences Oil	#2 Oil	-	1000 gallons	0.00	gallons	0.0	kg/MMBTU	GRP Table 12.9	0.0000	0.0000
EU # 27	Gateway Cleaver Brooks Boilers (2)	N.G.	141,480	Therms	14,148.00	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0127	0.0140
EU # 26	Gateway Lattern Boilers (2)	N.G.	39,497	Therms	3,949.70	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0036	0.0039
	Salisbury Estates Heating	N.G.	129,085	Therms	12,908.48	MMBTU	0.9	g/MMBTU	GRP Table 12.7	0.0116	0.0128
Mobile Fuel Combustion											
	Non-Highway Motor Vehicles	diesel			1,118.62	gallons	0.26	g/gal	GRP Table 13.7	0.0003	0.0003
	Tier 1 - Light Trucks	gasoline			1,339.20	gallons	0.0871	g/mi	GRP Table 13.4	0.0016	0.0018
	Tier 2 - Light Trucks	gasoline			10,518.12	gallons	0.0066	g/mi	GRP Table 13.4	0.0010	0.0011
	Tier 2 - Passenger Cars	gasoline			1,050.00	gallons	0.0647	g/mi	GRP Table 13.4	0.0014	0.0015
REFRIGERATION R134A[5] - GWP 1300											
	HVAC Units - Facility Wide	R134A	150.0000	pounds	0.0750	tons	1,300	GWP		98	107
REFRIGERATION Acetylene - GWP 1300											
		Acetylene			20	cubic feet	0.1043	kg CO2 / CF	GRP Chapter 12.4 P72	0.002086	0.00230
REFRIGERATION R410A[5] - GWP 1725											
		R410A	30.0000	pounds	0.0150	tons				23	26
REFRIGERATION R404A[5] - GWP 3260											
		R404A	24.0000	pounds	0.0120	tons				35	39
VEHICLE REFRIGERATION R134A[6] - GWP 1300											
		R134A	15.1333		0.0076	tons				9	10
TOTAL										**9,713**	**10,707**

(1) Based on General Reporting Protocol 1.1 last updated on 1/14/2011. Nat Gas heat content used is 1028 MMBTU/MMCFper 40 CFR 98 Subpart C Table C-1

(2) Threshold for reporting GHGs all facilities exceeding 5,000 short-tons of CO2 emissions.

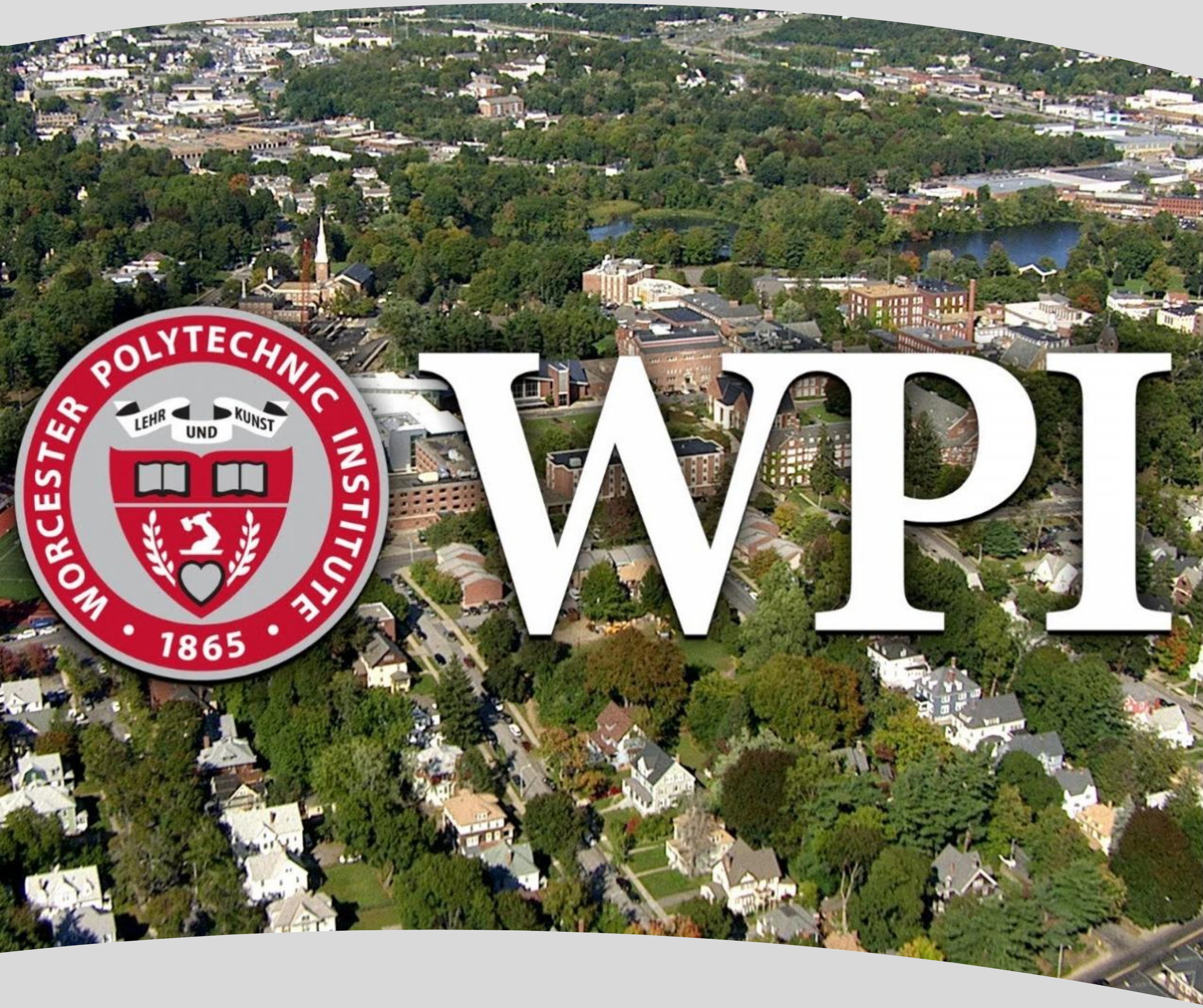
(3) Threshold for reporting GHGs to USEPA: all facilities exceeding 25,000 metric-tons of CO_2 emissions.

(4) Fuel usage was provided by WPI Chief Engineer

(5) Reporting of refrigerant was based on purchasing records for 2012

(6) Reporting of refrigerant was based on vehicle refrigerant capacity and operating emission factor of 20%

GREENER U



SCOPING AUDIT

Worcester Polytechnic Institute

January 3, 2017

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EXECUTIVE SUMMARY

Worcester Polytechnic Institute has retained GreenerU to provide a high-level assessment of the energy efficiency opportunities on campus. This effort is intended to identify opportunities to invest in campus energy efficiency and to support work toward WPI's greenhouse gas reduction goals. This study presents GreenerU's findings which include identification of **$4.2M in potential Energy Efficiency Opportunities**. Combined with previously identified, but not yet implemented opportunities on campus, **WPI has a total of $6M of potential Energy Efficiency work.**

Implementation of all identified Energy Efficiency work would reduce campus energy use by **20,300 MMBTU** or an additional **8% of the 2016 campus energy consumption,** and campus greenhouse gas (GHG) emissions by **1,600 metric tons of CO_2 equivalents (MTCDE) or 8% of the 2016 greenhouse gas emissions**. These projects would generate almost $534,000 in annual energy cost savings.

As part of our study, GreenerU looked at 17 buildings on WPI's campus. Energy efficiency reduction opportunities were identified through our walkthroughs, energy use data provided by WPI and benchmarking these buildings against similar buildings in the GreenerU database. The energy efficiency opportunities identified in these buildings include the following:

- » LED Lighting
- » Intelligent Lighting Controls
- » Recommissioning & Optimization of Equipment
- » Building Envelope Upgrades
- » HVAC Equipment & Control Upgrades
- » Cogeneration the Sports & Rec Center

AT A GLANCE

Energy Efficiency Opportunities on the WPI Campus:

- ❖ **GHG emissions reductions – 1,600 MTCDE**
- ❖ **Energy savings – 20,300 MMBTU**
- ❖ **Cost savings - $534,000**
- ❖ **8% campus Energy & Carbon Reduction**

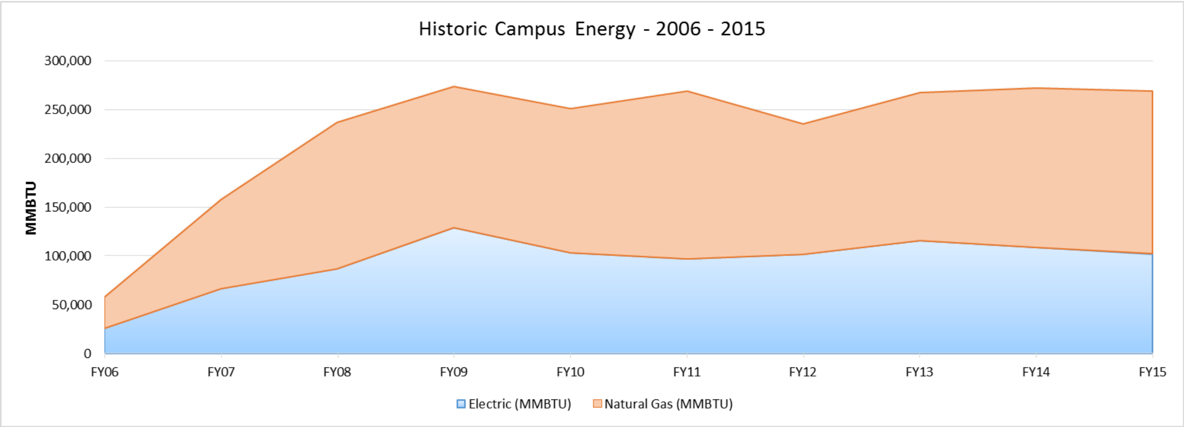
HISTORY – 2011 – 2015

Since 2011, Worcester Polytechnic Institute has implemented nearly $4 million in energy projects – both on their own and with GreenerU. Measures completed include:

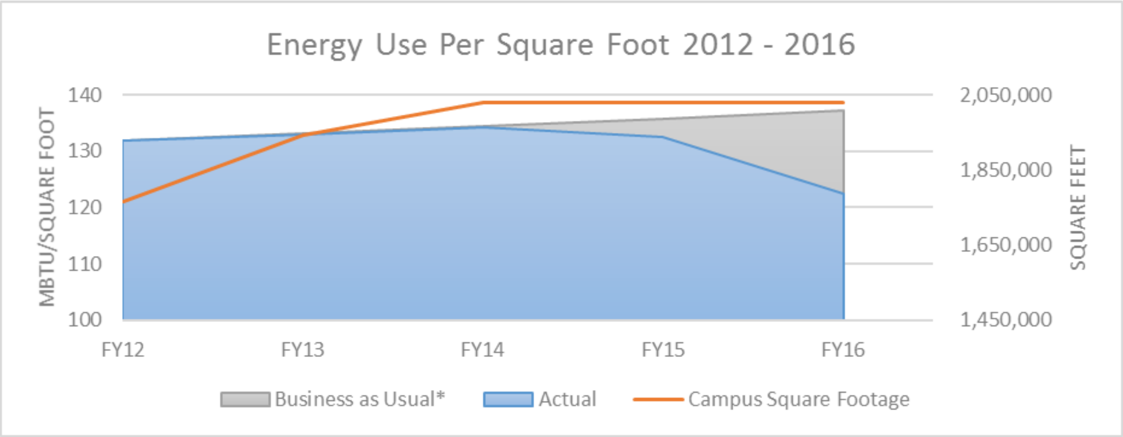
- » Energy Efficiency work at the Rubin Campus Center including:
  - – Major upgrades to HVAC controls, including use of VAV occupancy based controls
  - – Melink Kitchen Hood Controls
  - – Replacement of VAV reheat valve actuators & MAU steam valve actuator
  - – Lighting improvements and lighting controls
- » Gateway LSBE Building including:
  - – Upgrades to HVAC controls, fume hood controls, and ventilation optimization
  - – Dynamic static pressure reset and discharge air temperature reset on MAUs and RTUs
  - – Optimization of glycol heat recovery pump hours of operation
  - – Installation of Tecogen cogeneration modules
  - – Lighting improvements and lighting controls

- Extensive energy upgrades at Higgins Labs and Goddard Hall including:
  - Upgrades to building controls, and air handling equipment, including fume hood controls
  - Optimization of glycol system
  - Weatherization
  - Lighting improvements and lighting controls
- Extensive energy upgrades at Alden Memorial Hall, Atwater Kent Laboratory, & Morgan Hall, including:
  - Major upgrades to HVAC controls, including occupancy base controls and scheduling
  - Expansion of the DDC system at Atwater Kent
  - Installation of VFDs on fans and pumps
  - Kitchen Hood Controls
- Several Lighting retrofit projects around campus

The chart below illustrates the effects on energy consumption this work has had. Through the success of this work, WPI has held energy consumption close to 2006 levels, while adding 15% to its building stock over that period during construction of the Sports & Recreation Center and Faraday Hall dormitory.



Normalizing this data by square footage of campus building stock over the same period, as is done in the chart below, better illustrates the accomplishments of WPI's program. If WPI was to have done no energy efficiency work over the same period of time.



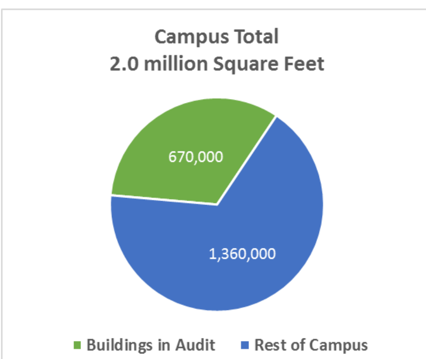
FINDINGS

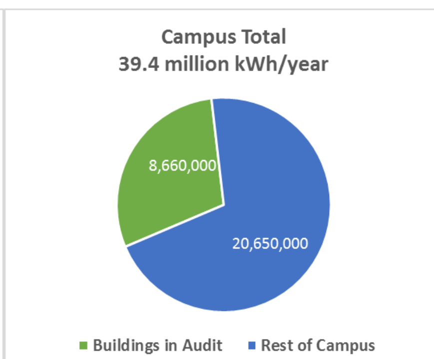
The buildings audited under this scope of work were developed in collaboration with WPI Facilities staff, and represent about a third of WPI's total built square footage. Buildings on campus not included in this study either have been recently renovated, will soon be renovated, or are not energy priorities for the staff. The buildings in this study are:

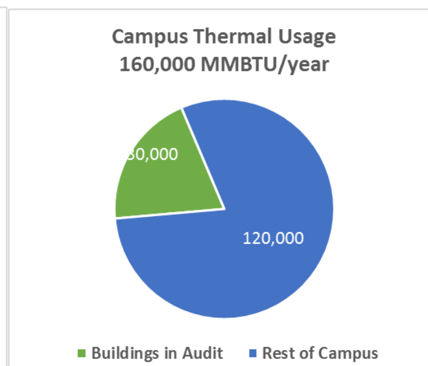
2016 Scoping Audit Building	
11 Einhorn	Founders Hall
20 Trowbridge	Fuller Labs
8 Elbridge	Institute Hall
8 Hackfeld	Salisbury Estates
Bartlett Center	Sports & Recreation Center
Ellsworth Apartments 1	Stoddard C
Ellsworth Apartments 2	Stratton Hall
Ellsworth Apartments 3	Washburn Shops – Stoddard Labs
Faraday Hall	

The buildings included in this study comprise 33% of the campus total gross square footage. The estimated annual electrical usage of these buildings is about 22% of the campus total. This proportion is significant to the square footage in part because the selected buildings are among the most energy intensive on campus. For thermal usage, the annual usage of these buildings is about 13%.

	Campus Total	Buildings in Scoping Audit	
Square Feet (SF)	2,030,000	670,000	33%
Annual Electric Usage (kWh)	29,310,000	8,660,000	30%
Annual Thermal Usage (MMBTU)	150,000	30,000	20%



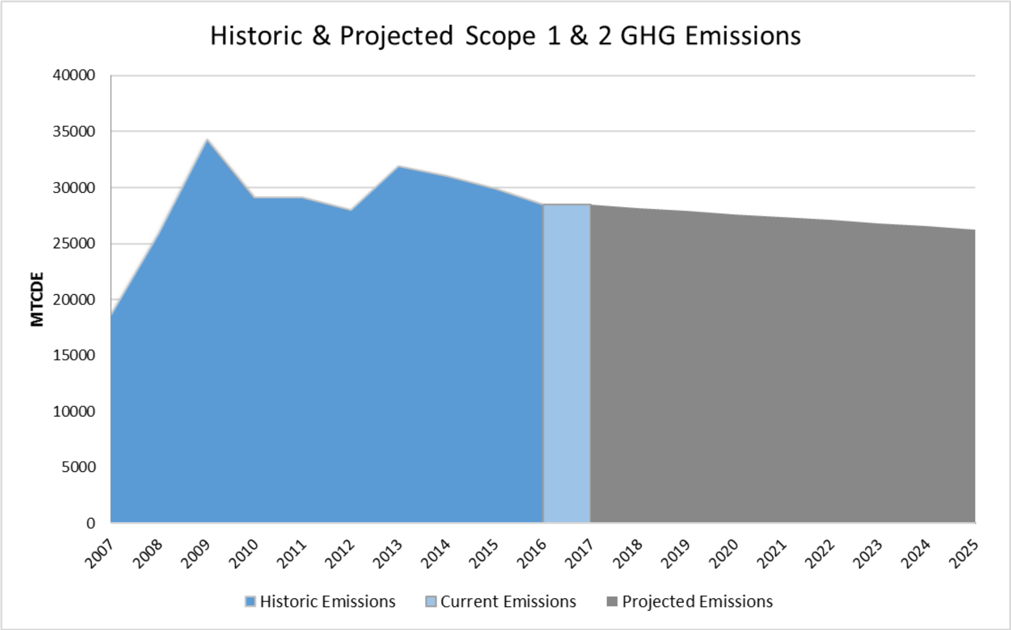




Areas of focus during the walk-throughs included: HVAC systems and controls, lighting and controls, and building envelope. Measures to improve building systems were evaluated on a building-by-building and measure-by-measure basis.

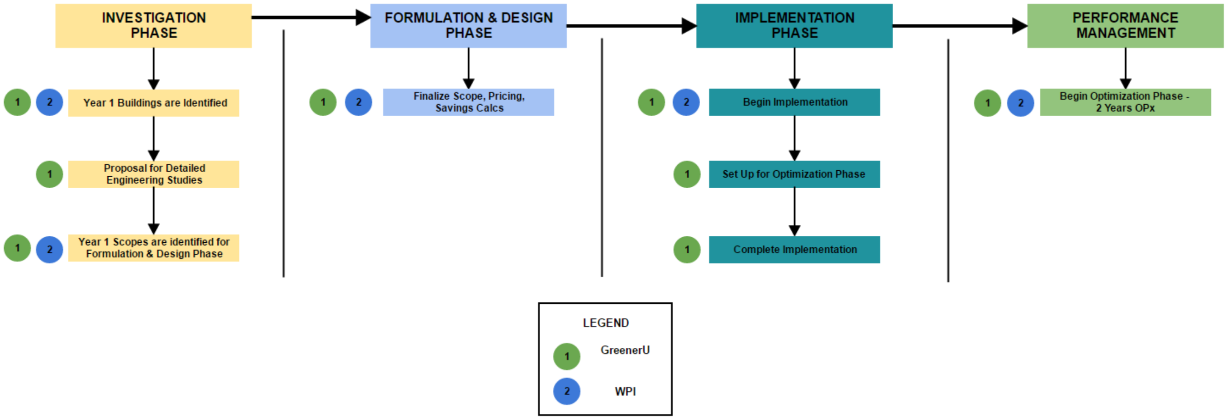
Results from this study identified some great energy efficiency reduction opportunities. GreenerU recommends continuing a path towards their greenhouse gas goals by devising a multi-year plan that will help Worcester Polytechnic Institute achieve their energy efficiency goals, as well as address deferred maintenance through energy project funding. GreenerU estimates that if WPI implements all opportunities identified, there is opportunity to reduce campus energy by nearly 20,300 MMBTU. GreenerU estimates that WPI can achieve 1,600 MTCDE reduction from these projects. Based on our experience working on 24 campuses, we estimate an investment of **$5M to $6M** achieving a simple ROI of 8% to 10%.

This strategy, focusing on technologies like LED lighting and intelligent lighting controls, as well as existing technologies that are not fully taken advantage of like DDC controls and building envelope improvements helps WPI continue towards their energy efficiency improvement goals.



NEXT STEPS

We recommend the following process to continue on the path towards implementation:



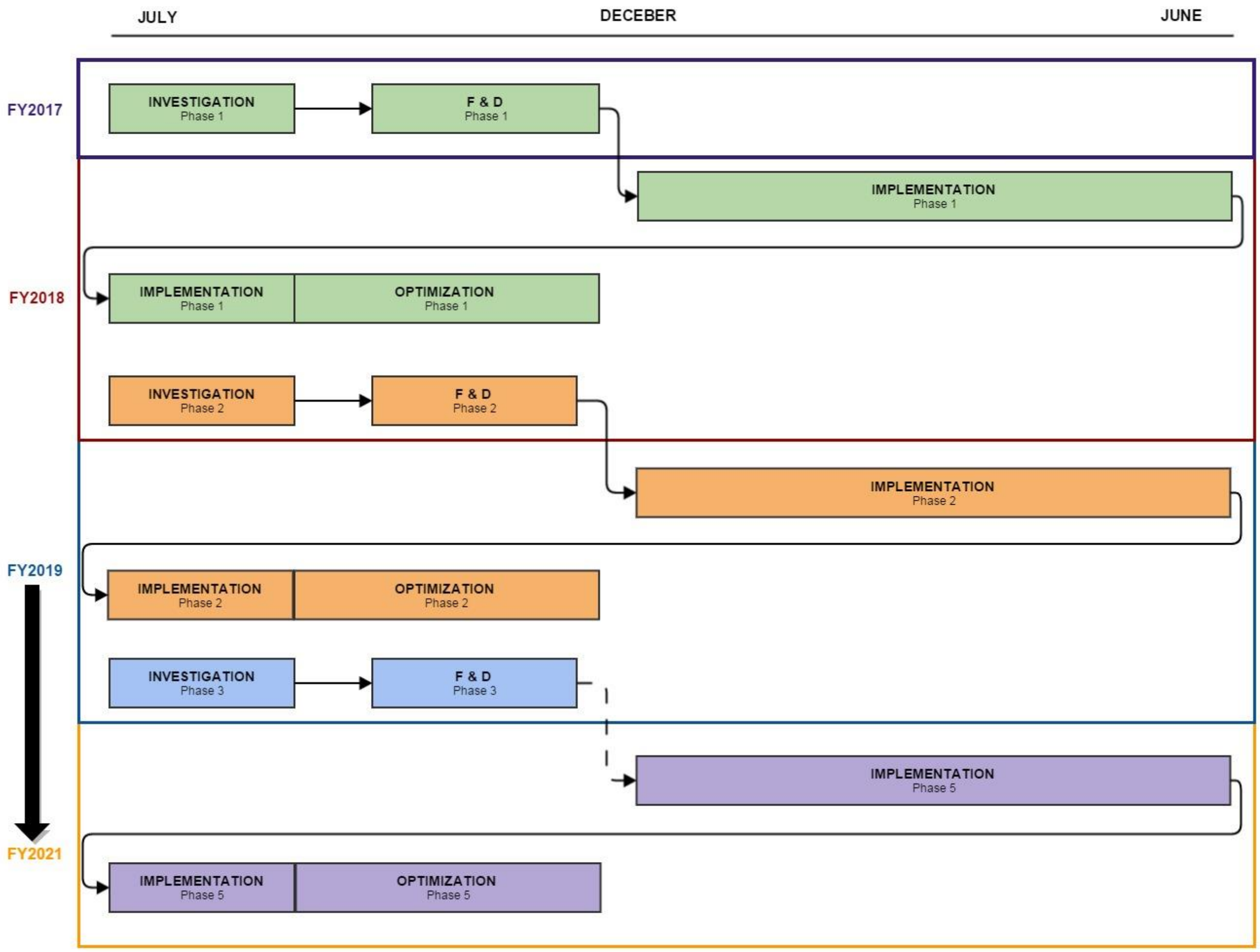
This path forward starts with identification of year 1 buildings and commencement of engineering studies for this first group of buildings which represent the best opportunity for carbon reduction and energy savings. The initial findings and savings estimates in this report require additional engineering work to gain a more accurate view of actual savings. A project development team would conduct more in-depth audits of the buildings, including operational controls reviews, utility analysis, condition and function assessments, and facilities personnel interviews.

Results from this investigation will then propel the next phase, which is the Formulation & Design phase to finalize ECMs to be implemented in year 1. A detailed audit report would be prepared, including contractor pricing, estimated incentive amounts and calculated savings and paybacks.

Following approval of the phase 1 ECMs, implementation of the year 1 ECMs would take place while year 2 ECMs are investigated and developed. Planning of the implementation phase should take into consideration the busy schedule of university buildings, and work around these unique challenges.

At the end of implementation, a program should be developed to monitor the ECMs implemented to maintain savings long term. This optimization program would prevent energy creep and deterioration of savings over time. This program can be tailored for multiple layers of complexity, depending on the needs and capabilities of the facilities staff.

GreenerU’s business is built around implementing energy efficiency and deferred maintenance programs like this for our customers. We would welcome the opportunity to continue working with Worcester Polytechnic Institute on implementing this program.



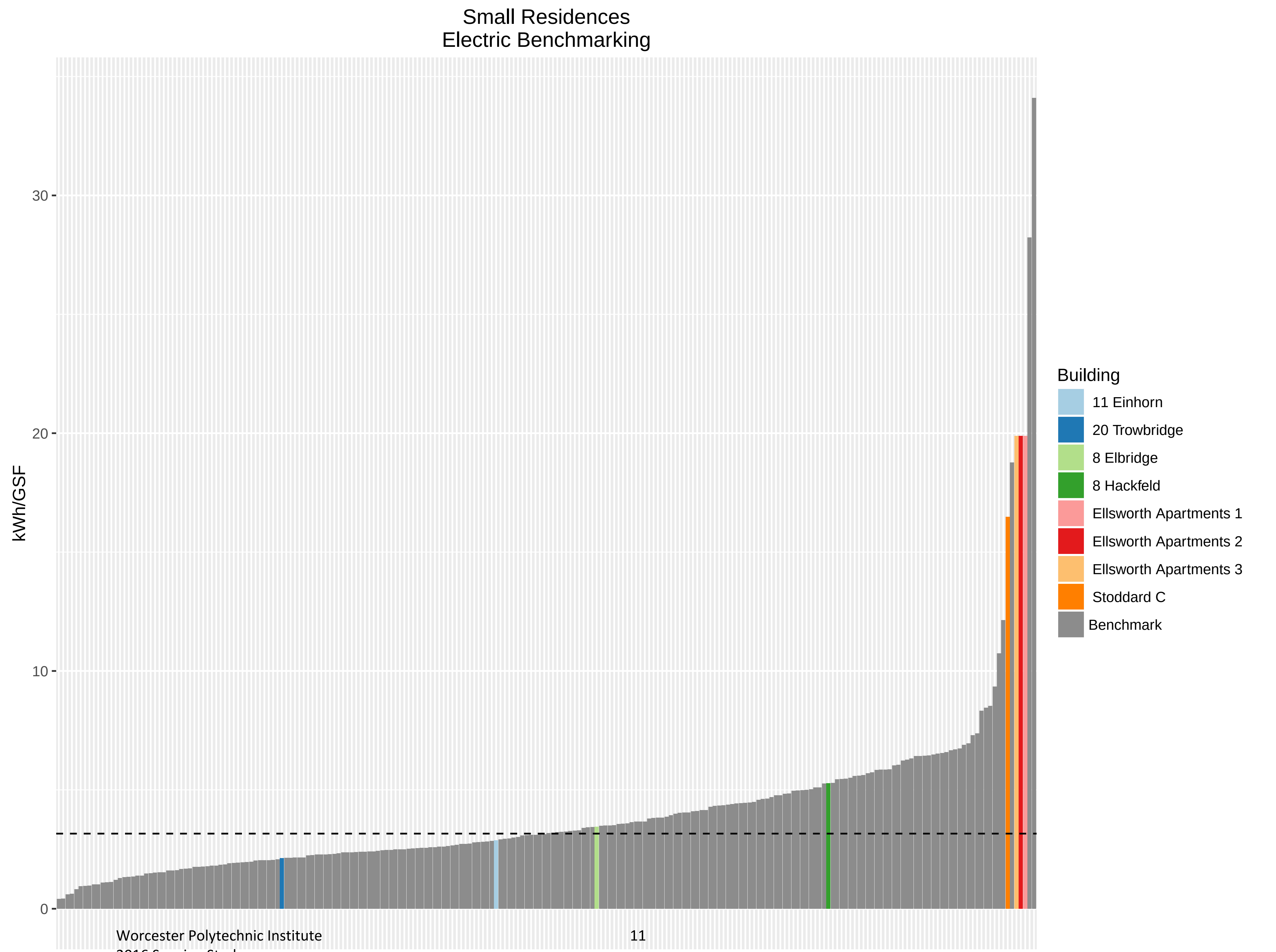
NOTE: FY2019, FY2020, and FY2021 follow the same process flow for the remainder of Phase 3, Phase 4, and Phase 5, respectively.

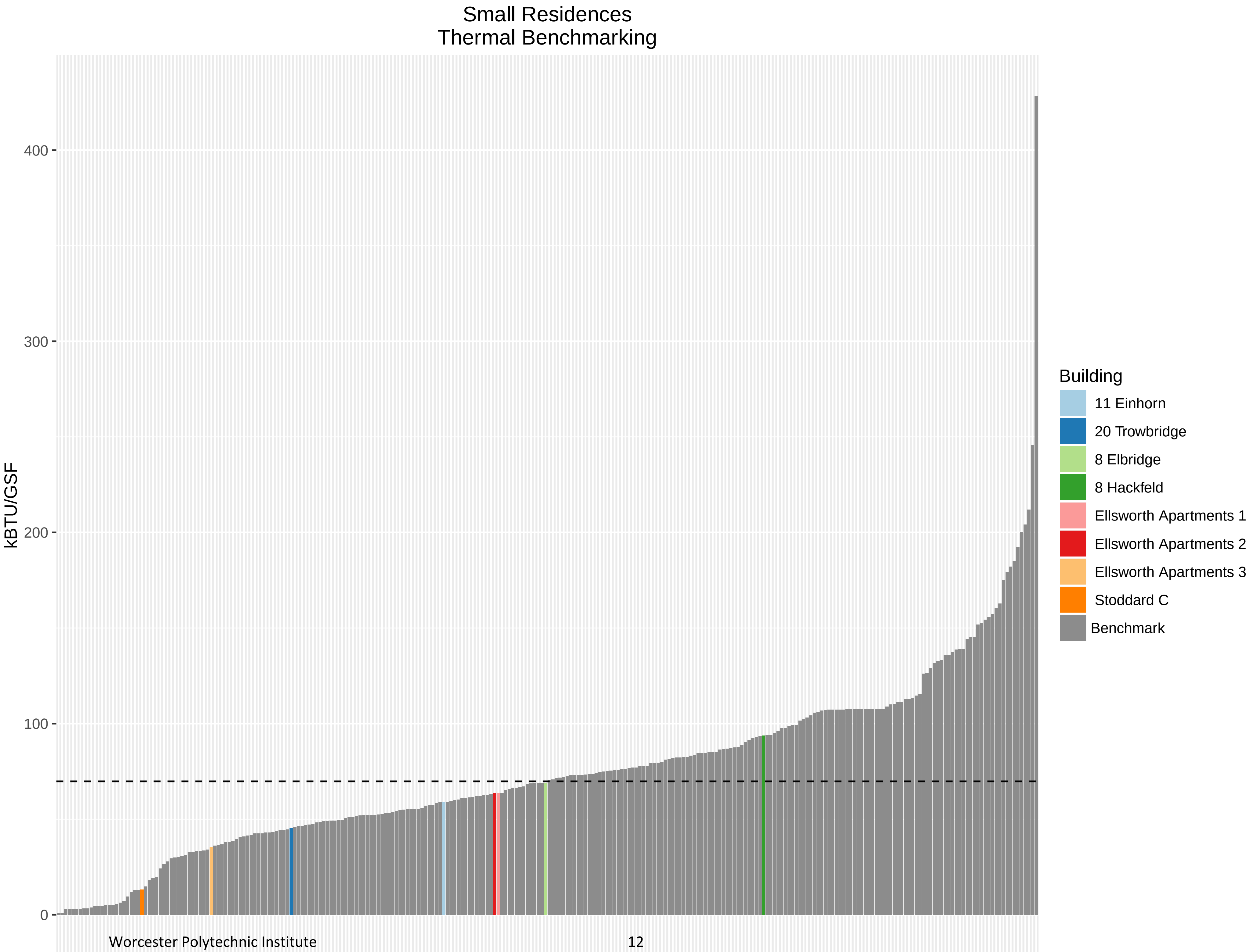
GREENER U

Program Summary by Building

	Building	GSF	Space Use	Existing Electric kWh	Existing Thermal kBtu	Proposed Electric kWh	Proposed Thermal kBtu	Savings Electric kWh	Savings Thermal kBtu	Savings Total MMBtu	Savings Total Cost Savings	Installed Cost	Deferred Maintenance Addressed	Simple Payback	GHG Emissions Reduction MTCO2
2016 Scoping Study	Fuller Labs	73,250	Academic	1,212,141	4,155,912	699,741	3,010,561	512,400	1,145,351	2,894	$ 73,300	$ 695,100	$ 183,100	9.5	225
	Stratton Hall	24,380	Academic	290,879	1,656,962	199,479	1,342,262	91,400	314,700	627	$ 14,200	$ 140,500	$ -	9.9	50
	Washburn ShopsStoddard Labs	42,606	Academic	151,913	4,028,823	102,413	2,925,823	49,500	1,103,000	1,272	$ 17,200	$ 470,800	$ 311,000	27.4	79
	Bartlett Center	16,200	Administration	268,078	893,592	130,151	670,192	137,926	223,400	694	$ 18,819	$ 348,300	$ 202,500	18.5	55
	20 Trowbridge	4,536	Administration	9,668	205,200	6,368	112,900	3,300	92,300	104	$ 1,300	$ 23,800	$ -	18.3	11
	Sports & Recreation Center	145,000	Athletic Facilities	2,931,400	7,887,900	1,958,560	6,507,500	972,840	1,380,400	4,700	$ 130,777	$ 1,261,600	$ 565,500	9.6	380
	11 Einhorn	3,600	Grad Housing, faculty/ staff	10,357	212,200	7,157	122,200	3,200	90,000	101	$ 1,200	$ 20,700	$ -	17.3	11
	Salisbury Estates	130,000	Grad Housing, faculty/ staff	1,537,120	6,042,990	1,212,820	5,005,990	324,300	1,037,000	2,144	$ 49,400	$ 263,300	$ -	5.3	161
	8 Elbridge	6,200	Grad Housing, faculty/ staff	21,386	427,500	17,086	246,200	4,300	181,300	196	$ 2,400	$ 28,900	$ -	12.0	16
	8 Hackfeld	3,900	Grad Housing, faculty/ staff	20,586	365,700	13,086	254,600	7,500	111,100	137	$ 2,000	$ 34,600	$ -	17.3	13
	Faraday Hall	88,000	Residence Halls	926,800	4,541,300	691,400	4,264,800	235,400	276,500	1,080	$ 31,000	$ 308,000	$ -	9.9	93
	Institute Hall	15,300	Residence Halls	117,360	834,300	73,360	623,800	44,000	210,500	361	$ 7,400	$ 91,900	$ -	12.4	30
	Founders Hall	96,994	Residence Halls	707,200	908,700	424,000	770,600	283,200	138,100	1,104	$ 35,500	$ 412,200	$ -	11.6	100
	Stoddard C	12,326	Residence Halls	203,200	161,400	142,900	116,300	60,300	45,100	251	$ 7,700	$ 62,900	$ -	8.2	26
	Ellsworth Apartments 3	5,488	Residence Halls	109,130	195,000	81,830	195,000	27,300	-	93	$ 3,300	$ 33,000	$ -	10.0	13
	Ellsworth Apartments 2	3,136	Residence Halls	62,360	199,200	46,760	199,200	15,600	-	53	$ 1,900	$ 17,300	$ -	9.1	10
	Ellsworth Apartments 1	3,920	Residence Halls	77,950	249,000	58,550	249,000	19,400	-	66	$ 2,300	$ 23,500	$ -	10.2	11
	2016 Scoping Study TOTAL	674,836		8,657,528	32,965,680	5,865,661	26,616,928	2,791,866	6,348,751	15,875	$ 399,696	$ 4,236,400	$ 1,262,100	10.60	1,284
Previously Studied, Not Implementd	Salisbury Labs	69,830	Laboratory	966,955	5,613,000	667,128	4,791,000	299,827	822,000	1,845	$ 44,323	$ 442,300			137
	Exterior Lighting (Non-Athletics)		Exterior	744,120	-	172,000	-	572,120	-	1,952	$ 68,654	$ 900,000			177
	Exterior Lighting (Athletics)		Exterior	218,750	-	43,750	-	175,000	-	597	$ 21,000	$ 450,000			54
	Previously Studied TOTAL	69,830		1,929,825	5,613,000	882,878	4,791,000	1,046,947	822,000	4,394	$ 133,977	$ 1,792,300		-	368
	TOTAL Campus Opportunity	744,666		10,587,353	38,578,680	6,748,539	31,407,928	3,838,813	7,170,751	20,269	$ 533,673	$ 6,028,700	$ 1,262,100	10.60	1,652

APPENDIX A
BUILDING BENCHMARKING & AUDIT SUMMARIES


Small Residences
Electric Benchmarking
kWh/GSF
30
20
10
0
Building
11 Einhorn
20 Trowbridge
8 Elbridge
8 Hackfeld
Ellsworth Apartments 1
Ellsworth Apartments 2
Ellsworth Apartments 3
Stoddard C
Benchmark


Small Residences
Thermal Benchmarking
kBTU/GSF
0
100
200
300
400
Building
11 Einhorn
20 Trowbridge
8 Elbridge
8 Hackfeld
Ellsworth Apartments 1
Ellsworth Apartments 2
Ellsworth Apartments 3
Stoddard C
Benchmark

GREENER U

Building Name/Photo	**8 Hackfeld** 
Description Building square footage Type of facility	8 Hackfeld is a 3,900 square foot, off-campus residence for graduate students and faculty / staff. The building has three apartments and was built in 1905.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	Occupants leave windows open during the heating season due to overheating and lack of control between the three apartments. The chimney is detoriating and needs masonry work. The building is due for a controls upgrade. LED lighting conversion and occupant engagement could be the main measures in this building.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	There is one zone between the three apartments which is controlled via an electric thermostat on the second floor.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	There is no airside equipment for the building.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by one-pipe steam cast iron radiators. A Weil-McLain gas-fired steam boiler is located in the basement which serves the building.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Lighting is comprised of a combination of incandescent and fluorescent. Occupants also have plug-in lighting as needed. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	Each apartment has their own kitchen and bathroom. Although GreenerU was unable to access the individual apartment, it can be assumed that the shower heads, faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is a three-story house composed a stone foundation, wood beam framing, and vinyl siding. The operable windows are a mix of single and double pane.
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provided via a Weil-McLain gas-fired steam boiler. There is uninsulated steam piping found throughout the basement and remainder of the building.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	There is no cooling systems in this building. Occupants may use window air conditioning units.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by an A.O. Smith gas-fired heater.

GREENER U

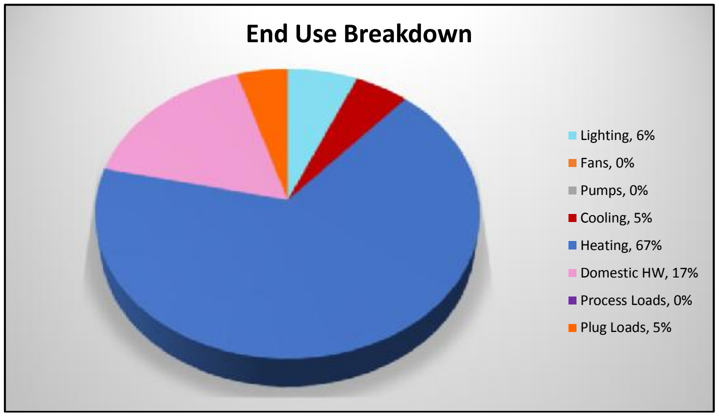
General Information

Building	8 Hackfeld
GSF	3,900
Space Use	Grad Housing, faculty/ staff

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	20,586	5.3	13,086	3.4
Thermal Usage (kBtu)	365,700	93.8	254,600	65.3
TOTAL (kBtu)	**435,939**	**111.8**	**299,249**	**76.7**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	8,234	-
Fans	-	-
Pumps	-	-
Cooling	6,382	-
Heating	-	292,560
DHW	-	73,140
Process Loads	-	-
Plug Loads	5,970	-
TOTAL	**20,586**	**365,700**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
3	TRV Installation	-	14,600	$ 100	$ 11,700	117.0	1
3	Building Envelope Improvements	300	14,600	$ 200	$ 7,800	39.0	1
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	100	58,500	$ 600	$ 2,000	3.3	3
1	LED Lighting Conversion	7,100	-	$ 900	$ 11,700	13.0	2
1	Pipe Insulation	-	23,400	$ 200	$ 1,400	7.0	1
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**7,500**	**111,100**	**2,000**	**34,600**	**17.3**	**13**

Building Name/Photo

11 Einhorn

Description

Building square footage

Type of facility

11 Einhorn is a 3,600 square foot, off-campus residence for graduate students and faculty / staff. The building is a three story building and was built in 1905.

Ask Facilities Staff

Major problems
Recent renovations
Planned renovations
Ideas for energy conservation
Recent efficiency projects

Occupants leave windows open during the heating season due to overheating. LED lighting conversion and occupant engagement could be the main measures in this building.

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

The majority of thebuilding is served via a furnace with one thermostatic controller. A supplemental furnace serving the second floor is controlled via a separate thermostatic controller.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

There is no airside equipment in the building.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Space heating is provided to the majority of the buidling by a Rudd furnace. Supplemental heat for the second floor is provided by a wall mounted furnace.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

Lighting is comprised of a combination of incandescent and fluorescent. Occupants also have plug-in lighting as needed. Upgrading to LED system is recommended.

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

Each apartment has their own kitchen and bathroom. Although GreenerU was unable to access the individual apartment, it can be assumed that the shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

The building is two-story house composed a brick and stone foundation, wood beam framing, and a combination shingle siding and stucco. The operable windows are a mix of single and double pane.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

Heating is provided via an outdated Rudd furnace. A smaller, wall mounted furnace provides additional heat as needed to the second floor.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

There is no central cooling system in this building. Occupants may use window air conditioning units.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is provided by an A.O. Smith ProMax +Plus gas-fired heater.

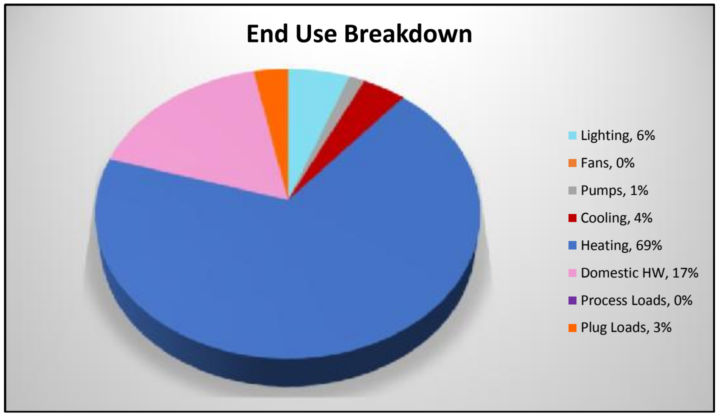
General Information

Building	11 Einhorn
GSF	3,600
Space Use	Grad Housing, faculty/ staff

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	10,357	2.9	7,157	2.0
Thermal Usage (kBtu)	212,200	58.9	122,200	33.9
TOTAL (kBtu)	**247,538**	**68.8**	**146,620**	**40.7**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	4,143	-
Fans	-	-
Pumps	1,036	-
Cooling	2,900	-
Heating	-	169,760
DHW	-	42,440
Process Loads	-	-
Plug Loads	2,279	-
TOTAL	**10,357**	**212,200**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
3	Building Envelope Improvements	-	42,400	$ 400	$ 9,000	22.5	2
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	34,000	$ 300	$ 2,700	9.0	2
2	LED Lighting Conversion	3,200	-	$ 400	$ 7,200	18.0	1
2	Pipe Insulation	-	13,600	$ 100	$ 1,800	18.0	1
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**3,200**	**90,000**	**1,200**	**20,700**	**17.3**	**11**

Building Name/Photo	**8 Elbridge**
Description Building square footage Type of facility	8 Elbridge is a 6,200 square foot, off-campus residence for graduate students and faculty / staff. The building has three apartments and was built in 1905.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	During the site visit, all first floor windows were open due to overheating and lack of control between the three apartments. The building is due for a controls upgrade. LED lighting conversion, control upgrade, and occupant engagement could be the main measures in this building.
Occupied Spaces	
• EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	Two steam boilers separate the three apartments into two zones. One zone controls the first floor apartment and the other zone controls the second and third floor apartments.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	There is no airside equipment in the building.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by one-pipe steam cast iron radiators. Two Weil-McLain gas-fired steam boilers are located in the basement which serve the building.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Lighting is comprised of a combination of incandescent and fluorescent. Occupants also have plug-in lighting as needed. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	Each apartment has their own kitchen and bathroom. Although GreenerU was unable to access the individual apartment, it can be assumed that the shower heads, faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is a three-story house composed a stone foundation, wood beam framing, and vinyl siding. The operable windows are a mix of single and double pane and should be replaced.
Mechanical Rooms	
• Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provided by two Weil-McLain gas-fired steam boilers. One boiler serves the first floor apartment and the other serves the second and third floor apartments. There is uninsulated steam piping found throughout the basement and remainder of the building.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	There is no central cooling system in this building. Occupants may use window air conditioning units.
• Domestic hot water o Type: elec, gas, instantaneous	Each apartment is served by an individual electric domestic hot water heater.

GREENER U

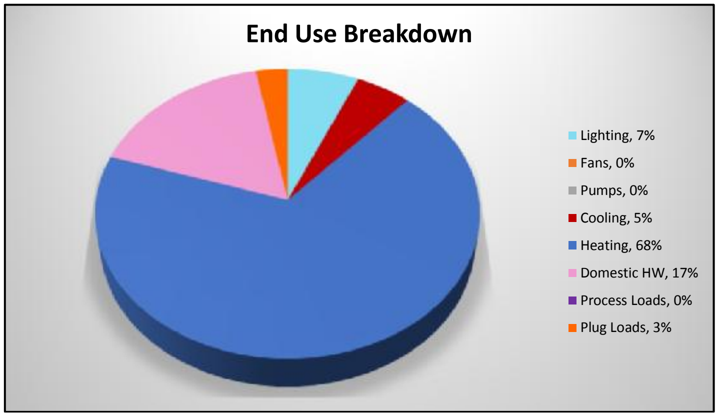
General Information

Building	8 Elbridge
GSF	6,200
Space Use	Grad Housing, faculty/ staff

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	21,386	3.4	17,086	2.8
Thermal Usage (kBtu)	427,500	69.0	246,200	39.7
TOTAL (kBtu)	**500,469**	**80.7**	**304,497**	**49.1**

**Thermal Usage is quantified by Gas Data

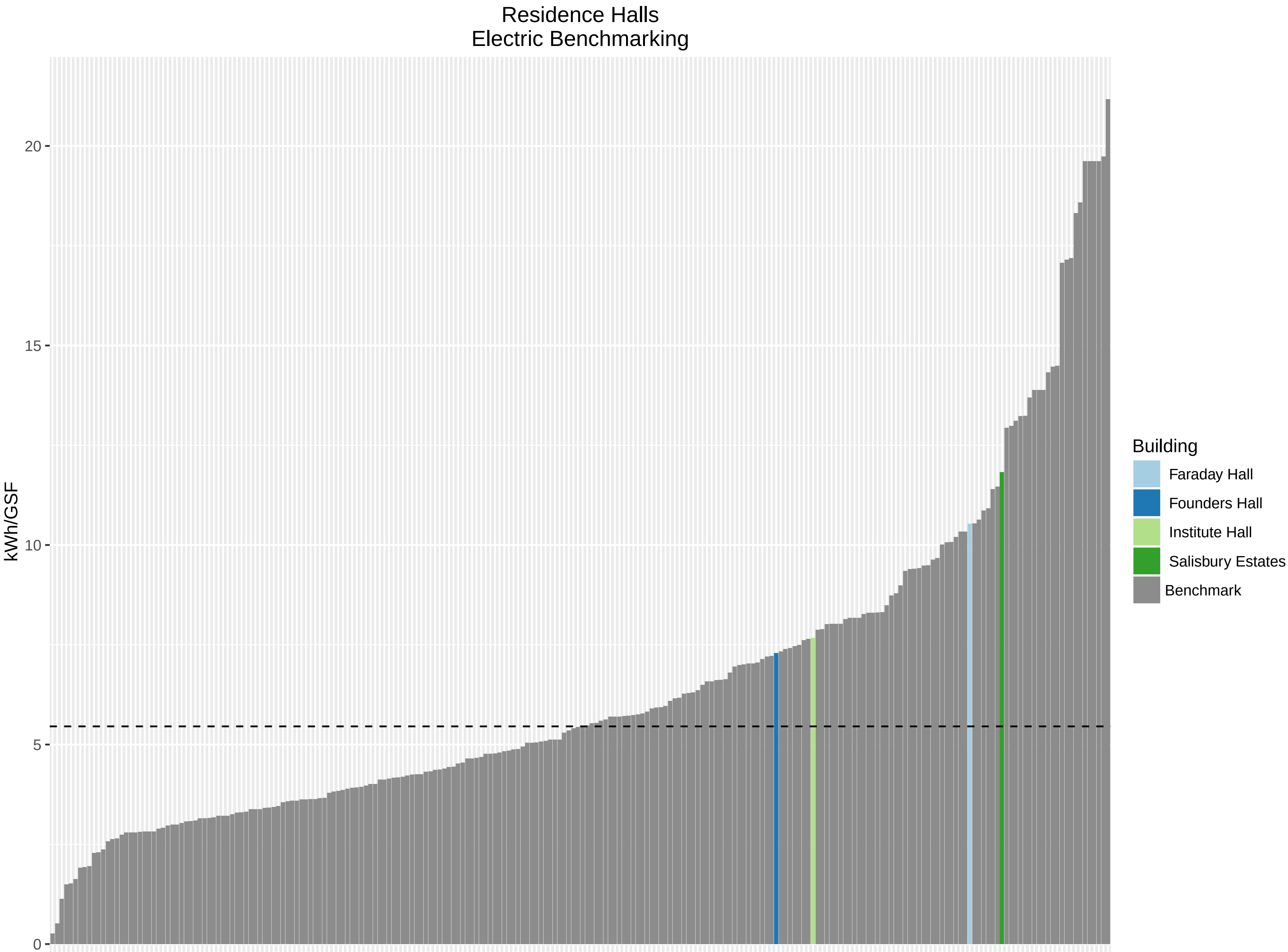


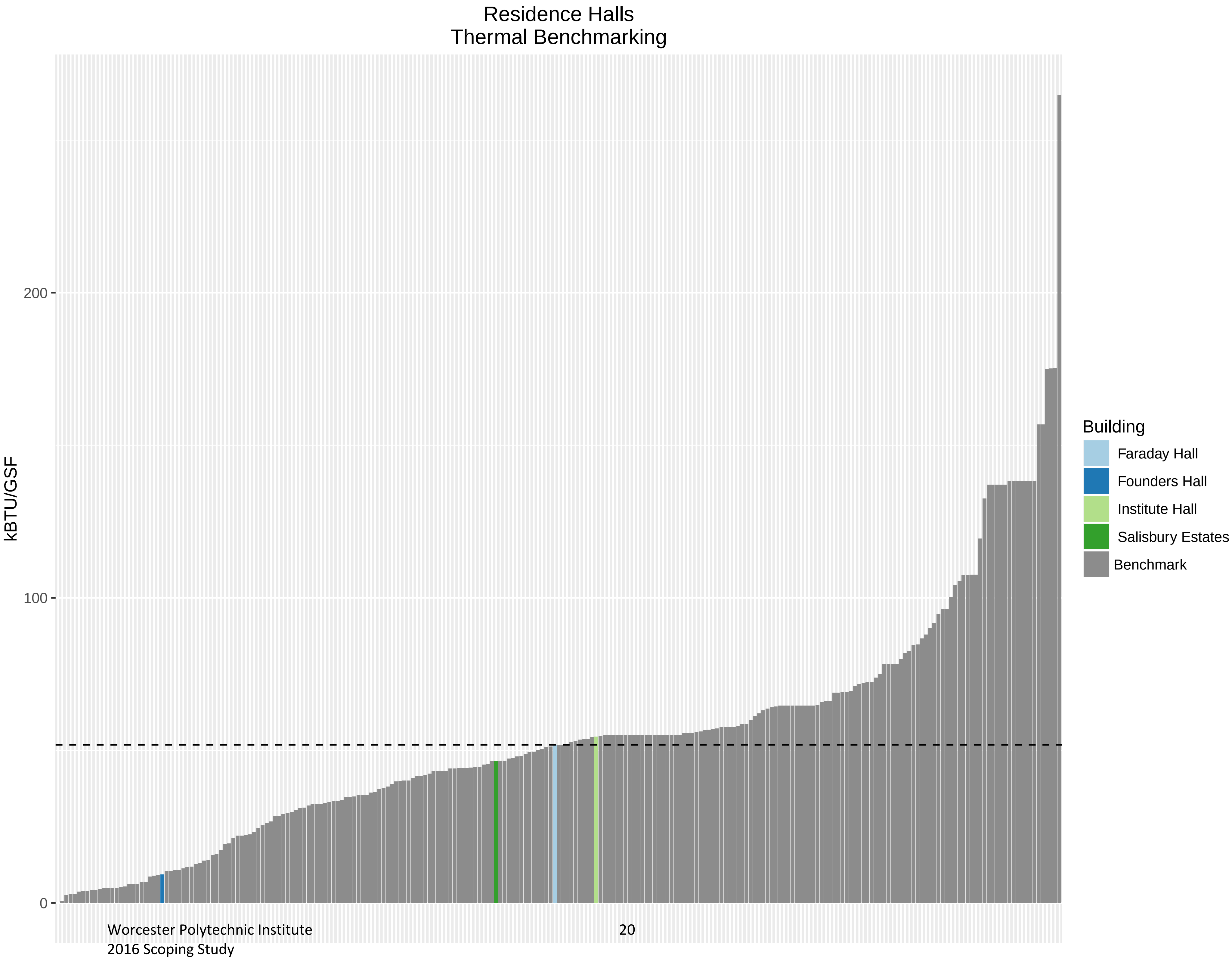
End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	9,624	-
Fans	-	-
Pumps	-	-
Cooling	7,485	-
Heating	-	342,000
DHW	-	85,500
Process Loads	-	-
Plug Loads	4,277	-
TOTAL	**21,386**	**427,500**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	68,400	$ 700	$ 6,200	8.9	4
1	Building Envelope Improvements	-	17,100	$ 200	$ 1,900	9.5	1
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	68,400	$ 700	$ 3,100	4.4	4
3	LED Lighting Conversion	4,300	-	$ 500	$ 15,500	31.0	1
1	Pipe Insulation	-	27,400	$ 300	$ 2,200	7.3	1
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**4,300**	**181,300**	**2,400**	**28,900**	**12.0**	**16**


Residence Halls
Electric Benchmarking
kWh/GSF
0
5
10
15
20
Building
Faraday Hall
Founders Hall
Institute Hall
Salisbury Estates
Benchmark


Residence Halls
Thermal Benchmarking
kBTU/GSF
200
100
0
Building
Faraday Hall
Founders Hall
Institute Hall
Salisbury Estates
Benchmark

Building Name/Photo

Stoddard A-C

Description

Building square footage

Type of facility

The Stoddard Complex consists of three buildings (A-C), for a total of approximately 12,326 square feet. It primarily serves as a student dorm building with the Health Center located in Stoddard C. The complex was built in 1970. Each building has three floors made up of single and triples rooms and accomodates approximately 84 students.

Ask Facilities Staff

Major problems
Recent renovations
Planned renovations
Ideas for energy conservation
Recent efficiency projects

The building is due for controls upgrade. LED lighting upgrade and and building envelope improvements could have significant opportunity

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

The Health Center in Stoddard C is the only portion of the complex on the Schneider control system. The AC units and eight sections of electric fin tube radiation are monitored via the Schneider control system. The remainder of the complex is not on a central management system and is only locally controlled. Each single or triple room has an electric thermostat to control electric baseboard radiation. Local Mitsubishi thermostats serve the split units in the common areas.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

The building has a gas fired makeup air unit for heating purposes. Split AC units provide cooling to the common areas of the complex as well as the infirmary. Fan coil units provide heat to common areas.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Building heating is provided by electric heat baeboard radiation which are located in all areas.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

Almost all lights are fluorescents except in the common areas which have recessed LED screw-in lamps. Upgrading to LED system is recommended

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

The shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

The building is of block construction with brick and metal façade. The windows in common areas are inoperable, double pane windows. Windows in single and triple rooms are operable double pane windows.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

Heating is provided via electric baseboard radiation. An electric DHW serves the buildings during the summer months.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

Split AC units provide cooling to the common areas and Health Center during the summer months.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is made with an electric water heater.

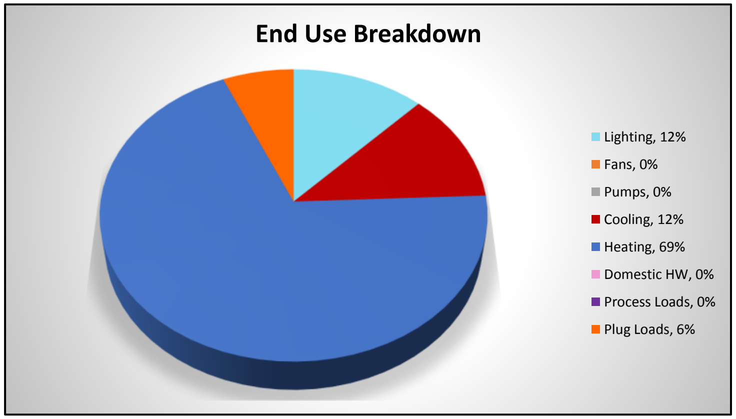
General Information

Building	Stoddard C
GSF	12,326
Space Use	Residence Halls

Utility Usage

	Existing		Proposed	
	Total Usage	EUI	Total Usage	EUI
Electric Usage (kWh)	203,200	16.5	142,900	11.6
Thermal Usage (kBtu)	161,400	13.1	116,300	9.4
TOTAL (kBtu)	**854,718**	**69.3**	**603,875**	**49.0**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	30,480	-
Fans	-	-
Pumps	-	-
Cooling	30,480	-
Heating	125,984	161,400
DHW	-	-
Process Loads	-	-
Plug Loads	16,256	-
TOTAL	**203,200**	**161,400**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	6,300	8,100	$ 800	$ 3,700	4.6	2
1	Control Sequence Optimization	12,500	16,100	$ 1,700	$ 6,200	3.6	5
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	7,600	4,800	$ 1,000	$ 8,600	8.6	3
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	15,600	16,100	$ 2,000	$ 19,700	9.9	6
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	18,300	-	$ 2,200	$ 24,700	11.2	6
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-		$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**60,300**	**45,100**	**7,700**	**62,900**	**8.2**	**26**

Worcester Polytechnic Institute
Energy Efficiency Scoping Audit
Building Existing Conditions

Building Name/Photo

Ellsworth Apartments 1-3

Description

Building square footage

Type of facility

Ellsworth Apartments are a series of three upper class apartment residences that were built in 1973. Each apartment has approximately 5 to 7 students. The buildings are a combination of brick and vinyl siding with double pane windows. The total square footage of the three apartment buildings is 12,544 square feet.

Ask Facilities Staff

Major problems
Recent renovations
Planned renovations
Ideas for energy conservation
Recent efficiency projects

The building is due for a controls upgrade. LED lighting conversion and HW conversion could be the main measures in this building.

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

There is no energy management system in this building. Each apartment has individual control over the electric baseboard radiation via a wall mounted thermostat. All apartments have electric submeters.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

Apartments have portable window air conditioning units to provide cooling as needed.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Building heating is provided by electric heat baseboard radiation which is located throughout the building.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

Almost all lights are fluorescents and no lighting controls. Upgrading to LED system is recommended.

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

Each apartment has their own kitchen and bathroom. Although GreenerU was unable to access the individual apartment, it can be assumed that the shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

Ellsworth Apartments consist of two story apartments with basements. The building is of block construction with brick and vinyl siding. The double-pane windows with metal frames allow infiltration and weather stripping is recommended.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

There is no boiler system in this building. Heating is supplied via electric baseboard radiation.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

There is no mechanical cooling in the building. Apartments are cooled via window air conditioning units.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is provided by a gas-fired water heater.

GREENER U

General Information

Building	Ellsworth Apartments 3
GSF	5,488
Space Use	Residence Halls

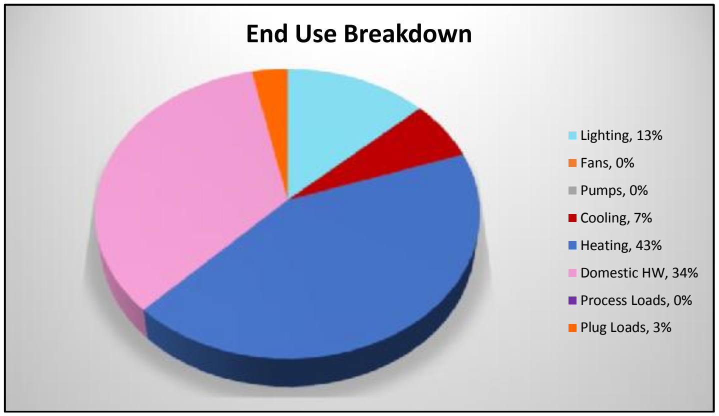
Utility Usage

	Existing Total Usage	EUI	Proposed Total Usage	EUI
Electric Usage (kWh)	109,130	19.9	81,830	14.9
Thermal Usage (kBtu)	195,000	35.5	195,000	35.5
TOTAL (kBtu)	**567,352**	**103.4**	**474,204**	**86.4**

**Thermal Usage is quantified by Gas Data

End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	21,826	-
Fans	-	-
Pumps	-	-
Cooling	10,913	-
Heating	70,935	-
DHW	-	195,000
Process Loads	-	-
Plug Loads	5,457	-
TOTAL	**109,130**	**195,000**



Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	8,200	-	$ 1,000	$ 11,000	11.0	3
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	8,200	-	$ 1,000	$ 5,500	5.5	3
1	LED Lighting Conversion	10,900	-	$ 1,300	$ 16,500	12.7	3
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**27,300**	**-**	**3,300**	**33,000**	**10.0**	**13**

GREENER U

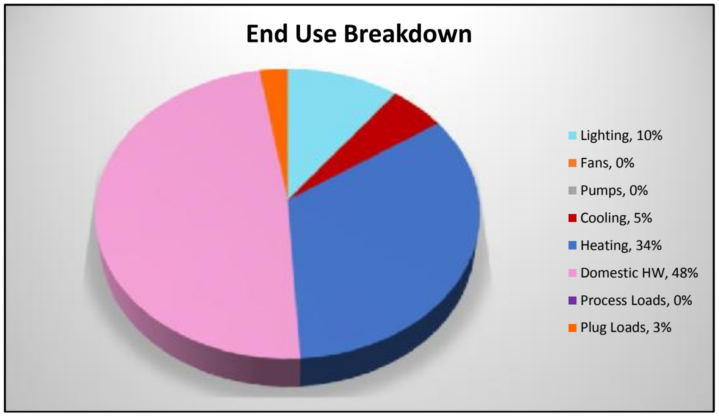
General Information

Building	Ellsworth Apartments 2
GSF	3,136
Space Use	Residence Halls

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	62,360	19.9	46,760	14.9
Thermal Usage (kBtu)	199,200	63.5	199,200	63.5
TOTAL (kBtu)	**411,972**	**131.4**	**358,745**	**114.4**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	12,472	-
Fans	-	-
Pumps	-	-
Cooling	6,236	-
Heating	40,534	-
DHW	-	199,200
Process Loads	-	-
Plug Loads	3,118	-
TOTAL	**62,360**	**199,200**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	4,700	-	$ 600	$ 6,300	10.5	1
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	4,700	-	$ 600	$ 1,600	2.7	1
1	LED Lighting Conversion	6,200	-	$ 700	$ 9,400	13.4	2
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**15,600**	**-**	**1,900**	**17,300**	**9.1**	**10**

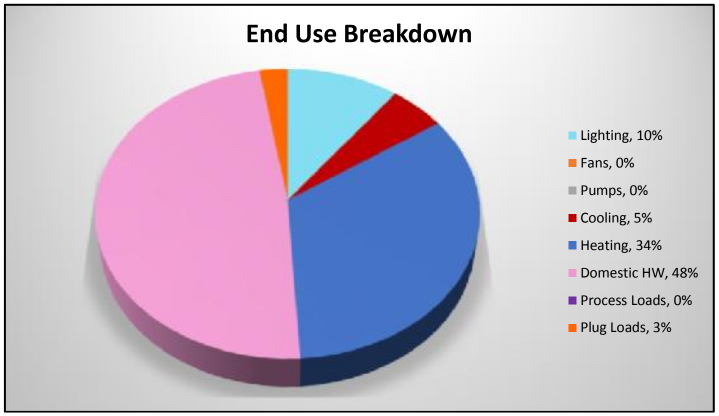
General Information

Building	Ellsworth Apartments 1
GSF	3,920
Space Use	Residence Halls

Utility Usage

	Existing Total Usage	EUI	Proposed Total Usage	EUI
Electric Usage (kWh)	77,950	19.9	58,550	14.9
Thermal Usage (kBtu)	249,000	63.5	249,000	63.5
TOTAL (kBtu)	**514,965**	**131.4**	**448,773**	**114.5**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	15,590	-
Fans	-	-
Pumps	-	-
Cooling	7,795	-
Heating	50,668	-
DHW	-	249,000
Process Loads	-	-
Plug Loads	3,898	-
TOTAL	**77,950**	**249,000**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	5,800	-	$ 700	$ 7,800	11.1	2
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	5,800	-	$ 700	$ 3,900	5.6	2
1	LED Lighting Conversion	7,800	-	$ 900	$ 11,800	13.1	2
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**19,400**	**-**	**2,300**	**23,500**	**10.2**	**11**

Building Name/Photo

Institute Hall

Description

Building square footage

Type of facility

Institute Hall is a 15,300 square foot, four story residence hall and was built in 1989. There are singles, doubles, triples, and quads which in total houses approximately 90 students. A study lounge is located on the first floor and the building also has a laundry room.

Ask Facilities Staff

Major problems
Recent renovations
Planned renovations
Ideas for energy conservation
Recent efficiency projects

A new rooftop unit was recently installed to provide ventilation to the building. All valves on hot water convectors were recently replaced as well.

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

The main building level controls are on ALC system. Temperature sensors are located throughout the building for monitoring purposes. Each room has an individual zone valve on the hot water convectors to regulate temperature.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

A new rooftop unit provides ventilation to the building.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Space heating is a combination of hot water convectors in the rooms with zone valve temperatures controls via local thermostatic controls. Three older McQuay fan coil units are located in the entryways and have ALC temperature controls.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

The lighting is a combination of compact fluorescent lamps and fluorescent T8 lamps. Upgrading to LED system is recommended.

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

The shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

The building is of block construction with brick. The old single-pane operable windows need to be replaced.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

Heating is provided by three Buderus gas-fired condensing boilers; two of the three have been taken from the Rec Center and reused in the building. Two hot water pumps are equipped with VFDs and circulate hot water to the zones in the building.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

There is no mechanical cooling in the building.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is provided by two gas-fired Rheem heaters.

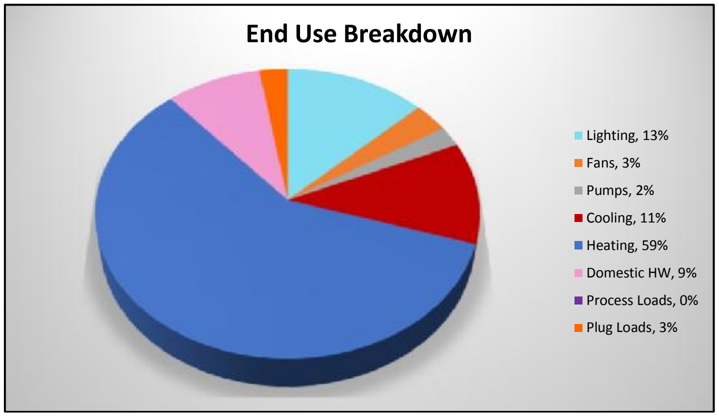
General Information

Building	Institute Hall
GSF	15,300
Space Use	Residence Halls

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	117,360	7.7	73,360	4.8
Thermal Usage (kBtu)	834,300	54.5	623,800	40.8
TOTAL (kBtu)	**1,234,732**	**80.7**	**874,104**	**57.1**

**Gas Data is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	46,944	-
Fans	11,736	-
Pumps	8,215	-
Cooling	41,076	-
Heating	-	725,841
DHW	-	108,459
Process Loads	-	-
Plug Loads	9,389	-
TOTAL	**117,360**	**834,300**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	3,100	36,300	$ 700	$ 6,100	8.7	3
1	Control Sequence Optimization	4,900	29,000	$ 900	$ 9,200	10.2	3
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	4,700	-	$ 600	$ 7,700	12.8	1
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	3,100	72,600	$ 1,100	$ 15,300	13.9	5
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	28,200	-	$ 3,400	$ 45,900	13.5	9
1	Pipe Insulation	-	72,600	$ 700	$ 7,700	11.0	4
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**44,000**	**210,500**	**7,400**	**91,900**	**12.4**	**30**

Building Name/Photo

Founders Hall

Description

- Building square footage
- Type of facility

Founders Hall is a 96,994 square foot residence hall built in 1985. The four story building has double to eight person suites, where each is equipped with a kitchen. The first floor houses the WPI Police Station and the Goat's Head Restaurant.

Ask Facilities Staff

- Major problems
- Recent renovations
- Planned renovations
- Ideas for energy conservation
- Recent efficiency projects

The two Bosch hot water boilers that serve the building were recently installed in 2013. The outdate Trane fan coil units in the Police Station are planned to be replaced with new Friedrichs units. The Goat's Head Restaurant has and older Trane makeup air unit that should be replaced with a more efficient unit. LED lighting conversion and retrocommissioning of the existing fan coil units in the suites could be the main measures in this building.

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

The building controls is on the Schneider Electric system. The ductless splits that serve the Police Station are controlled via local Mitsubishi thermostats. The Trane fan coil units are controlled via local thermostatic and fan controls. Hot water radiation in dorm suites is controlled by Honeywell T87 thermostats.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

Note: GreenerU could not access the Goat's Head Restaurant during the site visit. An outdated Trane Climate Changer makeup air unit serves the kitchen of the Goat's Restaurant. The unit provides heating only via hot water coils. There is no VFD on the supply fan. An exhaust fan located on the roof is linked to the makeup air unit controls. Two condensing units located on the second floor also serve the kitchen with two stages of cooling capabilities. Two air handling units provide the dining area with hot water heat and DX cooling.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Space heating consists of hot water baseboard radiation in the dorm suites and hallways. The Police Station is heated by six ductless split units and eight Trane fan coil units.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

Almost all lights are fluorescents. Upgrading to LED system is recommended.

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

The shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

The building is of block construction with brick facade. The windows are operable double-pane.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

Two Bosch hot water boilers were recently installed in 2013 to provide heat to Founders Hall. Two Armstrong hot water pumps operate in lead / lag to circulate hot water to the building and both are equipped with VFDs.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

The air handling units in the Goat's Restaurant provide DX cooling to the space. There are also two units that serve the kitchen area via two stages of cooling. Trane fan coil units and Mitsubishi ductless split units in the Police Station provide cooling year round as needed.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is provided by the gas-fired boilers.

GREENER U

General Information

Building	Founders Hall
GSF	96,994
Space Use	Residence Halls

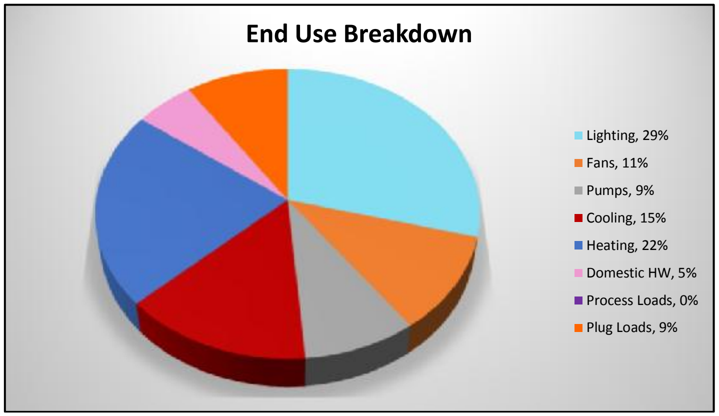
Utility Usage

	Existing Total Usage	EUI	Proposed Total Usage	EUI
Electric Usage (kWh)	707,200	7.3	424,000	4.4
Thermal Usage (kBtu)	908,700	9.4	770,600	7.9
TOTAL (kBtu)	**3,321,666**	**34.2**	**2,217,288**	**22.9**

**Thermal Usage is quantified by Gas Data

End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	282,880	-
Fans	106,080	-
Pumps	84,864	-
Cooling	141,440	-
Heating	-	726,960
DHW	-	181,740
Process Loads	-	-
Plug Loads	91,936	-
TOTAL	**707,200**	**908,700**



Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	16,600	36,300	$ 2,400	$ 29,100	12.1	7
1	Control Sequence Optimization	26,600	29,100	$ 3,500	$ 48,500	13.9	10
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	37,100	-	$ 4,500	$ 48,500	10.8	12
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	33,200	72,700	$ 4,700	$ 19,400	4.1	14
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	169,700	-	$ 20,400	$ 266,700	13.1	53
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**283,200**	**138,100**	**35,500**	**412,200**	**11.6**	**100**

Building Name/Photo

Faraday Hall

Description

- Building square footage
- Type of facility

Faraday Hall is a 88,000 square foot residence hall that was recently built in 2013. It houses approximately 260 students in studios, or four person suites with kitchens and common areas. There is a laundry room, lounge spaces, and game room.

Ask Facilities Staff

- Major problems
- Recent renovations
- Planned renovations
- Ideas for energy conservation
- Recent efficiency projects

The building was built 3 years ago. LED lighting conversion and retrocommissioning could be the main measures in this building.

Occupied Spaces

- EMS \ Controls
  - Manufacturer and vintage
  - Local Control or on EMS?
  - End device control (pneumatic, electric, DDC)

The building controls is on the Schneider Electric system. Each suite has two temperature sensors which is relayed back to the Schneider system. The hallway fan coil units are controlled by wall thermostats with heat / cool and fan controls.

- HVAC Systems (Airside)
  - Type of systems
  - AHUs, RTUs, FCUs, Unit Ventilators, H&V
  - Cooling/heating coils?

Each wing (three total) at Faraday Hall is ventilated by a York energy recovery unit located on the roof. The supply and return/exhaust fans on each unit are equipped with VFDs. Each wing also has two exhaust fans, one for the kitchen areas and the other for the bathrooms. The laundry room has it own respective exhaust fan.

- Space heating systems
  - Steam versus hot water
  - Any year round heating?
  - Any process steam? (i.e. kitchen, autoclaves, other)

Space heating is provided to suites by two-pipe valence units. Common areas and hallways are heated via hot water baseboard radiation.

- Lighting
  - Type of lighting (T8, T12, CF, LED)
  - Occupancy sensors? Where?

Almost all lights are fluorescents. Upgrading to LED system is recommended. Occupancy sensors are located in the hallways.

- Plumbing
  - City water or well water?
  - Showers: low flow?
  - Sinks – aerators?

The shower heads, faucets and toilets are all low flow.

- Envelope
  - No. of stories
  - Façade type
  - Type of windows (double hung, fixed, 1x/2x pane)

Faraday Hall is a five story building with an exterior façade made of glass and brick. The windows are double pane and inoperable.

Mechanical Rooms

- Primary Heating Systems
  - Boiler Type
  - Boiler and/or distribution pressure?
  - HW Pumps
    - CV or VFDs?

Heating is provided to the building by two gas-fired Lochinvar hot water boilers. Two hot water pumps circulate to the building and are equipped with VFDs.

- Primary Cooling Systems
  - Chiller? DX? Other?
  - Any year round cooling? (i.e. IT/data)
  - CHW Pumps
    - CV or VFDs?

Cooling is provided to the building via a Flex Sys Multi-stack air cooled chiller and an Evapco cooling tower located on the roof. The three chilled water pumps and three condenser water pumps are equipped with VFDs. Mitsusbishi Mr. Slim split air condtioning units provide cooling to data closets in each wing (6 total). Valence units in the suites are two-pipe systems which have the capability of heating hot water or chilled water cooling. Fan coil units in hallways provide cooling.

- Domestic hot water
  - Type: elec, gas, instantaneous

Domestic hot water is provided via the two Lochinvar gas-fired hot water boilers. Two Aqua Plex domestic hot water tanks store water which is then circulated to the building via two pumps that are equipped with VFDs.

GREENER U

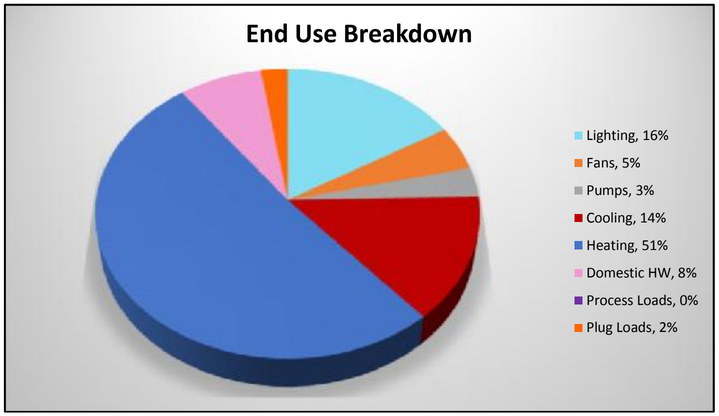
General Information

Building	Faraday Hall
GSF	88,000
Space Use	Residence Halls

Utility Usage

	Existing Total Usage	EUI	Proposed Total Usage	EUI
Electric Usage (kWh)	926,800	10.5	691,400	7.9
Thermal Usage (kBtu)	4,541,300	51.6	4,264,800	48.5
TOTAL (kBtu)	**7,703,542**	**87.5**	**6,623,857**	**75.3**

**Thermal Usage is quantified by Gas Data



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	370,720	-
Fans	111,216	-
Pumps	74,144	-
Cooling	315,112	-
Heating	-	3,950,931
DHW	-	590,369
Process Loads	-	-
Plug Loads	55,608	-
TOTAL	**926,800**	**4,541,300**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	10,000	79,000	$ 2,000	$ 17,600	8.8	7
1	Control Sequence Optimization	40,000	197,500	$ 6,800	$ 26,400	3.9	23
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	-	-	$ -	$ -	-	-
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	185,400	-	$ 22,200	$ 264,000	11.9	57
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**235,400**	**276,500**	**31,000**	**308,000**	**9.9**	**93**

Building Name/Photo	**Salisbury Estates** 
Description Building square footage Type of facility	Salisbury Estates is a 130,000 square foot complex that serves as residences for graduate students and faculty / staff and was built in 1955. WPI utilizes approximately 50 units as housing.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	The staff mentioned that WPI does not own this complex of apartments. LED lighting conversion and retrocommissioning could be the main measures for the units that WPI leases.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	There is no energy management system in this complex. Each apartment is controlled by a Honeywell T87 thermostat.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	There is no airside equipment in the building.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating system is provided by hot water cast iron radiators.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Lighting is comprised of a combination of incandescent and fluorescent. Occupants also have plug-in lighting as needed. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	Each apartment has their own kitchen and bathroom. The shower heads, faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is of block construction with brick with a full basement. Windows are double pane and operable, but may need weather stripping in areas.
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provide by Hydrotherm MultiTemp modular hot water boilers which are located in two separate mechanical rooms. Each mechanical room houses two boilers with five modular units per boiler. Hot water is provided to the spaces by two, constant volume circulation pumps.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	There is no mechanical cooling in the building.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by a gas-fired A.O. Smith DuraMax hot water heater in one mechanical room and a Tekmar hot water heater in the other. Each hot water heater is piped to two domestic hot water storage tanks.

General Information

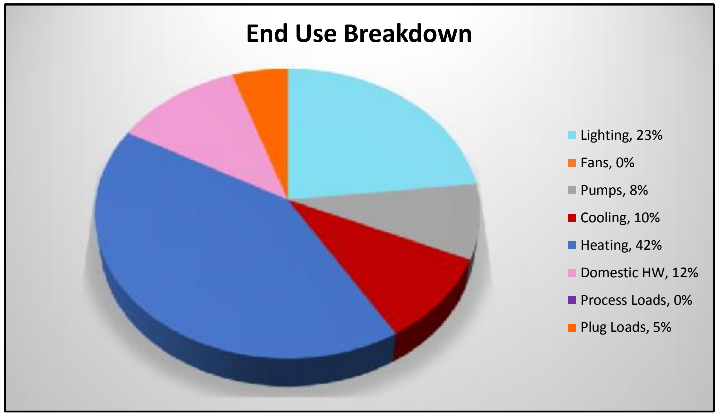
Building	Salisbury Estates
GSF	130,000
Space Use	Grad Housing, faculty/ staff

** Only Apartments Leased by WPI

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	1,537,120	11.8	1,212,820	9.3
Thermal Usage (kBtu)	6,042,990	46.5	5,005,990	38.5
TOTAL (kBtu)	**11,287,643**	**86.8**	**9,144,132**	**70.3**

**Thermal Usage is quantified by gas data

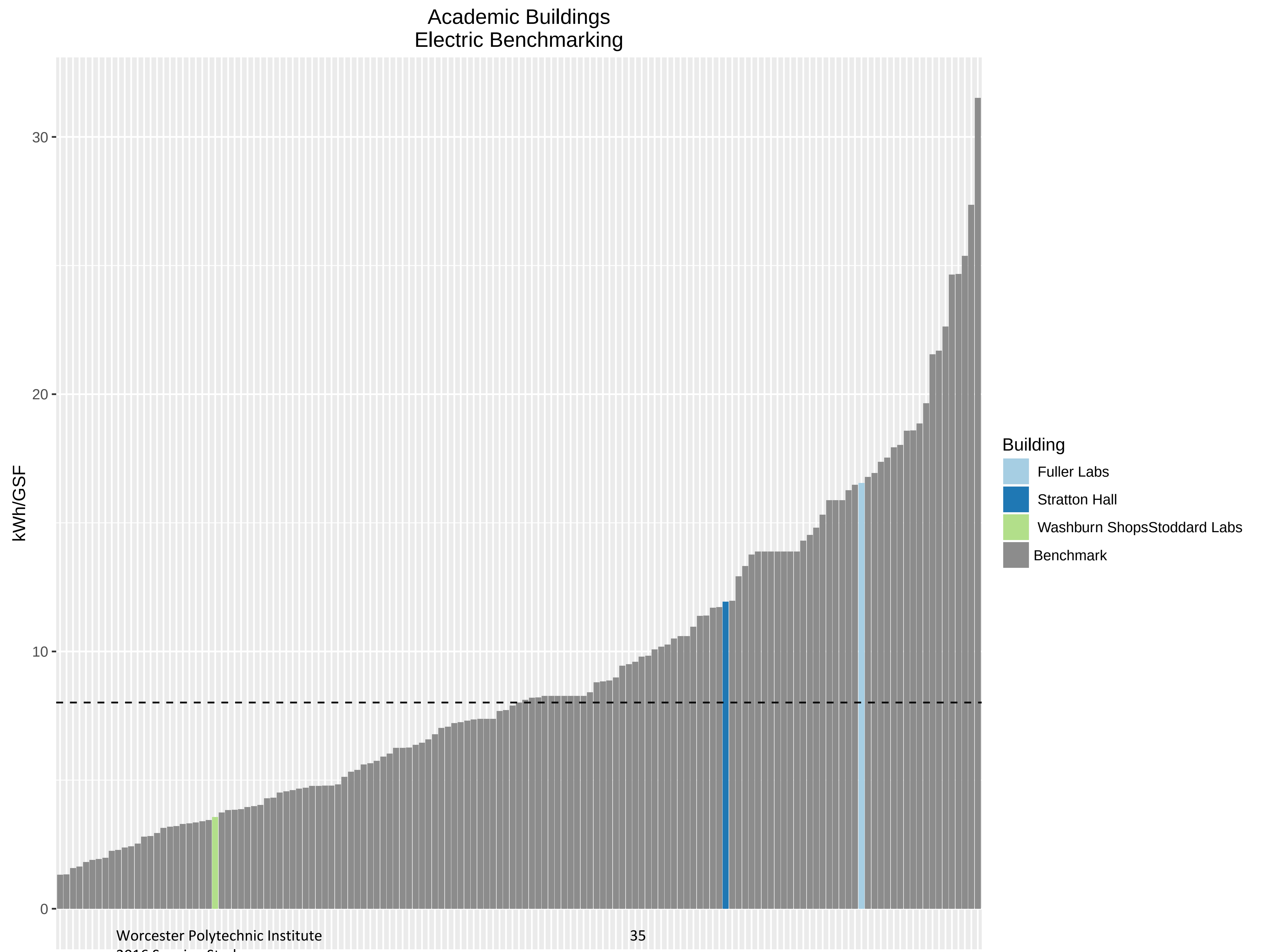


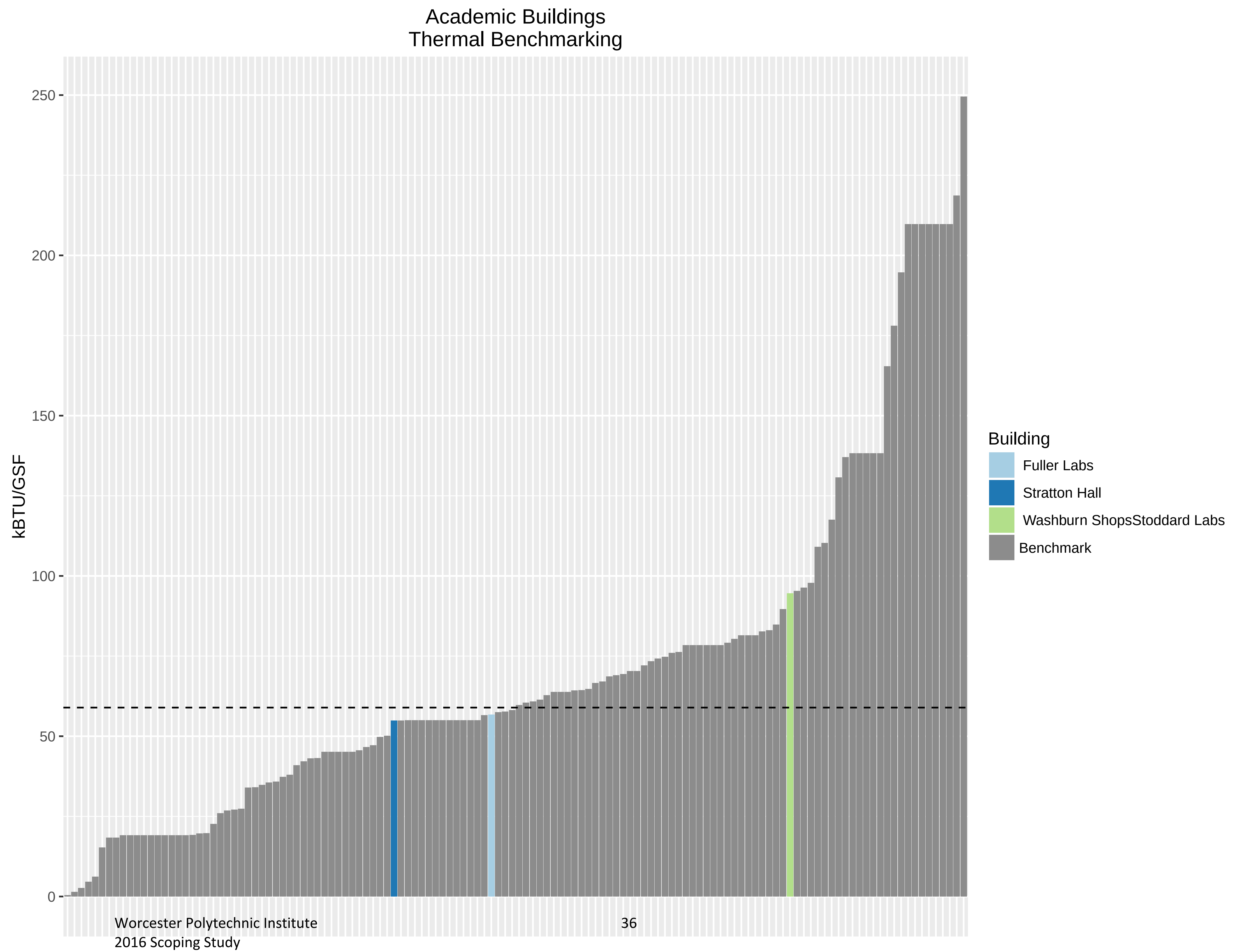
End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	768,560	-
Fans	-	-
Pumps	276,682	-
Cooling	322,795	-
Heating	-	4,713,532
DHW	-	1,329,458
Process Loads	-	-
Plug Loads	169,083	-
TOTAL	**1,537,120**	**6,042,990**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	110,700	235,700	$ 15,700	$ 19,500	1.2	47
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	-	377,100	$ 3,800	$ 26,000	6.8	20
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	59,900	424,200	$ 11,500	$ 22,800	2.0	41
1	LED Lighting Conversion	153,700	-	$ 18,400	$ 195,000	10.6	48
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**324,300**	**1,037,000**	**49,400**	**263,300**	**5.3**	**161**


Academic Buildings
Electric Benchmarking
kWh/GSF
0
10
20
30
Building
Fuller Labs
Stratton Hall
Washburn ShopsStoddard Labs
Benchmark


Academic Buildings
Thermal Benchmarking
kBTU/GSF
250
200
150
100
50
0
Building
Fuller Labs
Stratton Hall
Washburn ShopsStoddard Labs
Benchmark

Building Name/Photo	**Fuller Labs** 
Description Building square footage Type of facility	Fuller Labs is a 73,250 square foot academic building that was built in 1990. The building houses the Computer Science department, Computing and Communications Center, and Academic Technology Center.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	WPI is in the process of converting the energy management system at Fuller Labs from the Schneider to Automated Logic (ALC) controls system. LED lighting conversion could be the main measures in this building.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	The controls for the building is on Schneider Electric and ALC system. WPI is in the process of converting the building from Schneider to ALC. The chiller, air handling units, variable air volume (VAV) boxes, fan coil units, and pumps are all controlled and monitored using the EMS.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	AHU -1 serves the computer labs, AHU- 2 serves the administrative area, and AHU-3 serves the lecture halls. AHU-1 and AHU-2 have steam heating coils and chilled water coils. A steam to hot water heat exchanger provides hot water to the heating coils in AHU-3. AHU-3 also has chilled water coils. VAV boxes are located throughout the building and have electric reheat. A couple fan coil units serve a room in the basement and one on the second floor.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by a combination of steam and hot water heating coils in the AHUs and electric reheat in the VAV boxes. The lobby area has electric baseboard heat.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Lighting is predominantly fluorescent. Occupants also have task lighting as needed. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is of block construction with brick and metal framing. The windows are double-pane with adequate weather stripping around the perimeter.
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provide by campus steam loop in winter. There is a HW converter that produces HW for AHU-3 heating. Remaining heat is provided by electric reheat. Pumps do not have VFDs.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	Cooling is provided by two Carrier chillers that were installed approximately 6 years ago. Chilled water is circulated by three pumps. The pumps do not have VFDs. Free cooling is provided via a heat exchanger in the winter. The chiller system serves the IT/data room year round.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is made with gas-fired hot water heater.

GREENER U

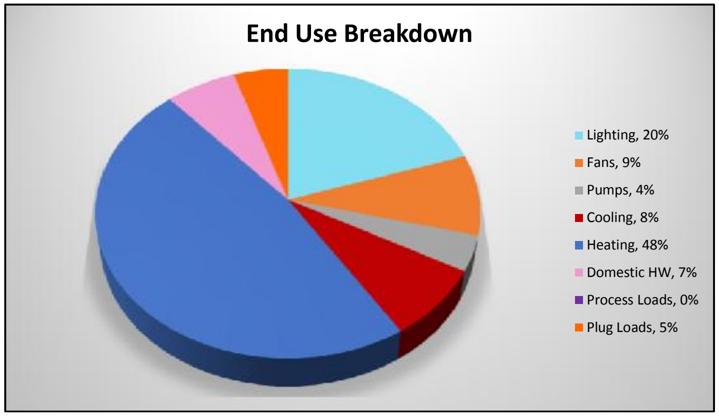
General Information

Building	Fuller Labs
GSF	73,250
Space Use	Academic

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	1,212,141	16.5	699,741	9.6
Thermal Usage (kBtu)	4,155,912	56.7	3,010,561	41.1
TOTAL (kBtu)	**8,291,737**	**113.2**	**5,398,077**	**73.7**

**Thermal Usage allocated based on Square Footage and Usage Type
** Electric Usage is allocated on square footage and use type



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	484,856	-
Fans	218,185	-
Pumps	96,971	-
Cooling	193,943	-
Heating	96,971	3,615,643
DHW	-	540,269
Process Loads	-	-
Plug Loads	121,214	-
TOTAL	**1,212,141**	**4,155,912**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	18,200	361,600	$ 5,900	$ 29,300	5.0	25
1	Control Sequence Optimization	36,400	325,400	$ 7,700	$ 36,600	4.8	29
1	Occupancy Based Controls	18,200	253,100	$ 4,800	$ 25,000	5.2	19
1	Demand Controlled Ventilation	15,800	180,800	$ 3,700	$ 18,300	4.9	15
1	VFD Installation on Fans	37,100	-	$ 4,500	$ 47,600	10.6	12
1	VFD Instllation on Pumps	29,100	-	$ 3,500	$ 36,600	10.5	9
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	18,200	289,300	$ 5,100	$ 25,600	5.0	21
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	242,400	-	$ 29,100	$ 293,000	10.1	75
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
2	Electric to HW Conversion	97,000	(264,849)	$ 9,000	$ 183,100	20.3	16
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**512,400**	**1,145,351**	**73,300**	**695,100**	**9.5**	**225**

Building Name/Photo	**Stratton Hall** 
Description Building square footage Type of facility	Stratton Hall is a 24,380 square foot academic building and was built in 1894. It originally housed the Mechanical Engineering department. The building now houses the Mathematical Sciences department and Center for Industrial Mathematics and Statistics. There are approximately seven classrooms in the buildings and the remainder are offices.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	WPI is in the process of converting all energy management systems on campus from Schneider to Automated Logic (ALC) controls system. LED lighting conversion and converting to the ALC system could be the main measures in this building.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	The building is controlled by the Schneider Electric controls system. The EMS monitors the chilled water pumps and air handling unit. Thermostatic radiators valves allow occupants control of heat in the building.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	One AHU provides ventilation and temperature controls for the building. A general exhaust serves the building as well.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by hot water radiators which are equipped with thermostatic radiator valves.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Lighting in Stratton Hall is predominantly fluorescent. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is of block construction with brick. The windows have been upgraded to double-pane with metal framing. Occupants use window AC units
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provided from the campus steam plant which is converted to hot water and supplies the building via hot water radiators equipped with TRVs.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	Thereare no cooling systems in this building. Occupants use window air conditioning units for individual spaces.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by an electric hot water heater.

GREENER U

General Information

Building	Stratton Hall
GSF	24,380
Space Use	Academic

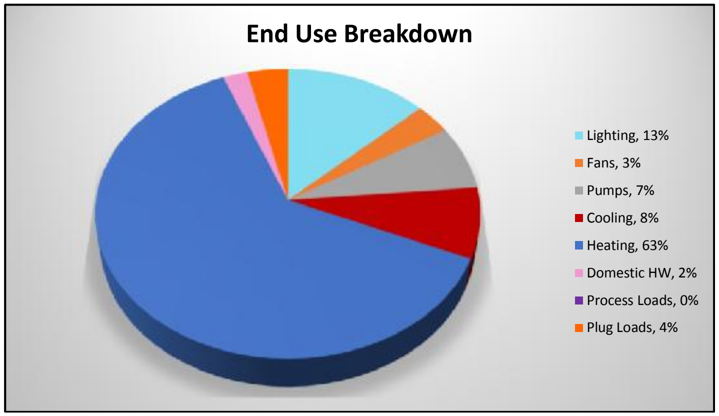
Utility Usage

	Existing		Proposed	
	Total Usage	EUI	Total Usage	EUI
Electric Usage (kWh)	290,879	11.9	199,479	8.2
Thermal Usage (kBtu)	1,656,962	68.0	1,342,262	55.1
TOTAL (kBtu)	**2,649,441**	**108.7**	**2,022,885**	**83.0**

**Thermal Usage allocated based on Square Footage and Usage Type

End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	101,808	-
Fans	26,179	-
Pumps	55,267	-
Cooling	61,085	-
Heating	-	1,656,962
DHW	17,453	-
Process Loads	-	-
Plug Loads	29,088	-
TOTAL	**290,879**	**1,656,962**



Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	7,100	82,800	$ 1,700	$ 9,800	5.8	7
1	Control Sequence Optimization	11,400	66,300	$ 2,000	$ 12,200	6.1	7
1	Occupancy Based Controls	4,300	33,100	$ 900	$ 10,000	11.1	3
1	Demand Controlled Ventilation	1,000	49,700	$ 600	$ 4,900	8.2	3
3	VFD Installation on Fans	9,600	-	$ 1,200	$ 9,800	8.2	3
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	7,100	82,800	$ 1,700	$ 14,600	8.6	7
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	50,900	-	$ 6,100	$ 79,200	13.0	16
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**91,400**	**314,700**	**14,200**	**140,500**	**9.9**	**50**

GREENER U

Building Name/Photo	**Washburn Shops / Stoddard Labs** 
Description Building square footage Type of facility	Washburn Shops / Stoddard Labs is a 42,606 square foot academic building that was built in 1868. Washburn houses offices, departments for manufacturing engineering and materials science as well as the Materials Characterization Laboratory and the Metal Processing Institute.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	A water sourced heat pump system was installed in the building approximately 25 years ago which serve approximately 20 to 25 Trane heat pump units. LED lighting conversion and retrocommissioning could be the main measures in this building.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	The building is not on the energy management system. The fin tube radiation is locally controlled via pneumatic thermostatic controls.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	Part of the third floor is ventilated by three Carrier rooftop units which provide DX cooling only. Three exhaust fans serve fume hoods located in the lab spaces on the third floor. Other exhaust fans serve the first floor machine shop.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating consists of hot water fin tube radiation throughout the building which are split into zones and controlled via pneumatically controlled thermostats. There is no year round heating or process steam in the building.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Almost all lights are fluorescents with no occupancy or vacancy sensors. Upgrading to LED system with lighitng controls is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	Washburn Shops / Stoddard Labs is a three story building constructed of brick with double pane windows.
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provide by the campus steam loop in winter. There is a steam to hot water converter in the Powerhouse that provides hot water to Washburn. The hot water pumps are equipped with VFDs.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	DX cooling for third floor offices, labs, and classrooms. A water source heat pump system for cooling only was installed approximately 25 years ago. The system serves approximately 20 to 25 Trane heat pumps in the building.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by a gas-fired hot water heater.

GREENER U

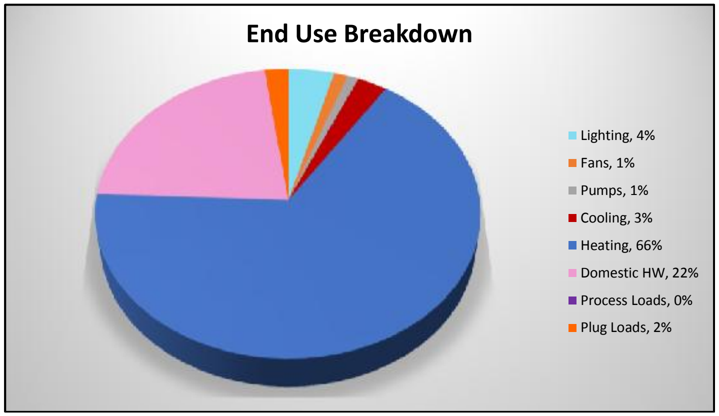
General Information

Building	Washburn ShopsStoddard Labs
GSF	42,606
Space Use	Academic

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	151,913	3.6	102,413	2.4
Thermal Usage (kBtu)	4,028,823	94.6	2,925,823	68.7
TOTAL (kBtu)	**4,547,151**	**106.7**	**3,275,257**	**76.9**

**Thermal Usage allocated based on Square Footage and Usage Type

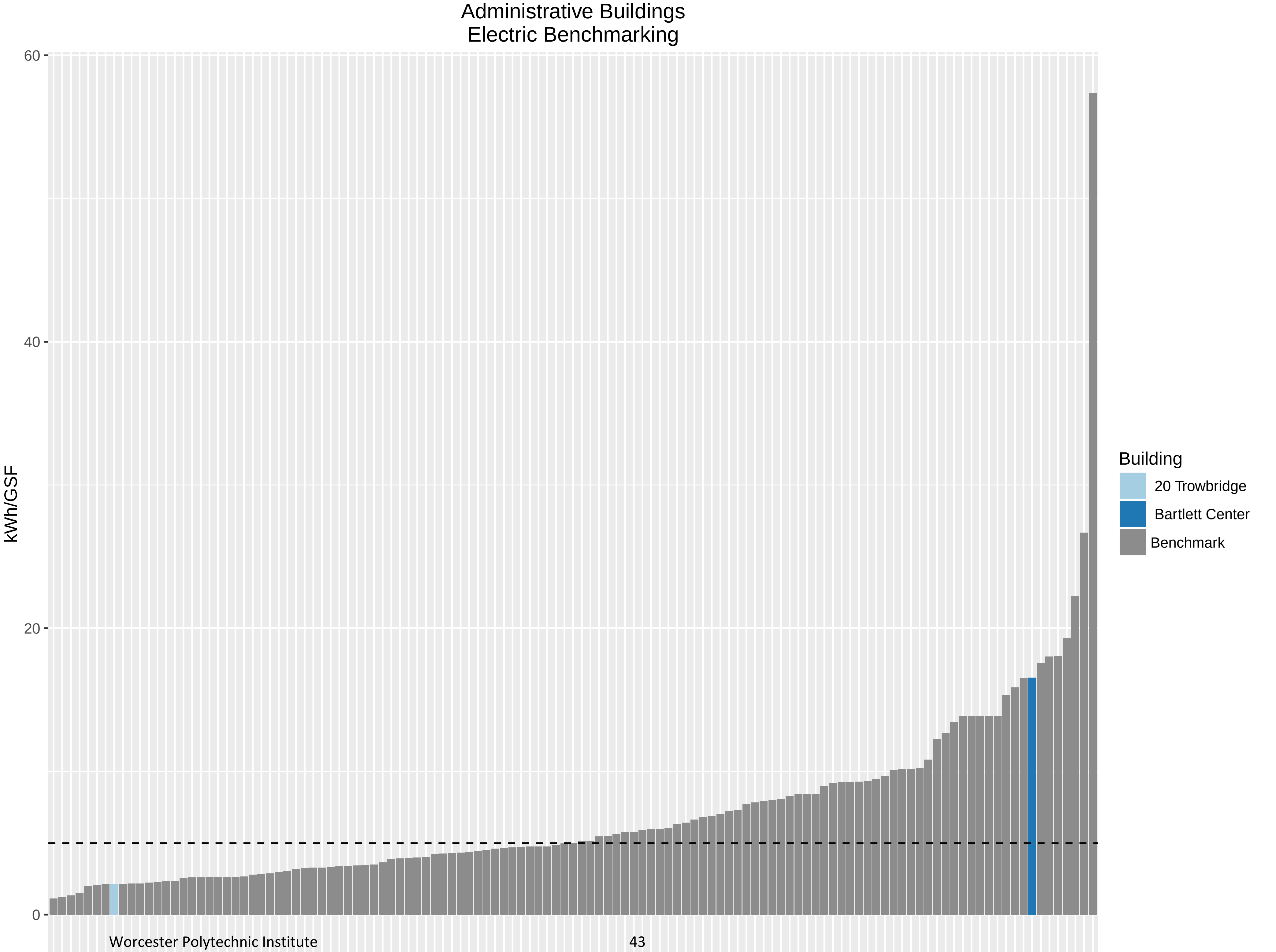


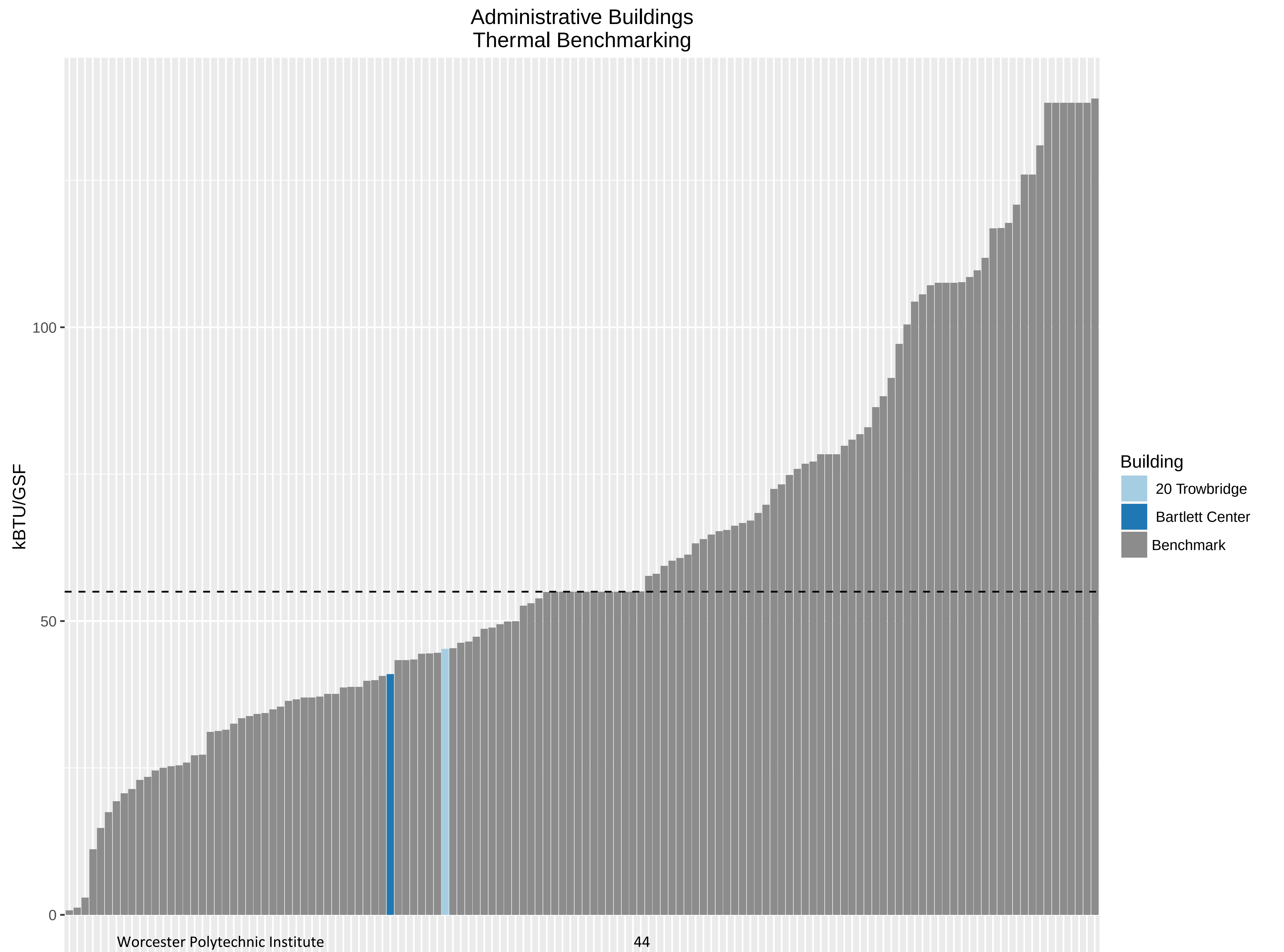
End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	56,208	-
Fans	16,710	-
Pumps	13,672	-
Cooling	36,459	-
Heating	-	3,021,618
DHW	-	1,007,206
Process Loads	-	-
Plug Loads	28,863	-
TOTAL	**151,913**	**4,028,823**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
3	Building Envelope Improvements	3,300	105,800	$ 1,500	$ 32,000	21.3	7
2	Pneumatic to DDC Conversion	11,400	695,000	$ 8,400	$ 140,600	16.7	41
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
3	LED Lighting Conversion	28,100	-	$ 3,400	$ 127,800	37.6	9
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
3	AHU Replacement	6,700	302,200	$ 3,900	$ 170,400	43.7	18
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**49,500**	**1,103,000**	**17,200**	**470,800**	**27.4**	**79**


Administrative Buildings
Electric Benchmarking
60
40
20
0
kWh/GSF
Building
20 Trowbridge
Bartlett Center
Benchmark


Administrative Buildings
Thermal Benchmarking
kBTU/GSF
100
50
0
Building
20 Trowbridge
Bartlett Center
Benchmark

GREENER U

Building Name/Photo	**Bartlett Center** 
Description Building square footage Type of facility	Bartlett Center is a 16,200 square foot administrative building and was built in 2006. The building is LEED ceritified and is home to the Office of Admissions and Financial Aid.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	Staff were not aware of any major issues in the building. WPI is in the process of converting all buildings from Schneider to ALC. LED lighting conversion and a building controls upgrade ould be the main measures in this building.
Occupied Spaces • EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	The controls for the building is on Schneider Electric controls system. WPI is in the process of converting the building from Schneider to ALC. The air handling unit and hot water system are all monitored using the EMS. The fan coil unit / fan power boxes are also monitored on the EMS via wall temperature sensors.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	One York air handling unit serves the building. The unit is equipped with a VFD for the supply and return fan and provides DX cooling. Fan power boxes located throughout the building have hot water coils for reheat. A general exhaust fan is located on the roof. Two return fans are equipped with VFDs. The condensing unit is located on the roof.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by the fan power boxes / fan coil units which are equipped with hot water coils.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Almost all lights are fluorescents. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building is of block construction with brick with double pane windows.
Mechanical Rooms • Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provide by campus steam loop in winter. There is a steam to hot water converter which provides the AHU and fan coil units / fan power boxes with hot water.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	AHU-1 provides DX cooling to the building. A Mitsubishi Mr. Slim split air conditioning unit provides cooling to the IT / data room year round.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by an electric hot water heater.

GREENER U

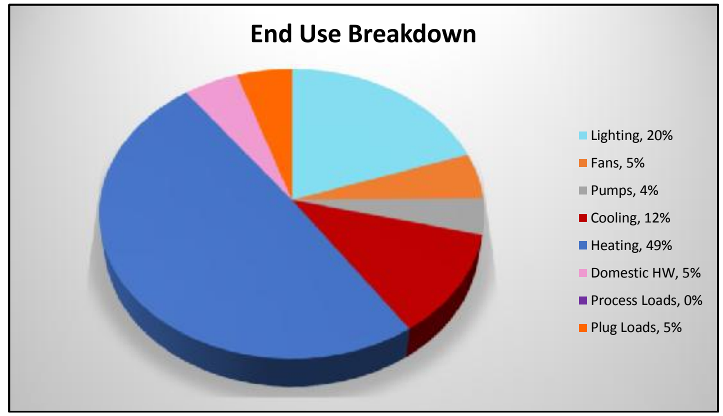
General Information

Building	Bartlett Center
GSF	16,200
Space Use	Administration

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	268,078	16.5	130,151	8.0
Thermal Usage (kBtu)	893,592	55.2	670,192	41.4
TOTAL (kBtu)	**1,808,273**	**111.6**	**1,114,268**	**68.8**

**Thermal Usage allocated based on Square Footage and Usage Type
** Electric Usage is allocated on square footage and use type



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	104,550	-
Fans	26,808	-
Pumps	21,446	-
Cooling	61,658	-
Heating	-	893,592
DHW	26,808	-
Process Loads	-	-
Plug Loads	26,808	-
TOTAL	**268,078**	**893,592**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	5,500	44,700	$ 1,100	$ 8,100	7.4	4
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	8,800	44,700	$ 1,500	$ 16,200	10.8	5
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
2	HVAC Controls Upgrade	22,000	134,000	$ 4,000	$ 56,700	14.2	14
1	LED Lighting Conversion	52,300	-	$ 6,300	$ 64,800	10.3	16
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
3	DX to Chilled Water Cooling	49,326	-	$ 5,919	$ 202,500	34.2	15
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**137,926**	**223,400**	**18,819**	**348,300**	**18.5**	**55**

Building Name/Photo	**20 Trowbridge** 
Description Building square footage Type of facility	20 Trowbridge is a two story, 4,536 square foot administrive building that was constructed in 1905. It houses the Office of Pre-Collegiate Outreach Programs. Typical operating hours are from 8am to 5pm.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	The heating system in the building was recently renovated with a new boiler, pumps, and piping. LED lighting conversion and occupant engagement could be the main measures in this building. Also, retrocommissioning is recommended for the heating system which could include scheduling and an outside air reset strategy.
Occupied Spaces	
• EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	There is no energy management system in this building. There are three zones on each floor which are locally controlled via Honeywell T87 thermostats. The Lochinvar boiler has capabilities to control pump speed, night setback, and zone temperature setpoints. The system should be verified to ensure that the system is working properly.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	There is no airside equipment in this building.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided via hot water from a Lochinvar hot water boiler to newer baseboard radiation located throughout the building.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Almost all lights are fluorescents. Occupants use task lighting at their desks. Upgrading to LED system is recommended.
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	20 Trowbridge is a three story building with a basement. The exterior is wood siding with operable, double pane windows.
Mechanical Rooms	
• Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provided by a recently installed gas-fired Lochinvar condensing hot water boiler. There are three Grundfos zone pumps which are variable speed.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	There is no central cooling system in this building. Occupants may use window air conditioning units.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided to the building via an electric A.O. Smith Energy Saver heater.

GREENER U

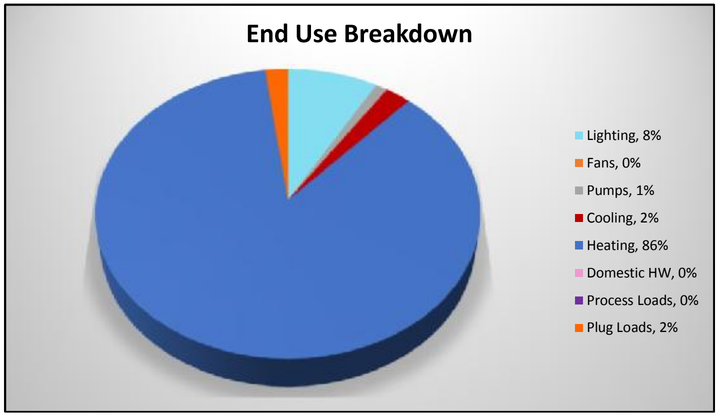
General Information

Building	20 Trowbridge
GSF	4,536
Space Use	Administration

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	9,668	2.1	6,368	1.4
Thermal Usage (kBtu)	205,200	45.2	112,900	24.9
TOTAL (kBtu)	**238,187**	**52.5**	**134,628**	**29.7**

**Thermal Usage is quantified by Gas Data

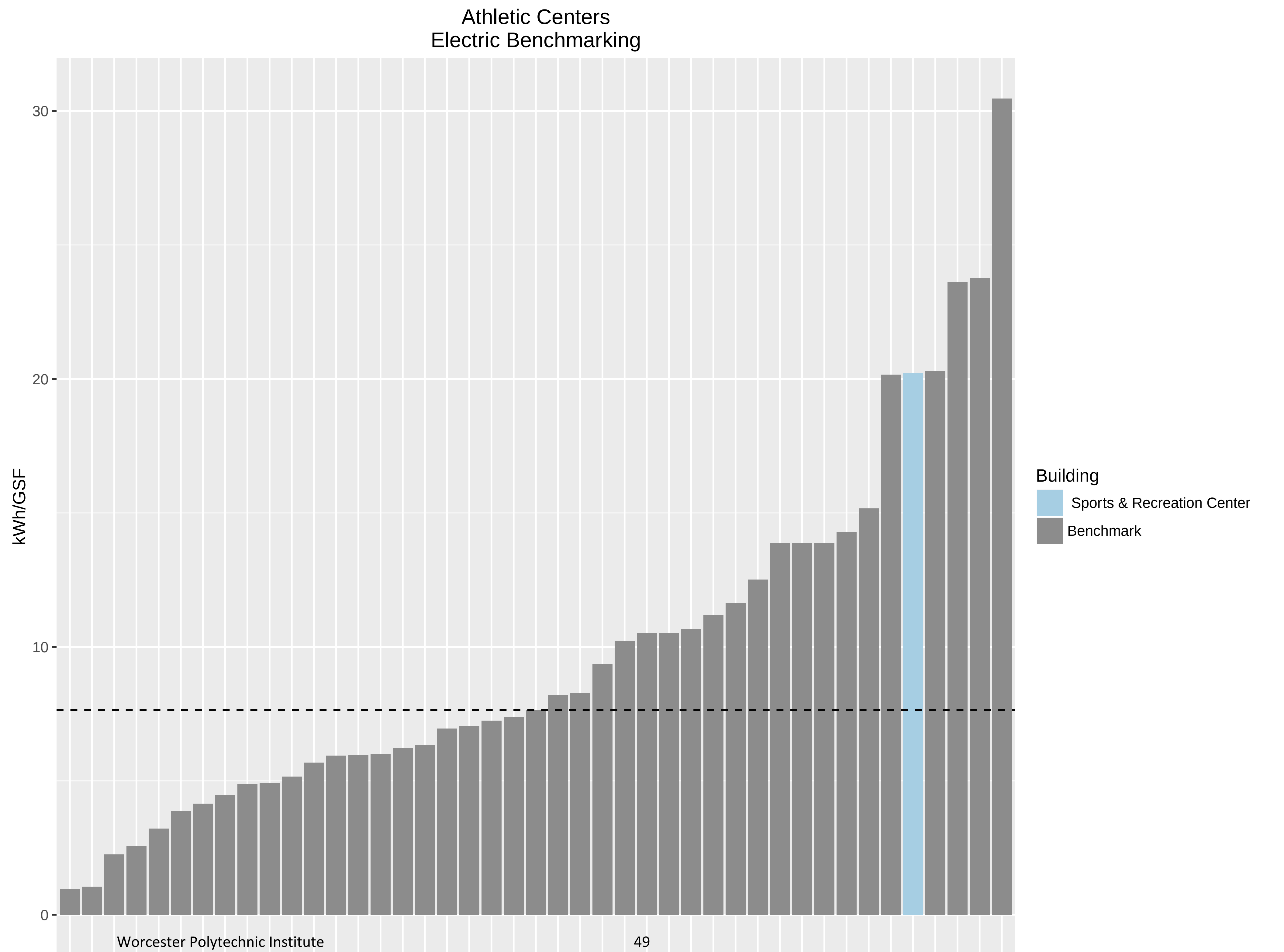


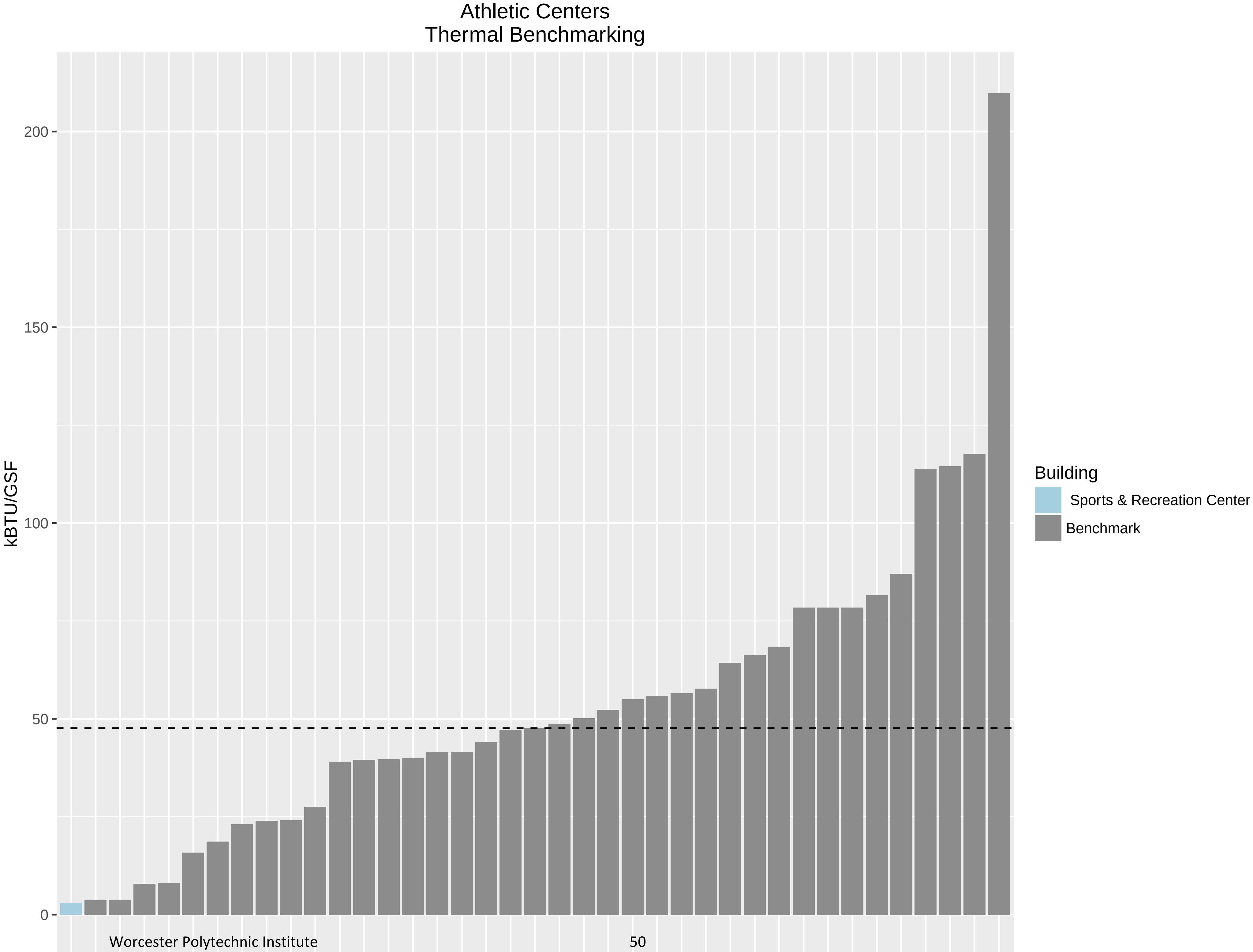
End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	5,801	-
Fans	-	-
Pumps	773	-
Cooling	1,644	-
Heating	-	205,200
DHW	-	-
Process Loads	-	-
Plug Loads	1,450	-
TOTAL	**9,668**	**205,200**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	-	-	$ -	$ -	-	-
1	Control Sequence Optimization	-	-	$ -	$ -	-	-
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
2	Building Envelope Improvements	400	30,800	$ 400	$ 6,800	17.0	2
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	41,000	$ 400	$ 4,500	11.3	2
3	LED Lighting Conversion	2,900	-	$ 300	$ 9,100	30.3	1
2	Pipe Insulation	-	20,500	$ 200	$ 3,400	17.0	1
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
1	Cogen	-	-	$ -	$ -	-	-
	TOTAL	**3,300**	**92,300**	**1,300**	**23,800**	**18.3**	**11**


Athletic Centers
Electric Benchmarking
kWh/GSF
30
20
10
0
Building
Sports & Recreation Center
Benchmark


Athletic Centers
Thermal Benchmarking
kBTU/GSF
200
150
100
50
0
Building
Sports & Recreation Center
Benchmark

Building Name/Photo	**Sports & Recreation Center** 
Description Building square footage Type of facility	The Sports & Recreation Center is a 154,000 square foot athletics building and was built in 2012. The building houses a fitness center, gymnasium, competition swimming pool, rowing room, squash and tennis courts, and an aerobics area. The typical hours of operation are from 6am to 12am daily.
Ask Facilities Staff Major problems Recent renovations Planned renovations Ideas for energy conservation Recent efficiency projects	The Sports & Recreation Center was recently built in 2012. The summer boilers which are used for the swimming pool are approximately two years old yet there has been issues with the boilers; the pool temperature setpoint is approximately 82°F, but the pool usual has an actual temperature of 78°F. LED lighting conversion and retrocommissioning could be the main measures in this building.
Occupied Spaces	
• EMS \ Controls o Manufacturer and vintage o Local Control or on EMS? o End device control (pneumatic, electric, DDC)	The building controls is on the ALC system. The EMS controls and monitors the hot water system, chillers, hot water radiation, VAV reheat boxes, cabinet unit heaters, fan coil units, air handling units, and energy recovery units.
• HVAC Systems (Airside) o Type of systems o AHUs, RTUs, FCUs, Unit Ventilators, H&V o Cooling/heating coils?	Four Trane air handling units, AHU-1 through AHU-4, are located on the roof of the building and serve the main gymnasium year round. Two units typically operate at one time, in lead / lag and are equipped with hot water and chilled water coils. AHU-5 serves the raquetball and squash courts and AHU-6 serves the track / aerobics area. Each unit is equipped with hot water and chilled water coils. Three energy recovery units serve the dance studios, weight room areas, stairwells, and offices. Five exhaust fans are located on the roof and provide ventilation for various areas in the building.
• Space heating systems o Steam versus hot water o Any year round heating? o Any process steam? (i.e. kitchen, autoclaves, other)	Space heating is provided by hot water VAV duct reheat coils, fan coil units, and cabinet unit heaters for the majority of areas. Two heat exchangers are located in the swimming pool mechanical room and provide hot water to the building.
• Lighting o Type of lighting (T8, T12, CF, LED) o Occupancy sensors? Where?	Almost all lights are fluorescents. Upgrading to LED system is recommended. Occupancy sensors for some common areas
• Plumbing o City water or well water? o Showers: low flow? o Sinks – aerators?	The shower heads, faucets and toilets are all low flow.
• Envelope o No. of stories o Façade type o Type of windows (double hung, fixed, 1x/2x pane)	The building has four stories and is of block construction with brick. The windows are double pane and original to the building when it was constructed in 2012.
Mechanical Rooms	
• Primary Heating Systems o Boiler Type o Boiler and/or distribution pressure? o HW Pumps ▪ CV or VFDs?	Heating is provide by campus steam loop in winter. There are two hot water converters that produces hot water for the air handling units, VAV duct reheat coils, fan coil units and cabinet unit heaters. The pumps are equipped with VFDs. The swimming pool is heated by two Lochinvar hot water boiler during the summer.
• Primary Cooling Systems o Chiller? DX? Other? o Any year round cooling? (i.e. IT/data) o CHW Pumps ▪ CV or VFDs?	Cooling is provided by the two chillers located in the mechanical room. Chilled water is circulated by three pumps which are equipped with VFDs.
• Domestic hot water o Type: elec, gas, instantaneous	Domestic hot water is provided by a gas-fired hot water heater.

GREENER U

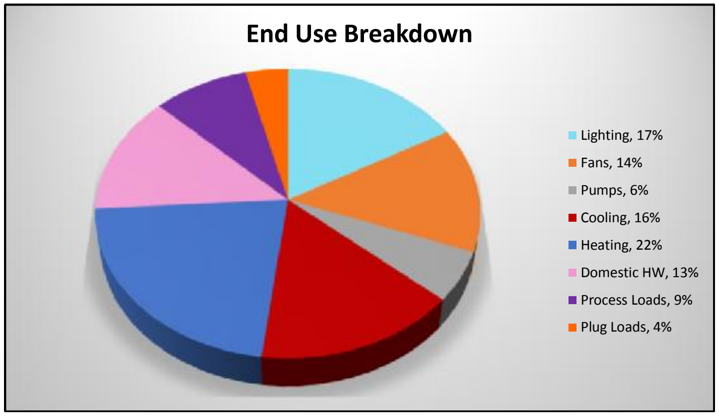
General Information

Building	Sports & Recreation Center
GSF	145,000
Space Use	Athletic Facilities

Utility Usage

	Existing Total Usage	Existing EUI	Proposed Total Usage	Proposed EUI
Electric Usage (kWh)	2,931,400	20.2	1,958,560	13.5
Thermal Usage (kBtu)	7,887,900	54.4	6,507,500	44.9
TOTAL (kBtu)	**17,889,837**	**123.4**	**13,190,107**	**91.0**

**Thermal Usage is a combination of Summer gas usage and Winter Central Plant Usage



End Use Breakdown

	Electric kWh	Thermal kBtu
Lighting	879,420	-
Fans	732,850	-
Pumps	293,140	-
Cooling	820,792	-
Heating	-	3,943,950
DHW	-	2,366,370
Process Loads	-	1,577,580
Plug Loads	205,198	-
TOTAL	**2,931,400**	**7,887,900**

Measures

Cost level	Measure	Target Reduction Electric kWh	Target Reduction Thermal kBtu	Cost Savings	Installed Cost	Simple Payback	Lifetime Reduction Equivalent CO2 (MTeCO2)
1	Retrocommissioning	92,300	591,600	$ 17,100	$ 58,000	3.4	60
1	Control Sequence Optimization	110,800	591,600	$ 19,300	$ 79,800	4.1	66
1	Occupancy Based Controls	-	-	$ -	$ -	-	-
1	Demand Controlled Ventilation	-	-	$ -	$ -	-	-
1	VFD Installation on Fans	-	-	$ -	$ -	-	-
1	VFD Instllation on Pumps	-	-	$ -	$ -	-	-
1	TRV Installation	-	-	$ -	$ -	-	-
1	Building Envelope Improvements	36,900	197,200	$ 6,400	$ 14,500	2.3	22
1	Pneumatic to DDC Conversion	-	-	$ -	$ -	-	-
1	HVAC Controls Upgrade	-	-	$ -	$ -	-	-
1	LED Lighting Conversion	439,700	-	$ 52,800	$ 543,800	10.3	136
1	Pipe Insulation	-	-	$ -	$ -	-	-
1	Thermal Jackets Installation	-	-	$ -	$ -	-	-
1	Window Replacement	-	-	$ -	$ -	-	-
1	AHU Replacement	-	-	$ -	$ -	-	-
1	Electric to HW Conversion	-	-	$ -	$ -	-	-
1	OA AHU for data center	-	-	$ -	$ -	-	-
1	Heat Recovery Installation	-	-	$ -	$ -	-	-
1	Fume Hood Improvements	-	-	$ -	$ -	-	-
1	Electric to VRF Conversion	-	-	$ -	$ -	-	-
1	DX to Chilled Water Cooling	-	-	$ -	$ -	-	-
2	Cogen	293,140	-	$ 35,177	$ 565,500	16.1	91
	TOTAL	**972,840**	**1,380,400**	**130,777**	**1,261,600**	**9.6**	**380**

APPENDIX B

ENERGY EFFICIENCY OPPORTUNITIES

Below is a summary of the energy conservation and deferred maintenance measures proposed in this analysis report:

RETRO-COMMISSIONING

Proper functionality of HVAC systems and associated controls is critical for energy efficient building operations. Recommissioning of controls systems is recommended for several buildings included in the study. GreenerU recommends an approach to existing building commissioning (EBCx) that includes the use of both on site field testing and diagnostic analytics. This approach allows for the initial identification of controls issues.

CONTROL SEQUENCE OPTIMIZATION

Based on our site visits and EMS (Energy Management System) observation, we identified several opportunities to optimize existing control sequences which would yield significant energy savings. Typical control sequence optimization strategies include, but not limited to, discharge air temperature setpoint reset, duct static pressure setpoint reset, optimize HVAC equipment time schedules, optimize air flow setpoints, economizer operation optimization, and differential pressure reset.

OCCUPANCY BASED CONTROLS

There are many areas in the campus (classrooms, offices, conference rooms, etc.,) where implementing occupancy based temperature and ventilation controls is a good strategy. In this measure, occupancy sensors would be installed, wired to the EMS, and be used to setback temperatures and flows during unoccupied periods. In locations where a lighting upgrade project is implemented and lighting occupancy controls are added, these sensors can be utilized for integration with the EMS.

DEMAND CONTROLLED VENTILATION

CO_2 levels in spaces can be used as an indicator of air quality. We have identified large spaces with highly variable occupancy that would benefit from reducing the amount of outside ventilation being provided during periods of low or no occupancy. CO_2 sensor(s) would be installed either in the space or in the return air duct to monitor the air quality in the space. The outside air intake would be modulated to maintain the space CO_2 level below acceptable level.

VFD INSTALLATION ON FANS AND PUMPS

Many fans and pumps in the buildings we surveyed operate at full capacity all the time, and do not have VFDs installed on the motors. In this measure, VFDs would be installed on these fan and pump motors, so that they can be operated at lower speeds when the demand is low. This measure will reduce fan/pump energy consumption, and could potentially reduce heating/cooling energy in areas that have simultaneous heating and cooling issues.

TRV INSTALLATION ON RADIATORS

Two of the buildings that we surveyed have one-pipe steam radiators systems to provide space heating. Although there are zone level controls on these radiators, significant energy savings could be generated with the installation of TRVs (Thermostatic Radiator Valves) on each radiator. By providing occupants with temperature control at the radiator level, control occupant comfort is improved and less heating energy is wasted as compared to radiators that run as a zone, controlled by single centralized thermostat. Additionally, rooms with better thermal control tend to have fewer open windows during the winter months, reducing the risk for pipe-freeze conditions.

BUILDING ENVELOPE IMPROVEMENTS

GreenerU identified several building envelope improvement opportunities in all the buildings in this study because many exterior doors and windows had gaps. Infiltration of unconditioned air increases the heating load in the winter and the cooling load in the summer. GreenerU recommends door and window weather stripping, and window sash sealing.

PNEUMATIC TO DDC CONVERSION

Some of the valve and damper actuators have pneumatic actuators, controlled by the EMS via E-to-P transducers. Old pneumatic actuators tend to fail or operate inaccurately leading to higher energy consumption in some scenarios. We recommend converting these actuators to DDC. This will also reduce the load on air compressors. This measure is applicable to the thermostats located in Washburn Shops / Stoddard Labs.

HVAC CONTROLS UPGRADE

Residential buildings recommended for a HVAC Controls Upgrade include installing smart thermostats such as Nest thermostats or equal manufacturer. Smart thermostats allow individual control of the system, ability to schedule for days of the week with temperature setbacks, and external communication via internet / WIFI.

LED LIGHTING CONVERSION

GreenerU identified opportunities in almost all buildings to continue retrofitting or replacing existing lighting systems throughout Babson College with LED and additional lighting controls. Lighting controls will include day lighting and occupancy controls – both local and networked lighting control systems – as appropriate.

PIPE INSULATION

There are multiple mechanical rooms in the buildings surveyed that have exposed steam or hot water piping. This measure will insulate piping and fittings to reduce heating and cooling energy. Insulating steam piping and fittings is a low payback measure that can generate significant savings

AHU REPLACEMENT

This measure would replace the three rooftop units at Washburn Shops / Stoddard Labs which have rusted out and frequently require maintenance. GreenerU recommends replacing the unit with an efficient model that would be sized to provide the necessary ventilation rates according to ASHRAE's requirements.