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Prepared by: Suzanne Marinello, P.E.
Jacob Gradwohl
Yuki Klein

Field Research Laboratory
3455 NE Granger Ave
Corvallis, OR 97330

Table of Contents

Abbreviations 1

Disclaimer 2

Preface 3

Related Contacts 4

Building Efficiency Measure (EEM) Summary 4

Building Description 5

Best Practice 7

Energy Cost Analysis 8

Major Energy Consuming Equipment 9
- Mechanical Systems 9
- Lighting Systems 10
- Controls 10

Detailed Energy Efficiency Measures 11
- EEM 1: Lighting Upgrade 11
- EEM 2: Occupancy Sensors 13
- EEM 3: Envelope Upgrade 15
- EEM 4: Programmable Thermostats 18
- EEM 5: Motor Upgrade 19

Appendix 20
- Light Fixture Photos 20
- Mechanical Photos 24

Abbreviations

AFUE Annual Fuel Utilization Efficiency

AHU Air Handling Unit

BTU British Thermal Unit

CFM Cubic Feet (per) Minute

CMU Concrete Masonry Unit

CV Constant Volume

DAT Discharge Air Temperature

DDC Direct Digital Control(s)

DegF Degrees Fahrenheit

DOE Department of Energy

DHW Domestic Hot Water

dP Discharge Pressure

dT Delta T (Temperature difference)

DX Direct Expansion

EEM Energy Efficiency Measure

EFLH Estimated Full Load Hours

ETO Energy Trust of Oregon

EUI Energy Use Index

HC Heating Coil

HP Horsepower

Hr Hour

HVAC Heating Ventilating & Air Conditioning

HW Heating Water

HWP Heating Water Pump

IAC Industrial Assessment Center

kBtu 1,000 Btus

kW Kilowatt

kWh Kilowatt-hours

lbs Pounds

LPD Lighting Power Density

MBH kBtu/hr (1,000 BTU/hr)

MAT Mixed Air Temperature

OAT Outside Air Temperature

RAT Return Air Temperature

RF Return Fan

SAT Supply Air Temperature

sf Square Feet

SF Supply Fan

SOO Sequence of Operations

SP Static Pressure

TMY3 Typical Meteorological Year

TU Terminal Unit

VAV Variable Air Volume

VFD Variable Frequency Drive

W Watts

Yr Year

Disclaimer

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

The intent of this energy analysis is to estimate energy savings associated with the recommended energy efficiency upgrades. This report is not intended to serve as a detailed engineering design document. Any description of proposed improvements that may be diagrammatic in nature are for the purpose of documenting the basis of cost and savings estimates for potential energy efficiency measures only. Detailed design efforts may be required by the participant to implement measures recommended as part of this energy analysis. While the recommendations in this study have been reviewed for technical accuracy and are believed to be reasonably accurate, all findings listed are estimates only. Actual savings and incentives may vary based on final installed measures and costs, actual operating hours, energy rates and usage.

Preface

The Commercial Building Energy Audit (CBEA) program is funded by the DOE and structured within the framework of its predecessor and parent program, the Industrial Assessment Center (IAC). The purpose of the CBEA is to provide customers with free energy assessments of commercial buildings, thereby increasing energy efficiency while simultaneously expanding the workforce of building efficiency professionals through the application of student participation from partnered colleges and universities. The scope of such audits is limited in nature, for the express purpose of identifying no-cost and low-cost energy savings opportunities, and a general view of potential capital improvements. This is accomplished by means of utility usage and billing evaluation, along with observation and analysis of energy using systems. The findings and recommendations within this report represent the conditions observed at the time of this site survey. Conditions and equipment usage are subject to change, and therefore the conclusions expressed within this report may not be evident in the future. The CBEA audit team has endeavored to meet what it believes is the applicable standard of care ordinarily exercised by others in conducting this energy audit. No other warranty, express or implied, is made regarding the information contained in this report.

Related Contacts

Participant (Customer) Contact	
Contact Name	
Title	
Phone	
Email	
CBEA Contact	
Contact Name	Suzanne Marinello P.E.
Title	Lead Energy Analyst Lead Instructor
Phone	541-207-8205
Email	marinellos@lanecc.edu
CBEA Contact	
Contact Name	Jacob Ray Gradwohl
Title	Lead Student Intern
Email	gradwoja@oregonstate.edu
CBEA Contact	
Contact Name	Yuki Klein
Title	Student Intern
Email	kleiny@oregonstate.edu

Building Efficiency Measure (EEM) Summary

These energy efficiency measures (EEMs) are suggested for the facility. Cost savings are based on average utility rates for electricity and natural gas. Actual rates and cost savings will differ. Non-energy cost benefits are related to cost-savings due to as-avoided maintenance. Simple payback is estimated using current utility rates and estimated project costs, which may vary over time.

Table 1. EEM Cost Estimates

Measure Number	Measure Description	Annual Energy and Cost Savings				Measure Cost and Simple Payback	
		Electricity Savings		Gas Fuel Savings	Total Cost Savings	Measure Cost	Simple Payback
		kWh	kW	Therms			Year
EEM 1	Lighting Upgrade*	30258	10	-	$ 3,123	$ 37,260	12
EEM 2	Occupancy Sensors	6750	-	-	$ 683	$ 3,000	4
EEM 3	Building Insulation*	34860	-	-	$ 3,529	$ 72,976	20.7
EEM 4	Programmable Thermostats	7500	-	-	$ 759	$ 2,250	3
EEM 5	Premium Efficient Motors*	604	-	-	$ 61	$ 300	5
Totals (Recommended Measures)		79972		0	$ 8,155	$ 115,786	14

Building Description

The Field Research Laboratory is a 16,500 sf building in Corvallis, Oregon. The laboratory was originally constructed in 1973. There has been one major addition on the northside of the facility, but the date of the addition is unknown.

The primary objective of the Field Research Laboratory is to conduct field research, extension, and teaching related to the development, production, and management of agronomic crops. The laboratory operates all year round. There is no schedule for the lights, staff come and go on their own accord. All lighting is controlled by manual wall switching.

The building is shaped like a backwards “c,” with the entrance of the building (bottom of the c configuration) is where the labs, office, rest rooms, and storage closet rooms are located. The hall that connects to upper and lower part of the building is where the coolers, cabinet dryers, and the larger labs are located. The upper part of the “c” configuration is where the fumigation, laboratory, and seed storage rooms are located. The labs near the front entrance have been upgraded to double pane, vinyl framed windows. The exterior walls of the front entrance have also been upgraded to (approx) R-11 wall insulation. The remaining windows of the facility are the original single pane, metal frame windows. Except for the front entrance, the exterior walls are uninsulated, consisting of wood framing and wood siding. There is no ceiling or roof insulation

visible. All the windows are manually operated to provide ventilation.

The section where the cooler and dryer are located is covered by expanded metal and concrete flooring. The cooler is refrigerated with a split system Carrier unit, with evaporators mounted along the wall, and the outdoor condensing unit mounted on the ground adjacent to the space. The ceiling of the walk-in consists of lay-in ceiling tiles with fluorescent light fixtures. Condensation is visible on the surface of the light fixtures, indicating a need for a vapor barrier in the space.

The north end of the facility (the addition) consists of an open storage room. This space is heated by a ceiling mounted gas fired unit heater. There is a hood located in the room with make-up air from wall mounted exterior wall louvers.

The laboratories are used to conduct agricultural research. Crops are collected from the surrounding fields and processed on site. The main staff consists of students conducting research and their occupancy schedules vary depending on the season. At the time of the site visit, there were observed to be less than 10 occupants present. The facility is heated with electric wall heaters which are manually controlled by wall mounted thermostats. There is no mechanical ventilation in any of the labs and offices.

There is no air conditioning of the labs or offices, except for a couple single wall mounted air conditioning units located in one of the labs and the maintenance garage.

Best Practice

This audit is per ASHRAE Level 1 requirements. The building's energy cost and efficiency were assessed by analyzing 2021 utility data.

Utility analysis was used to produce reports on the monthly consumption of both electricity and natural gas.

The mechanical and lighting schedules were used to generate outlines of energy usage in terms of demand and energy consumption.

A site visit conducted on July 26, 2022 provided a walk-through survey of the facility including its construction, operation, and maintenance, and major energy consuming equipment. Feedback from the customer related to facility performance and comfort was used to inform the survey and the resulting recommendations within this report.

The data was then used to identify no-cost and low-cost measures for improving energy efficiency. Because calculations at this level are minimal, savings and costs are approximate.

Energy Cost Analysis

Table 2. 2021 Energy Use

2021 Electrical Data						
Month	**kWh**	**kWh Charge**	**Charge / kWh**	**kW**	**kW Charge**	**Fees**
Jan	9,400	978	$0.104	36	$ 228	$ 110
Feb	12,840	1,266	$0.099	40	$ 226	$ 110
Mar	10,200	1,068	$0.105	46	$ 228	$ 110
Apr	12,720	1,190	$0.094	40	$ 226	$ 110
May	11,360	1,130	$0.099	36	$ 228	$ 110
Jun	12,560	1,188	$0.095	36	$ 226	$ 110
Jul	9,280	923	$0.099	36	$ 228	$ 110
Aug	7,960	861	$0.108	40	$ 226	$ 110
Sep	7,640	837	$0.110	40	$ 228	$ 110
Oct	9,960	1,024	$0.103	36	$ 226	$ 110
Nov	10,120	1,053	$0.104	40	$ 228	$ 110
Dec	10,680	1,108	$0.104	36	$ 226	$ 110
TOTALS	124,720	$12,626.00	$0.10	462.00	$2,724.00	$1,320.00

2021 Natural Gas Data					
Month	**Therms**	**Cost**	**Cost / Therm**	**Other Charges**	**Total**
Jan	223.1	$178.97	$0.802	$58.00	$236.97
Feb	254.7	$204.32	$0.802	$16.87	$221.19
Mar	66.2	$53.10	$0.802	$44.45	$97.55
Apr	18.9	$15.16	$0.802	$32.31	$47.47
May	9.6	$7.70	$0.802	$28.04	$35.74
Jun	798.4	$640.47	$0.802	$18.81	$659.28
Jul	757.0	$607.26	$0.802	$16.05	$623.31
Aug	146.9	$117.84	$0.802	$16.05	$133.89
Sep	113.1	$90.73	$0.802	$16.11	$106.84
Oct	255.5	$204.96	$0.802	$16.79	$221.75
Nov	921.5	$796.26	$0.864	$61.93	$858.19
Dec	381.3	$362.92	$0.952	$55.52	$418.44
TOTALS	3,946.2	$3,279.69	$0.83	$380.93	$3,660.62

Major Energy Consuming Equipment

Mechanical Systems

There were no mechanical schedules available for the building but the following information was obtained through observation.

The facility has no cooling system except a couple post-construction wall mounted air conditioners for some workspaces. Heating in the offices and labs is provided by wall mounted electric heaters. Heating in the north process labs is provided by gas fired unit heaters mounted directly in the space.

There is a walk-in cooler provided with a split system air conditioning unit. The evaporator is in the room and the condenser is located outside the lab building.

In the main entrance corridor there is a gas fired Reznor unit which provides process drying of crops and seeds.

Domestic water heating is provided by two tank type electric water heaters. Water heating is limited to lab and restroom sinks

The following tables detail the information available through nameplates. Please see Appendix II for accompanying figures.

Table 3. Split System Schedule

Tag	Area Served	Manufacturer	Model
C-1	Refrigerator	(Unreadable)	OHB10L44-E

Table 4. Water Heater Schedule

Tag	Manufacturer	Model	Manufacture Date	Capacity (Gal)
WH-1	General Electric	PE40M09AAH	July 2011	40
WH-2	Rheem	PRoE50 T2 AH95	November 2015	50

Table 5. Motor Schedule

Tag	Manufacturer	Model
M-1	A.O. Smith	SOP2201
M-2	Century	SC-213-FC3-35
M-3	Baldor	35B101P499H1

Lighting Systems

The lighting in the space consists of 15 fixture types as detailed from the Architect. Please see Appendix I for accompanying figures. A majority of the labs are lit by types A and C, though processing and specialized areas use the remaining types.

Table 6. Existing Lighting

Existing Lighting				
Fixture Type	**Description**	**Watt/Fixture**	**Quantity**	**Total Watt per Fixture**
A	Surface Wrap with acrylic lens, 4 ft with 2 lamps fluorescent	60	79	4740
B	Industrial - Open lamps with reflector 4 ft long 4 lamps fluorescent	160		0
C	Surface Wrap with acrylic lens, 8 ft with 2 lamps fluorescent	120	10	1200
D	Industrial strip - Open lamps with reflector 8 ft long with 4 lamps	120		0
E	Keyless Incansescent	60	8	480
F	High mount round HAT incansdescent or CFL	300	5	1500
G	Jelly jar incandescent	100		0
H	Pendant stem - HAT incandescent	300	6	1800
I	Clasified (explosion proff) jelly jar incandescent	200	4	800
J	Industrial strip with specular reflector 4 ft with 2 lamps	60	56	3360
K	Ice cube trap 4 ft 2 lamp T12 fluorescent	120	4	480
L	Troffer 2 x 4 4 lamp fluorescent	120	2	240
M	Exterior Barn Light	200	4	800
N	Exterior Small wall pack over man door	75	1	75
O	Exterior Wallpack medium front entrance	175	2	350
			SUM	**15825**

Controls

Lighting and heating operate during occupied periods and are manually controlled.

Detailed Energy Efficiency Measures

EEM 1: Lighting Upgrade

EXISTING CONDITIONS

The general lighting of the space consists of 15 different fixtures. These fixtures are old and mostly fluorescent, with an estimated range of 60 to 300 watts per fixture depending on the type.

PROPOSED MEASURE DESCRIPTION

Replace existing lamps with LED lamps for each fixture. These are estimated to be 20 to 80 watts depending on the type.

Table 7. Lighting Fixture Upgrade

Existing Lighting					Proposed Lighting				
Fixture Type	Description	Watt/Fixture	Quantity	Total Watt Fixture Type	Fixture Type	Description	Watt/Fixture	Quantity	Total Watt Fixture Type
A	Surface Wrap with acrylic lens, 4 ft with 2 lamps fluorescent	60	79	4740	L1	EMS-L48-4000LM-IMAFL-WD-40K-80CRI	24	79	1896
B	Industrial - Open lamps with reflector 4 ft long 4 lamps fluorescent	160	10	1600	L2	EMS-L24-9000LM-PST-MD-40K-80CRI	59	10	590
C	Surface Wrap with acrylic lens, 8 ft with 2 lamps fluorescent	120	10	1200	L3	EMS-L96-9000LM-IMAFL-WD-40K-80CRI	53	10	530
D	Industrial strip - Open lamps with reflector 8 ft long with 4 lamps	120		0	L4	EMS-L96-9000LM-IMAFL-WD-40K-80CRI	53		0
E	Keyless Incansescent	60	8	480	L5	LED MEDIUM BASE LAMP	20	8	160
F	High mount round HAT incansdescent or CFL	300	1	300	L6	PXLW-10000LM-WD-40K-80CRI-PM	74	1	74
G	Jelly jar incandescent	100	1	100	L7	PXLW-5000LM-WD-40K-80CRI-PM	35	1	35
H	Pendant stem - HAT incandescent	300	6	1800	L8	PXLW-10000LM-WD-40K-80CRI-PM	74	6	444
I	Clasified (explosion proff) jelly jar incandescent	200	4	800	L9	HRLL-8L-GO-AS-50K-CM	94	4	376
J	Industrial strip with specular reflector 4 ft with 2 lamps	60	56	3360	L10	EMS-L48-4000LM-IMAFL-WD-40K-80CRI	24	56	1344
K	Ice cube trap 4 ft 2 lamp T12 fluorescent	120	4	480	L11	EMS-L48-4000LM-IMAFL-WD-40K-80CRI	24	4	96
L	Troffer 2 x 4 4 lamp fluorescent	120	2	240	L12	HVT-2X4-DOP-5500-4OK	52	2	104
M	Exterior Barn Light	200	4	800	L13	PCLL	79	4	316
N	door	75	1	75	L14	HLWPC2-P10-40K-TFTM	28	1	28
O	entrance	175	1	175	L15	HLWPC2-P30-40K-TFTM	71	1	71
				16150					6064
			On Time Hrs						
	Total Existing Watt	16150	3000	48450	kWh				
	Total Proposed Watt	6064	3000	18192	kWh				

SAVINGS METHODOLOGY

Sayings are estimated using a spreadsheet calculation.

ESTIMATED COST

The estimated installation costs are as described in Table 7. Assuming 3000 hours of run time for all fixtures and $0.1 per kWh the following savings were estimated.

EEM #1 Estimated Savings		
Annual Energy Usage & Savings Estimate	Baseline Electric Usage (kWh)	48450
	Proposed Electric Usage (kWh)	18192
	Electric Savings (kWh)	30258
	Electric Cost Savings ($)	$ 3,063
	Demand Savings (kW)	10
	Electric Demand Savings ($)	$ 59
	Baseline Natural Gas Usage (Therms)	-
	Proposed Natural Gas Usage (Therms)	-
	Natural Gas Savings (Therms)	-
	Natural Gas Savings ($)	-
	Annual Energy Cost Savings	$ 3,123
Measure Cost & Simple Payback	Project Cost	$ 37,260
	Simple Payback (Cost/Savings)	11.9

EEM 2: Occupancy Sensors

EXISTING CONDITIONS

There are currently no occupancy sensors on site.

PROPOSED MEASURE DESCRIPTION

Add occupancy sensors for each room/area.

SAVINGS METHODOLOGY

Savings are estimated using a spreadsheet calculation. Existing ON time is estimated at 3000 hrs. Occupancy sensors are estimated to reduce ON time to 2500 hours per year, a reduction of 500 hrs. (A reduction of approx. 16% in ON time).

Existing Conditions
Rooms do not have Occupancy Sensors

Fixture Type	Description	Watt/Fixture	Quantity	Total Watt Fixture Type
A	Surface Wrap with acrylic lens, 4 ft with 2 lamps fluorescent	60	79	4740
B	Industrial - Open lamps with reflector 4 ft long 4 lamps fluorescent	160		0
C	Surface Wrap with acrylic lens, 8 ft with 2 lamps fluorescent	120	10	1200
D	Industrial strip - Open lamps with reflector 8 ft long with 4 lamps	120		0
E	Keyless Incansescent	60	8	480
F	High mount round HAT incansdescent or CFL	300	1	300
G	Jelly jar incandescent	100	1	100
H	Pendant stem - HAT incandescent	300	6	1800
I	Clasified (explosion proff) jelly jar incandescent	200	4	800
J	Industrial strip with specular reflector 4 ft with 2 lamps	60	56	3360
K	Ice cube trap 4 ft 2 lamp T12 fluorescent	120	4	480
L	Troffer 2 x 4 4 lamp fluorescent	120	2	240

kWh = watts/1000 x ON time hr

13500	Watt Existing	
40500	kWh Existing	Assume On Time at 3000 hrs per year
33750	kWh Proposed	Assume reduce to 2500 hrs per year ON time

ESTIMATED COST

Assuming $0.1 per kWh, 20 sensors, and $150 per sensor, the following costs were estimated.

EEM #2 Estimated Savings			
Annual Energy Usage & Savings Estimate	Baseline Electric Usage (kWh)		40500
	Proposed Electric Usage (kWh)		33750
	Electric Savings (kWh)		6750
	Electric Cost Savings ($)	$	683
	Baseline Natural Gas Usage (Therms)		
	Proposed Natural Gas Usage (Therms)	-	
	Natural Gas Savings (Therms)	-	
	Natural Gas Savings ($)	$	-
	Annual Energy Cost Savings	$	683
Measure Cost & Simple Payback	Project Cost	$	3,000
	Simple Payback (Cost/Savings)		4.4

EEM 3: Envelope Upgrade

EXISTING CONDITIONS

The current envelope includes an uninsulated sheet metal roof, concrete and sheet metal walls. The exterior walls of the front offices have been upgraded with R-11 insulation and double pane windows with vinyl frames. The remaining walls and roof are uninsulated. In addition, the remaining lab windows are single pane, metal framed operable windows.

PROPOSED MEASURE DESCRIPTION

Extend insulation throughout spaces to create a full thermal envelope. Replace single pane windows with updated and thermally efficient windows. Insulate the roof to further thermal envelope.

SAVINGS METHODOLOGY

Savings based on spreadsheet calculations and eQUEST modeling.

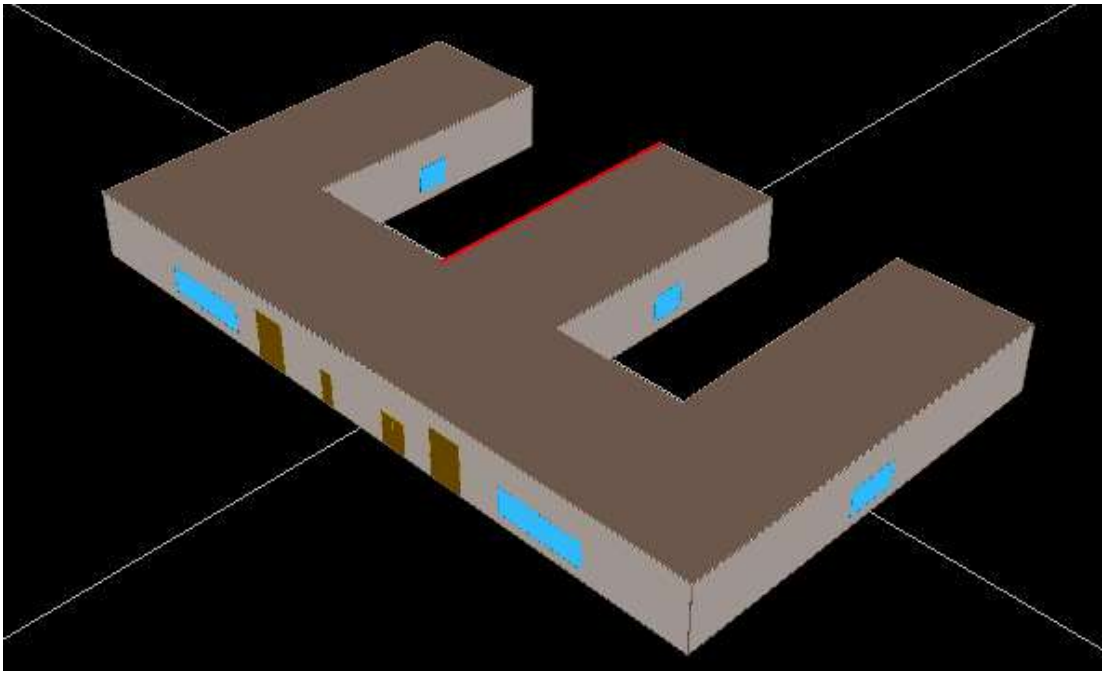
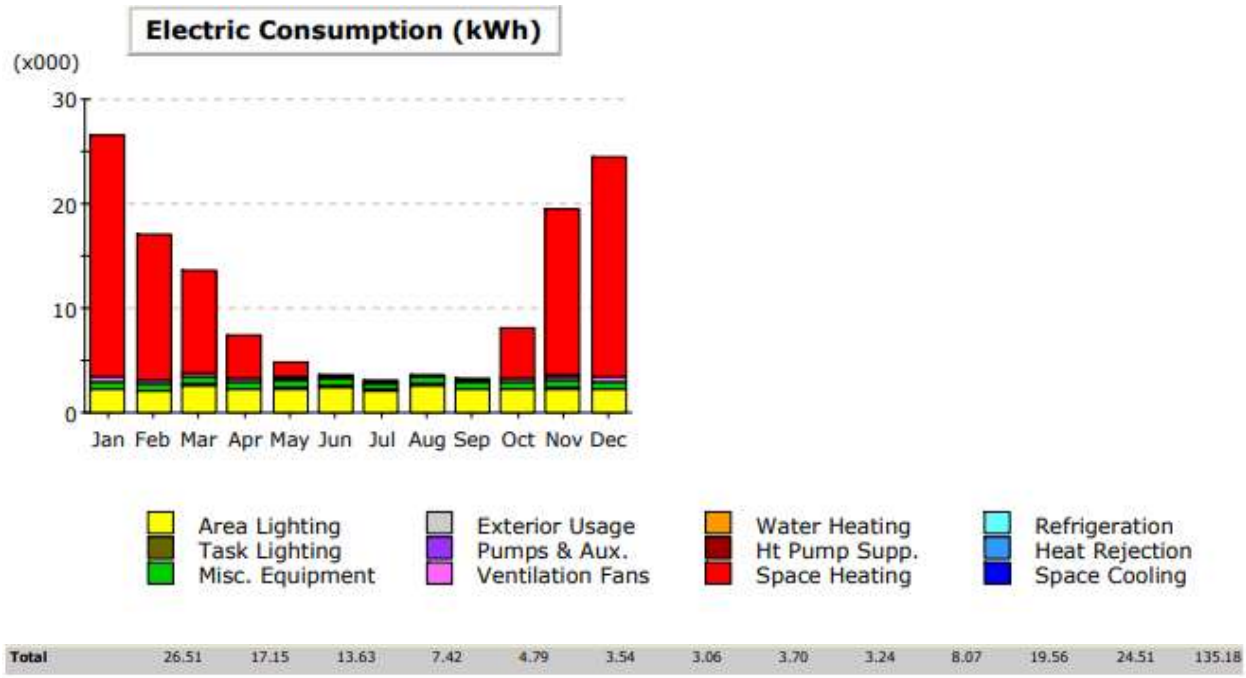
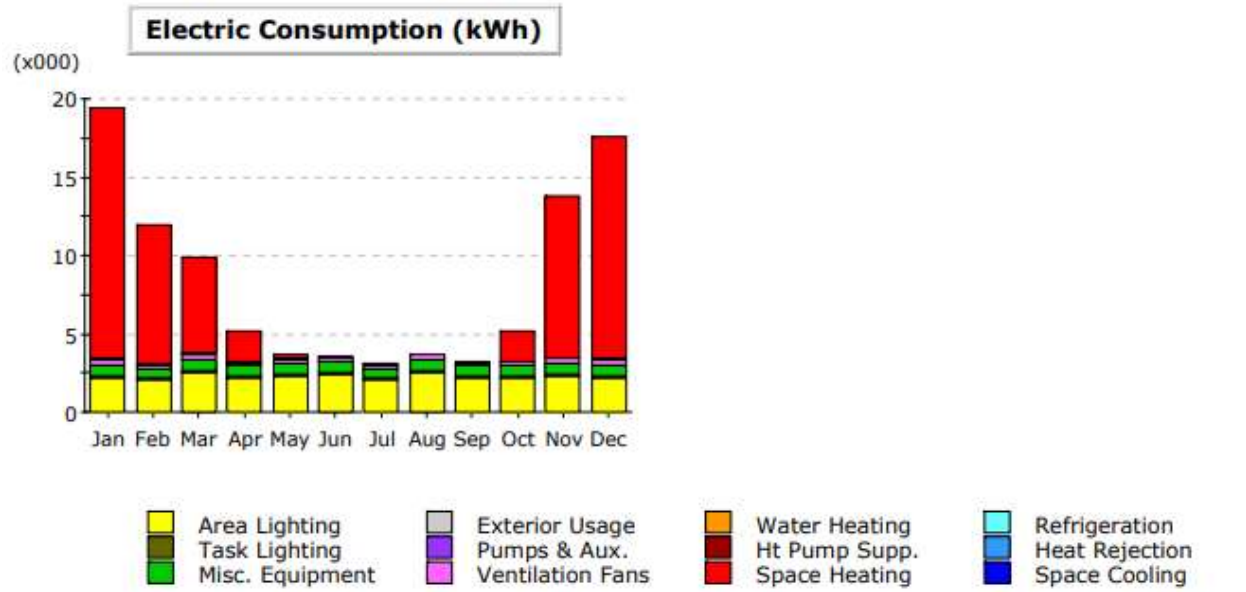


Figure 1. eQUEST model



Total	26.51	17.15	13.63	7.42	4.79	3.54	3.06	3.70	3.24	8.07	19.56	24.51	135.18

Figure 2. Estimated energy usage for current building



Total	19.39	12.01	9.94	5.18	3.69	3.52	3.06	3.70	3.20	5.17	13.83	17.63	100.32

Figure 3. Estimated energy usage for retrofit building

ESTIMATED COST

The envelope retrofit was estimated with prices sourced from the Architect for an approximate total of $73,000. Combined with the eQUEST energy data, the following costs were estimated.

EEM #3 Estimated Savings			
Annual Energy Usage & Savings Estimate	Baseline Electric Usage (kWh)		135180
	Proposed Electric Usage (kWh)		100320
	Electric Savings (kWh)		34860
	Electric Cost Savings ($)	$	3,529
	Baseline Natural Gas Usage (Therms)	-	
	Proposed Natural Gas Usage (Therms)	-	
	Natural Gas Savings (Therms)	-	
	Natural Gas Savings ($)	-	
	Annual Energy Cost Savings	$	3,529
Measure Cost & Simple Payback	Project Cost	$	72,976
	Simple Payback (Cost/Savings)		20.7

EEM 4 Programmable Thermostats

EXISTING CONDITIONS

There are 15 electric wall heaters manually controlled.

PROPOSED MEASURE DESCRIPTION

Install programmable thermostats to create setpoints and manual override for temperature control.

SAVINGS METHODOLOGY

Savings based on spreadsheet calculations.

Elec Heater Use (kWh) = kW x hrs ON

Currently the electric unit heaters do not have programmable thermostats and are manually controlled. Providing programmable thermostats will reduce the amount of time the spaces are heated when the spaces are unoccupied. ON time is estimated to be reduced by 100 hours per year per unit heater.

15 Electric Unit Heaters

5 kW per heater

Overheating hours = 100 hr /unit heater

5 kW x 15 x 100 hrs = 7500 kWh overheating energy use per year.

ESTIMATED COST

At $150 per thermostat the following costs were estimated.

EEM #4 Estimated Savings			
	Electric Savings (kWh)		7500
	Electric Cost Savings ($)	$	759
	Baseline Natural Gas Usage (Therms)		0
	Proposed Natural Gas Usage (Therms)		0
	Natural Gas Savings (Therms)		0
	Natural Gas Savings ($)	$	-
	Annual Energy Cost Savings	$	759
Measure Cost & Simple Payback	Project Cost	$	2,250
	Simple Payback (Cost/Savings)		3.0

EEM 5: Motor Upgrade

EXISTING CONDITIONS

There are currently 3 85% efficiency 3 hp motors.

PROPOSED MEASURE DESCRIPTION

Replace with 91.7% efficiency motors.

SAVINGS METHODOLOGY

Savings based on spreadsheet calculations.

EEM #5			Calculations			
Premium Efficiency Motors						
			Power (kW) = HP x .746 kW/HP x Load/efficiency			
Elec Cost =	$ 0.101		Hrs =	1200	hrs run time per year	
			Load =	75%		
Existing Conditions			efficiency =	84%	existing	
3 Qty 3 HP Motors 84% eff			efficiency =	91.70%	Premuim	
Energy Use Existing =	7194	kWh	Energy Use = Power (kW) x hrs			
			Material Cost =	$ 100	per motor	
Proposed Conditions						
3 Qty 3 HP Motors 91.7% eff	6590	kWh				

ESTIMATED COST

For 1200 operation hours per year and $250 per motor the following savings were estimated.

EEM #5 Estimated Savings			
Annual Energy Usage & Savings Estimate	Baseline Electric Usage (kWh)		7194
	Proposed Electric Usage (kWh)		6590
	Electric Savings (kWh)		604
	Electric Cost Savings ($)	$	61
	Baseline Natural Gas Usage (Therms)	-	
	Proposed Natural Gas Usage (Therms)	-	
	Natural Gas Savings (Therms)	-	
	Natural Gas Savings ($)	-	
	Annual Energy Cost Savings	$	61
Measure Cost & Simple Payback	Project Cost	$	300
	Simple Payback (Cost/Savings)		4.9

.

Appendix

I. Light Fixture Photos

Figure A: Existing Fixture A

Figure B: Existing Fixture C

Figure C: Existing Fixture E

Figure D: Existing Fixture F

Figure E: Existing Fixture H

Fixture F: Existing Fixture I

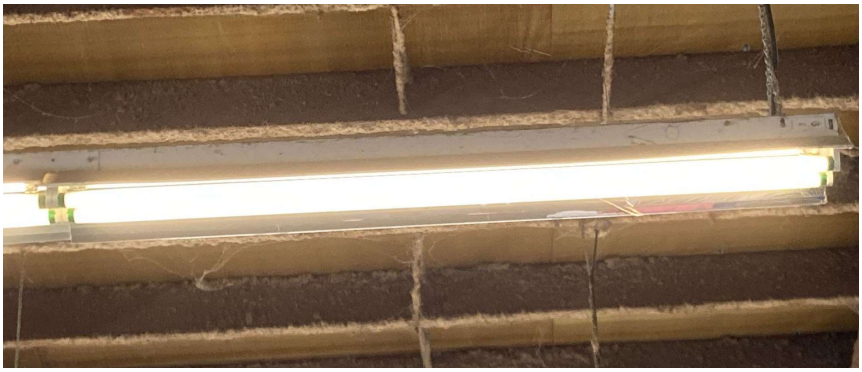


Figure G: Existing Fixture J

Figure H: Existing Fixture K

Figure I: Existing Fixture L

Figure J: Existing Fixture M

Figure K: Existing Fixture N

Figure L: Existing Fixture O

II. Mechanical Photos

Figure M: Typical Wall Mounted Electric Heater

Figure N: Motor

Figure O: Motor Tag 1

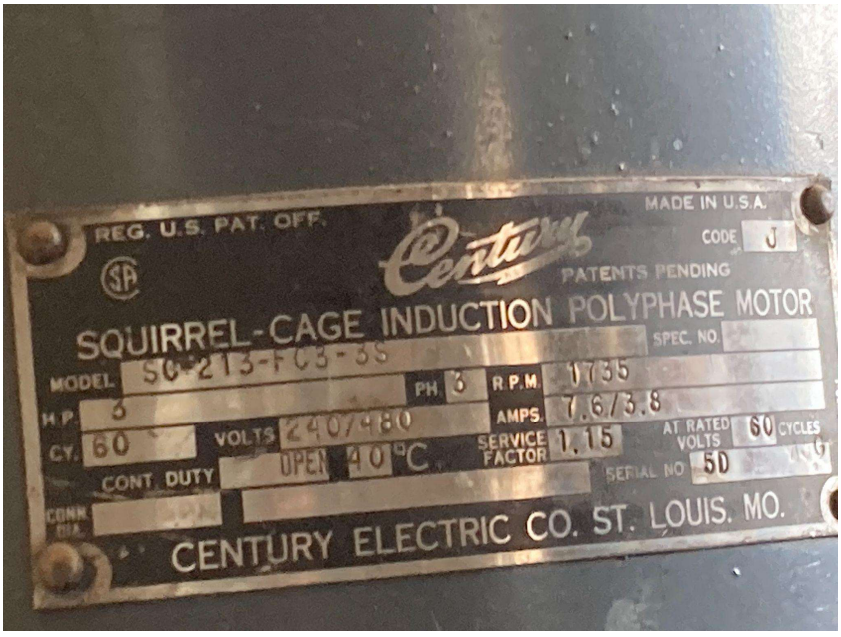


Figure P: Motor Tag 2

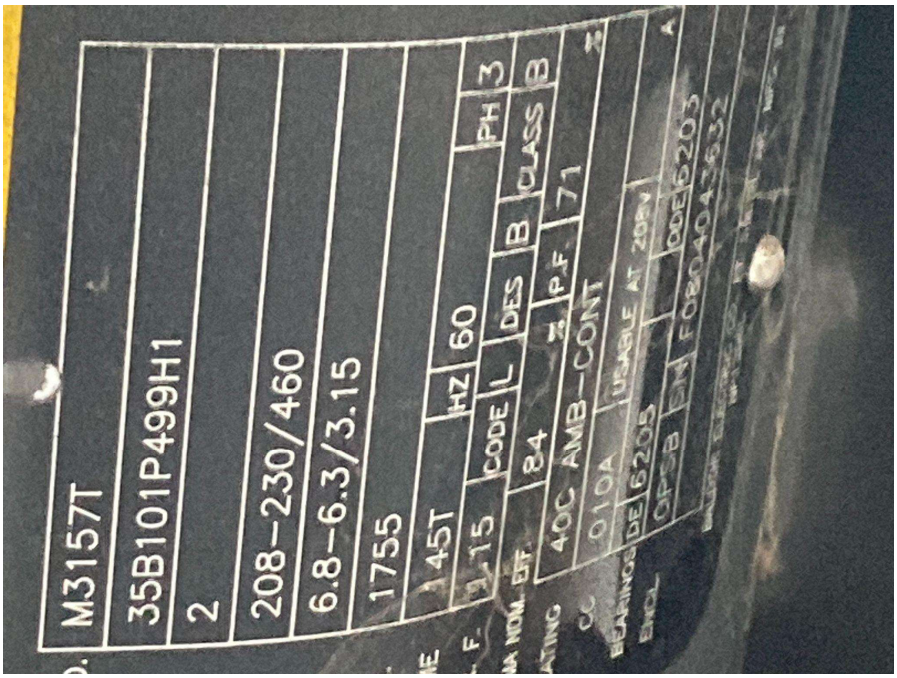


Figure Q: Motor Tag 3

Figure R: Outdoor Condensing Unit

Figure S: Indoor Evaporator of Walk-In Cooler

Figure T: Reznor Gas Fired Dryer

Figure U: Gas Fired Unit Heater

Figure V: Typical Domestic Water Heater