TECHNICAL ANALYSIS STUDY

JEFFERSON COUNTY SCHOOL DISTRICT
MADRAS PERFOMING ARTS CENTER
412 SE BUFF ST
MADRAS, OR 97741

PROJECT: ETECPS1542521947

SPONSORED BY:

ENERGY TRUST OF OREGON
EXISTING BUILDINGS

ELECTRIC UTILITY: PACIFIC POWER
GAS UTILITY: CASCADE NATURAL GAS

SUBMITTED BY:
R&W ENGINEERING, INC.

1/31/20
VERSION # 3

CONTACTS

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In no event will Energy Trust of Oregon, Inc. or ATAC be liable for (i) the failure of the customer to achieve the estimated energy savings or any other estimated benefits included herein, or (ii) for any damages to customer's site, including but not limited to any incidental or consequential damages of any kind, in connection with this report or the installation of any identified energy efficiency measures. The intent of this energy analysis study is to estimate energy savings associated with 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 participant in order to implement potential measures reviewed as part of this energy analysis. While the recommendations in this report have been reviewed for technical accuracy and are believed to be reasonably accurate, all findings listed are estimates only, as actual savings and incentives may vary based on final installed measures and costs, actual operating hours, energy rates and usage.

NEXT STEPS FOR THE PARTICIPANT

APPLY FOR ENERGY TRUST INCENTIVES

Make an implementation decision: *Please evaluate the information contained in this report and any potential measures and incentives listed in the Form 110C – Project Detail and Incentive Estimates (produced by ICF). Have your contractors bid for the measures(s) you wish to implement and send ICF a copy of the final bid. ICF will review your contractor's proposed scope to determine compliance with Existing Building's requirements and the energy efficiency measures as described in this report. After it is determined by ICF that the project bid specification match the studied measures, Form 120C-Incentive Application will be provided for you to review. If you apply for Energy Trust incentives for you project, your signed Form 120C – Incentive Application must be provided to ICF BEFORE you issue purchase orders or make other financial commitments to begin the project work.*

Upon Completion of the Project: *ICF must be notified once the project is completed in order to arrange a post-installation verification for projects that receive incentives greater than $5,000. The program must receive all required documentation and perform any required post installation verifications before incentives can be issued.*

APPLY FOR ENERGY TRUST SOLAR INCENTIVES

Make a solar implementation decision: *Please evaluate the solar site evaluation (SSE), if included in this report. Your PMC will arrange a meeting to discuss the results of the evaluation. Or, if you wish to move forward, your PMC will provide you with a list of qualified Trade Ally contractors. Obtain bids on the solar measures you want to implement. When you've selected a solar Trade Ally contractor for the installation, the Trade Ally will provide and submit the necessary incentive application paperwork to Energy Trust on your behalf. The PMC and Energy Trust's solar staff are available to answer all your solar questions.*

Upon Completion of the Solar Project: *The solar Trade Ally will arrange for the final Energy Trust verifications, and within 30 days of a successful verification you'll receive your solar incentive check from Energy Trust.*

EXECUTIVE SUMMARY

This report documents energy efficiency improvements for the HVAC systems at the Jefferson County School District Performing Arts Center at 412 Buff Street, Madras, OR 97741. The facility was built in 2014, is two stories above ground and contains a total floor area of 34,010 square feet. The energy efficiency measure (EEM) affects the entire building. Using data from 2016 through 2018, the average annual energy use for the building was 5,159 therms and 395,400 kWh. This translates to an Energy Use Index of 54.8 $kBtu/ft^2$/year. The EUI for this building is 44% higher than the average energy use per square foot for a building of this type. Table 1 below lists the energy efficiency recommendations for the facility. Combined, these recommendations are expected to reduce the building's gas usage by 32% and reduce the electricity consumption by 26%.

ENERGY EFFICIENCY MEASURE SUMMARY

1. **EEM 1: Retro-Commissioning:** Propose energy efficient changes to existing HVAC control system.

TABLE 1: EEM SUMMARY TABLE (ANNUAL)

Utility Rate Summary				
Electricity $/KW/Mo	Electricity $/kWh	Nat. Gas $/therm	Other Fuel $/Unit	Other Fuel $/MBtu
	$ 0.084	$0.63		

		Energy Savings Summary							Cost Savings Summary									
		Peak Demand Savings Electric	Energy Savings Electric	Energy Savings Natural Gas	Energy Savings All Other Fuel	Energy Savings Total	Savings % of Total Baseline Energy	EUI Change Per EEM (negative indicates savings)	Cost Savings Electricity	Cost Savings Natural Gas	Cost Savings All Other Fuels	Cost Savings Total	Measure Cost **	Simple Payback ***	ROI ****	Measure Life	CX Required *****
EEM #	EEM Description	KW	kWh/Yr	therms/ Yr	MBtu/ Yr	MBtu/Yr	%	kBtu/SF/Yr	$/Yr	$/Yr	$/Yr	$/Yr	$	Yrs	1/Yrs	Yrs	Yes/No
1	Controls Retro-Commissioning	0	101,072	1,625	0	507,358	27.2%	-14.9	$8,520	$1,024	$0	$9,544	$34,010	*3.6*	*0.3*	5	No
	TOTAL EEM Energy Savings	0	101,072	1,625	0	507,358	27.2%	-14.9	$8,520	$1,024	$0	$9,544	$34,010	*3.6*	*0.3*		

	Peak Demand	Electric	Natural Gas	All Other	Energy Total	% of Baseline	EUI	Cost Electricity	Cost Natural	Cost All Other	Cost Total
	KW	kWh/Yr	therms/ Yr	MBtu/ Yr	MBtu/Yr	%	kBtu/SF/Yr	$/Yr	$/Yr	$/Yr	$/Yr
TOTAL Baseline Energy Usage		395,400	5,159		1,864,971	100.0%	54.8	33,332	3,250		36,582
TOTAL Proposed Energy Usage		294,328	3,534		1,357,614	72.8%	39.9	24,812	2,226		27,038

NOTES:

* Cost savings are based on the blended rate of the customer's actual utility provider. The blended rate for each utility is as follows:

Electric: Pacific Power $0.0843

Natural Gas: Cascade $0.63

** Total retro-commissioning cost assumed to be $\$1/ft^2$ based on conservative estimates from the US Department of Energy (See EEM #1 Cost Estimates Pages 18-19).

*** Simple Payback is a measure of how quickly your investment in the measure will pay for itself and does not include any potential incentive and/or non-energy benefits.

**** Simple ROI is another measure of measure's benefits. This is simply the inverse of the Simple Payback and can be used as a rough comparison to other investment opportunities

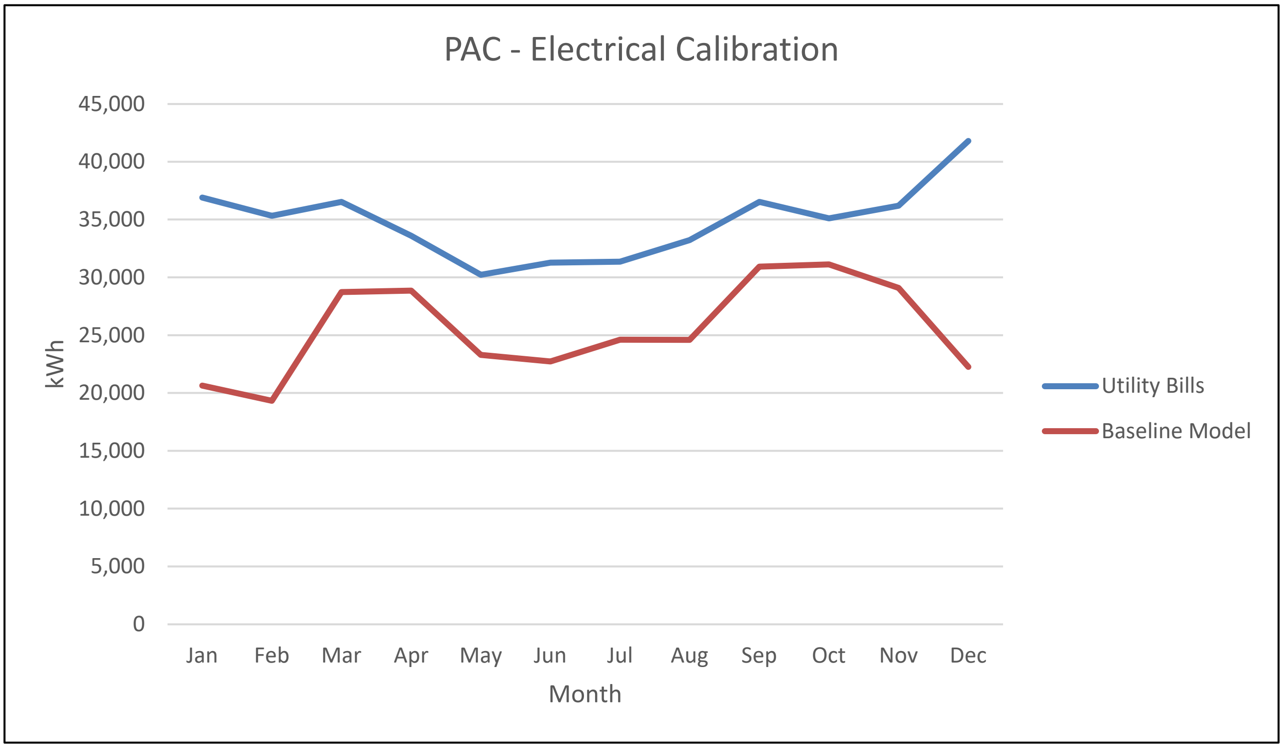
***** EEM 1 is a retro-commissioning measure and does not require additional commissioning

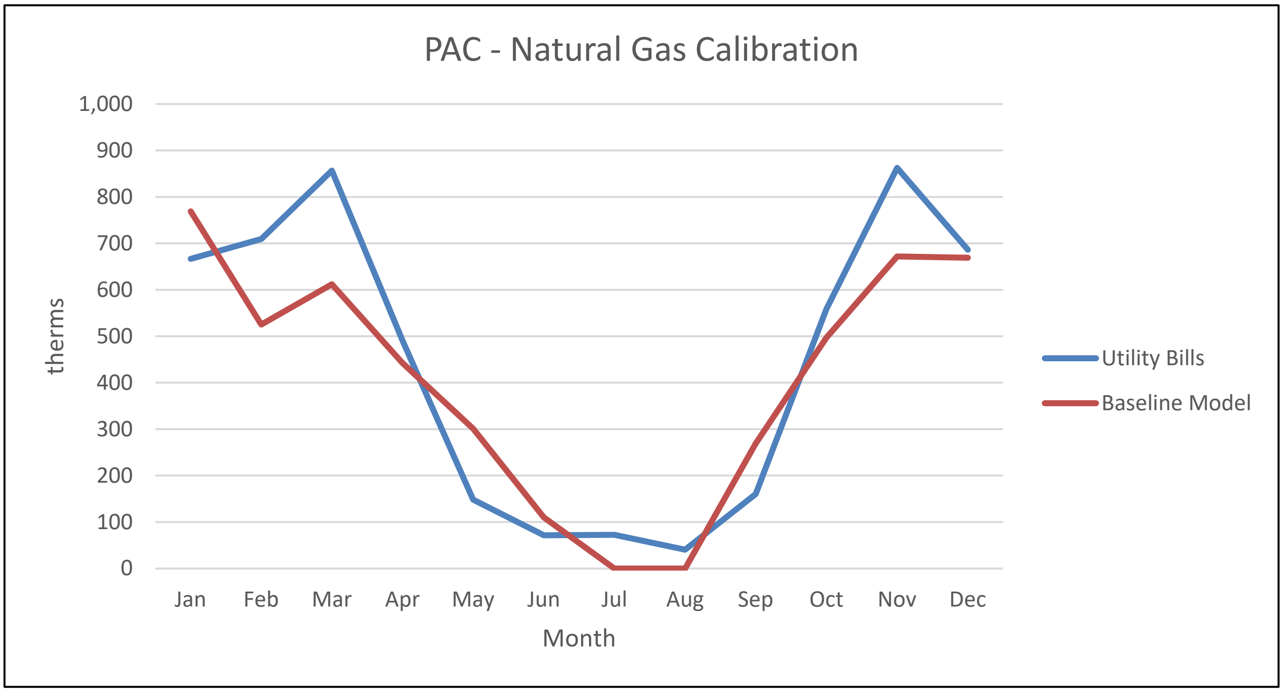
HISTORICAL ENERGY USE

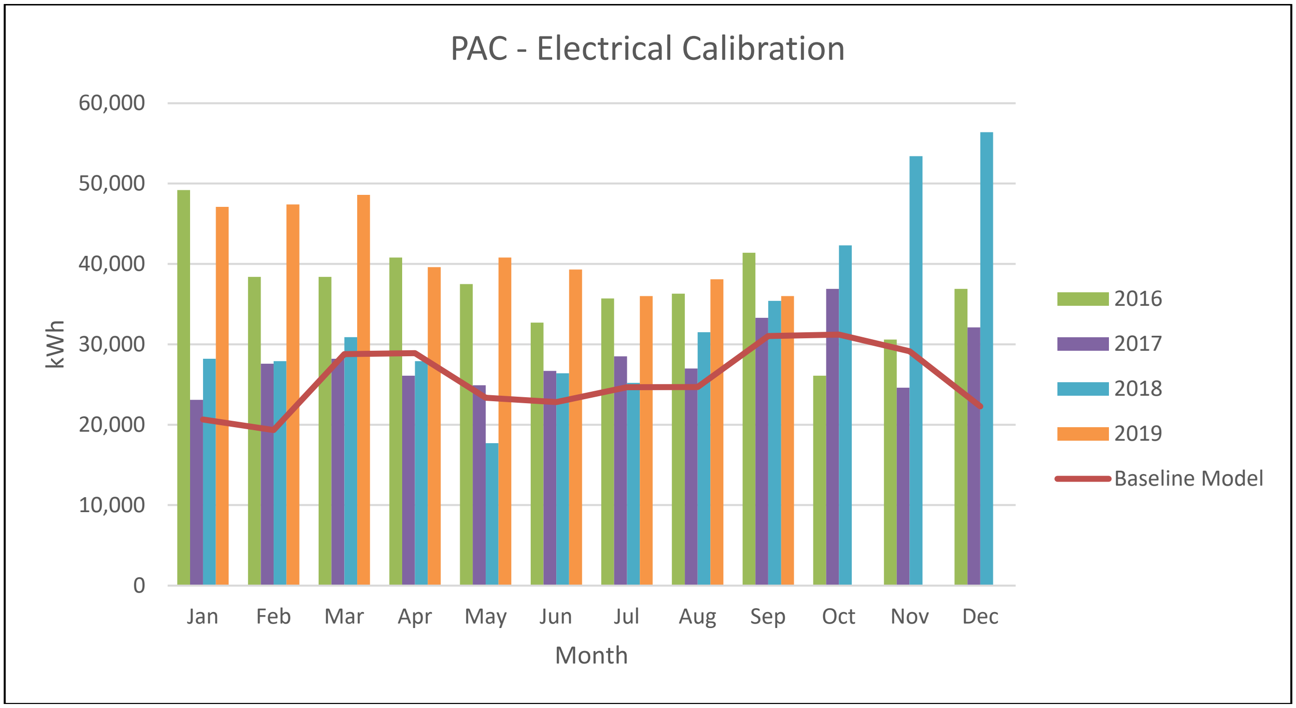
TABLE 2: HISTORICAL BUILDING ENERGY USE

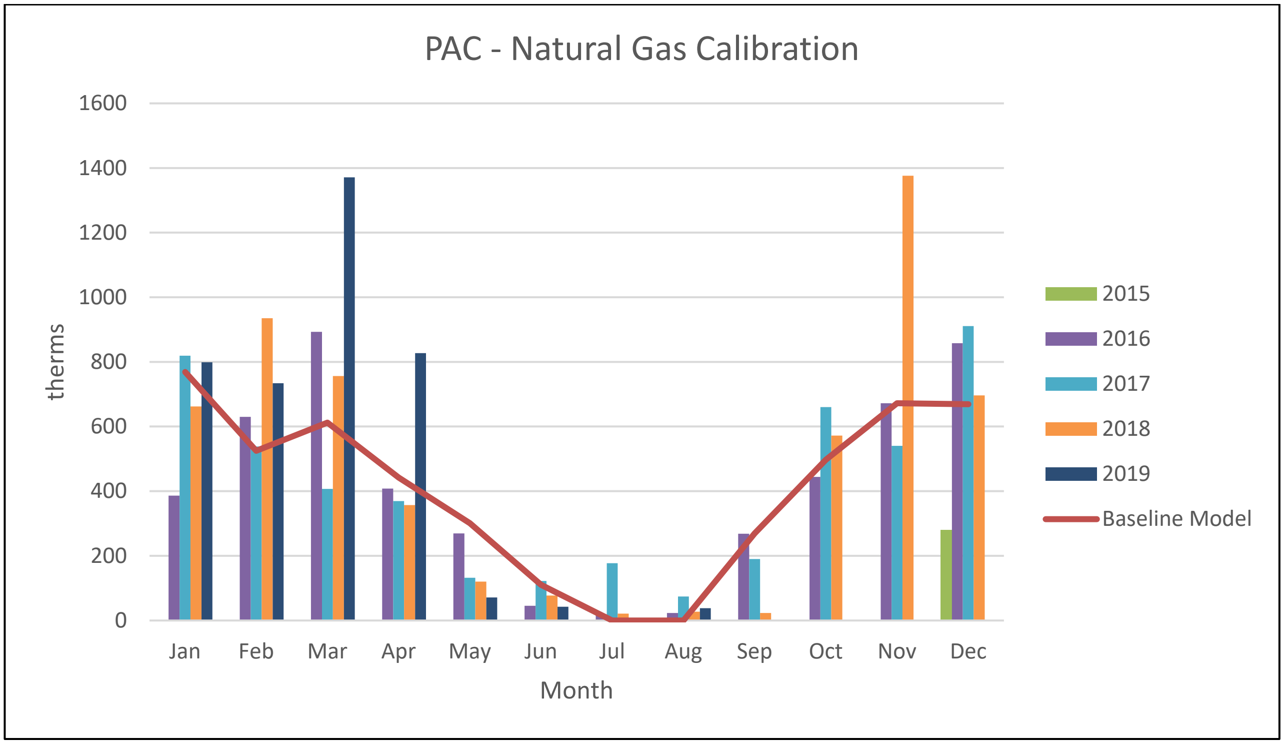
Beginning Year: 2016	End Year: 2019							
	Electricity			Fossil - Nat Gas			Total	
Month/Year*	Electricity Use (kWh)	Electricity Use (MBtu)	Electricity Cost ($)	Nat. Gas Use (therms)	Nat. Gas Use (MBtu)	Nat. Gas Cost ($)	Total Energy Use (MBtu)	Total Energy Cost ($)
01/2016	49,200	167,870	$4,148	386	38,600	$243	206,470	$4,391
02/2016	38,400	131,021	$3,237	630	63,000	$397	194,021	$3,634
03/2016	38,400	131,021	$3,237	893	89,300	$563	220,321	$3,800
04/2016	40,800	139,210	$3,439	408	40,800	$257	180,010	$3,696
05/2016	37,500	127,950	$3,161	269	26,900	$169	154,850	$3,331
06/2016	32,700	111,572	$2,757	45	4,500	$28	116,072	$2,785
07/2016	35,700	121,808	$3,010	19	1,900	$12	123,708	$3,021
08/2016	36,300	123,856	$3,060	23	2,300	$14	126,156	$3,075
09/2016	41,400	141,257	$3,490	268	26,800	$169	168,057	$3,659
10/2016	26,100	89,053	$2,200	444	44,400	$280	133,453	$2,480
11/2016	30,600	104,407	$2,580	672	67,200	$423	171,607	$3,003
12/2016	36,900	125,903	$3,111	858	85,800	$541	211,703	$3,651
1st Year Totals	**444,000**	**1,514,928**	**$37,429**	**$4,915**	**$491,500**	**$3,096**	**2,006,428**	**$40,526**
01/2017	23,100	78,817	$1,947	819	81,900	$516	160,717	$2,463
02/2017	27,600	94,171	$2,327	538	53,800	$339	147,971	$2,666
03/2017	28,200	96,218	$2,377	407	40,700	$256	136,918	$2,634
04/2017	26,100	89,053	$2,200	369	36,900	$232	125,953	$2,433
05/2017	24,900	84,959	$2,099	132	13,200	$83	98,159	$2,182
06/2017	26,700	91,100	$2,251	122	12,200	$77	103,300	$2,328
07/2017	28,500	97,242	$2,403	177	17,700	$112	114,942	$2,514
08/2017	27,000	92,124	$2,276	74	7,400	$47	99,524	$2,323
09/2017	33,300	113,620	$2,807	190	19,000	$120	132,620	$2,927
10/2017	36,900	125,903	$3,111	660	66,000	$416	191,903	$3,526
11/2017	24,600	83,935	$2,074	540	54,000	$340	137,935	$2,414
12/2017	32,100	109,525	$2,706	911	91,100	$574	200,625	$3,280
2nd Year Totals	**339,000**	**1,156,668**	**28,578**	**4,939**	**493,900**	**3,112**	**1,650,568**	**$31,689**
2-Year Average (Baseline Energy Usage)	**391,500**	**1,335,798**	**$33,003.45**	**4,927**	**492,700**	**$3,104.01**	**1,828,498**	**$36,107**
01/2018	28,200	96,218	$2,377	662	66,200	$417	162,418	$2,794
02/2018	27,900	95,195	$2,352	935	93,500	$589	188,695	$2,941
03/2018	30,900	105,431	$2,605	756	75,600	$476	181,031	$3,081
04/2018	27,900	95,195	$2,352	357	35,700	$225	130,895	$2,577
05/2018	17,700	60,392	$1,492	120	12,000	$76	72,392	$1,568
06/2018	26,400	90,077	$2,226	77	7,700	$49	97,777	$2,274
07/2018	25,200	85,982	$2,124	21	2,100	$13	88,082	$2,138
08/2018	31,500	107,478	$2,655	27	2,700	$17	110,178	$2,672
09/2018	35,400	120,785	$2,984	23	2,300	$14	123,085	$2,999
10/2018	42,300	144,328	$3,566	572	57,200	$360	201,528	$3,926
11/2018	53,400	182,201	$4,502	1,376	137,600	$867	319,801	$5,369
12/2018	56,400	192,437	$4,755	696	69,600	$438	262,037	$5,193
3rd Year Totals	**403,200**	**1,375,718**	**33,990**	**5,622**	**562,200**	**3,542**	**1,937,918**	**$37,532**
3-Year Average (Baseline Energy Usage)	**395,400**	**1,349,105**	**33,332**	**5,159**	**515,867**	**3,250**	**1,864,971**	**$36,582**
01/2019	47,100	160,705	$3,971	799	79,900	$503	240,605	$4,474
02/2019	47,400	161,729	$3,996	734	73,400	$462	235,129	$4,458
03/2019	48,600	165,823	$4,097	1,371	137,100	$864	302,923	$4,961
04/2019	39,600	135,115	$3,338	827	82,700	$521	217,815	$3,859
05/2019	40,800	139,210	$3,439	71	7,100	$45	146,310	$3,484
06/2019	39,300	134,092	$3,313	42	4,200	$26	138,292	$3,339
07/2019	36,000	122,832	$3,035				122,832	$3,035
08/2019	38,100	129,997	$3,212	38	3,800	$24	133,797	$3,236
09/2019	36,000	122,832	$3,035				122,832	$3,035
10/2019								
11/2019								
12/2019								
4th Year Totals	**372,900**	**1,272,335**	**31,435**	**3,882**	**388,200**	**2,446**	**1,660,535**	**$33,881**
4-Year Average (Baseline Energy Usage)	**389,775**	**1,329,912**	**32,858**	**4,840**	**483,950**	**3,049**	**1,813,862**	**$35,907**

ENERGY CONSUMPTION GRAPHS






PAC - Electrical Calibration
60,000
50,000
40,000
30,000
20,000
10,000
0
kWh
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2016
2017
2018
2019
Baseline Model


PAC - Natural Gas Calibration
1600
1400
1200
1000
800
600
400
200
0
therms
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2015
2016
2017
2018
2019
Baseline Model

ENERGY CONSUMPTION TABLE

	Electric Use (kWh)			Natural Gas Use (Therm)		
	Baseline	Model	% Deviation	Baseline	Model	% Deviation
Jan	36,900	20,660	-44.0%	667	769	15.4%
Feb	35,325	19,353	-45.2%	709	525	-26.0%
Mar	36,525	28,779	-21.2%	857	612	-28.6%
Apr	33,600	28,911	-14.0%	490	442	-9.8%
May	30,225	23,358	-22.7%	148	301	103.4%
Jun	31,275	22,814	-27.1%	72	110	53.8%
Jul	31,350	24,677	-21.3%	72	0	-100.0%
Aug	33,225	24,680	-25.7%	41	0	-100.0%
Sep	36,525	31,024	-15.1%	160	269	67.8%
Oct	35,100	31,213	-11.1%	559	497	-11.0%
Nov	36,200	29,151	-19.5%	863	672	-22.1%
Dec	41,800	22,272	-46.7%	686	669	-2.5%
Total	418,050	306,892	-26.6%	5,323	4,866	-8.6%

CONSUMPTION GRAPH NARRATIVE

The baseline model should be considered accurate. The HVAC loads (including fans and plants) and interior lighting loads are included in the model. The difference in the utility bills and the model is due to non-modeled energy usage and month-by-month variations in the building HVAC scheduling. The electrical non-modeled energy uses include plug loads, exterior lighting, kitchen equipment, and electric wall heaters. The gas non-modeled energy uses include domestic hot water, gas unit heaters, and kitchen equipment. The HVAC scheduling is changed every week to match building occupancy, so there are large variations between months each year.

BUILDING OCCUPANCY

Typical Daily Occupancy					
Indicate Building/Area	**Hours/Day**	**Days/Week**	**Weeks/Year**	**Annual Hrs**	**% of Bldg Used**
Locker Rooms	12	7	20	1680	17%
Restrooms	18	7	20	2520	4%
Theatre/Stage	14	7	20	1960	47%
Admin	18	7	20	2520	4%
Corridor	18	7	20	2520	23%
Multipurpose	18	7	20	2520	5%
Is building ever partially occupied?			**No**		
Indicate Use	**Additional Hours/Day**	**Days/Week**	**Weeks/Year**	**Annual Hrs**	**% of Bldg Used**
Locker Rooms					
Restrooms					
Theatre/Stage					
Admin					
Corridor					
Multipurpose					

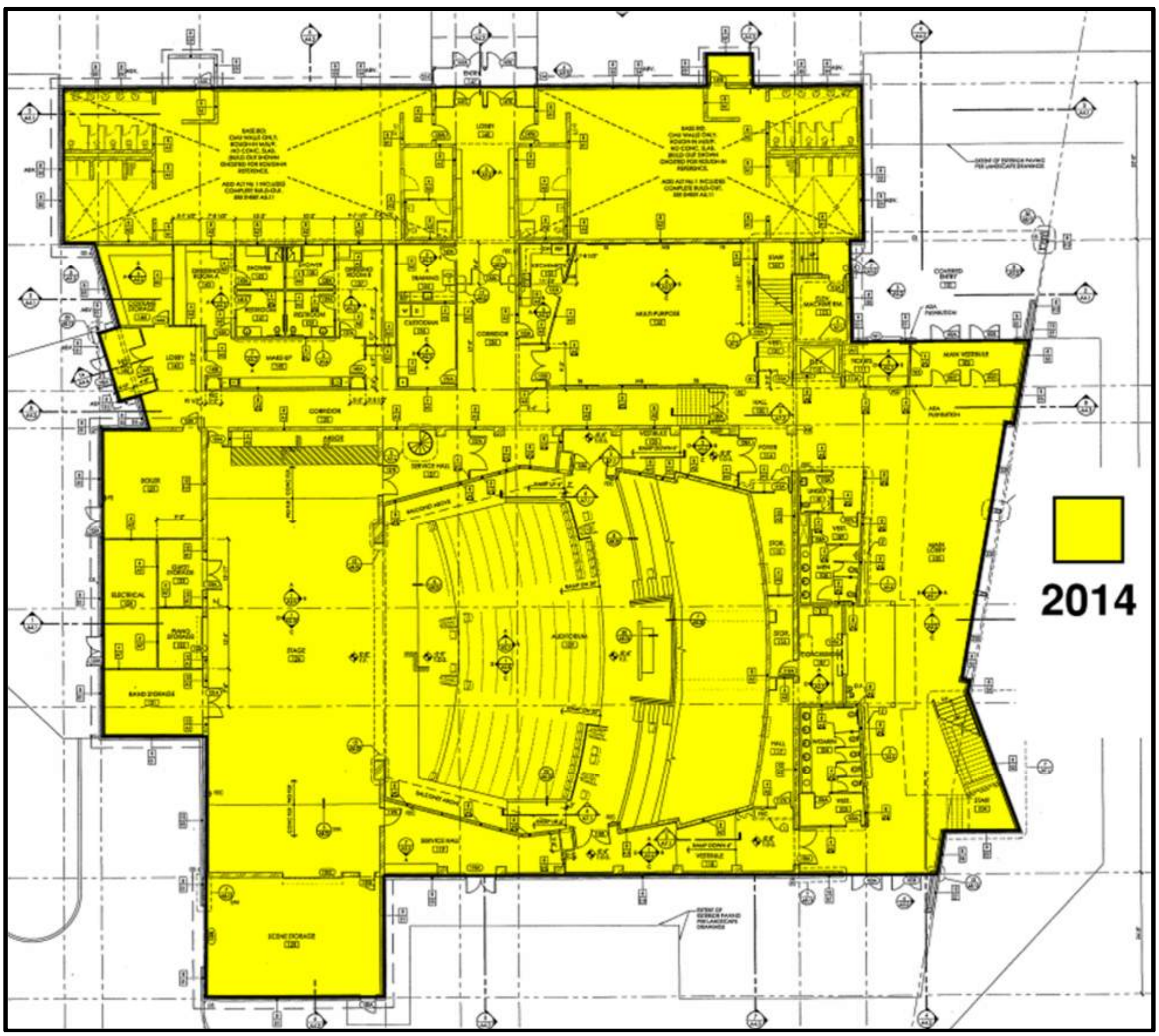
BUILDING OCCUPANCY NARRATIVE

The table above represents typical building occupancy. The building is used regularly during the school year and during seasonal sports periods (September through November, March through April). The building has events less frequently during the non-busy seasons (December through February, May through August).

FACILITY OVERVIEW

The Performing Arts Center (PAC) is located at 412 NE Buff Street in Madras, OR. The PAC was originally constructed in 2014. The building is two story with a floor area of 34,010 square feet which consists of locker rooms, restrooms, and a theatre which seats around 600 people. Various staff and students from the high school as well as the community use the building, however use is infrequent based on what is scheduled during the week. Students, parents, and the community district wide will attend periodically for holiday concerts and plays. Interior lighting mainly consists of LED lights which are controlled by switches and occupancy sensors. Exterior lighting is LED and is on a schedule. The HVAC system is comprised of two air handling units (AHUs), one rooftop unit (RTU) with heat recovery, 12 variable air volume (VAV) boxes, and two heating coils (HCs). The HVAC system is controlled by a web based direct digital control (DDC) system. The domestic hot water system consists of multiple water heaters. Heating is provided by two boilers (condensing, non-condensing) with the non-condensing boiler used for backup. The HVAC units all have DX cooling except for RTU-1. See below for additional details on the building's energy using systems. Table 2 above shows the utility use over the past four years.

Era Map



Building Envelope

The exterior walls of the building are composed of CMU veneer, air space, wall sheathing, and wall framing with batt insulation of various thicknesses. Some walls use a thicker CMU wall with rigid insulation. (*U – 0.064). The roof is composed of metal roof decking with rigid insulation. (*U – 0.048). Windows are tinted, double pane with aluminum frames (*U – 0.45, SC – 0.40). The windows were observed to not be sealed well. There is no exterior shading from outside vegetation. The building has a number of glass doors located at the main entry ways and metal doors around the exterior. Most of the glass doors have tinted, double pane windows.

*U-Values assumed to be code maximum from 2014 Oregon Energy Efficiency Specialty Code.

Main Entrance

Southeast Wall

East Entrance

Football Field-Side Entrance

WATERSIDE HVAC SYSTEM

The waterside heating system was installed in 2014 and is comprised of two natural gas fired boilers (B-1 is condensing, B-2 is non-condensing). The primary condensing boiler (B-1) manufactured by Advanced Thermal Hydronics has an input of 2,000-MBH and an AHRI efficiency rating of 90%. The secondary non-condensing boiler (B-2) manufactured by RBI has an input rating of 2,300-MBH and an efficiency of 82%. The secondary boiler is used as a backup. The distribution heating water loop consists of two 3-HP lead lag distribution pumps serving the VAV boxes and AHUs, one 1-HP booster pump serving the secondary boiler, and one fractional HP booster pump serving AHU-2. All pumps are constant speed and have NEMA premium efficiency ratings.

There is no waterside cooling plant at this building.

The domestic hot water system is provided by three Bradford White condensing, natural gas fired water heaters, each with an input of 199.9-MBH and a thermal efficiency of 98.5%.

AIR SIDE HVAC SYSTEM

The airside heating system was installed in 2014 and is comprised of two AHUs (AHU-1 & AHU-2), one RTU with heat recovery (RTU-1), 12 VAV boxes with hot water reheat coils (VAV1-1 - 10, VAV2-1 - 2), and two hot water heating coils (HC-1 & HC-2). AHU-1 is a variable air volume (VAV) system that provides 19,550-CFM of air which serves all VAV boxes at full capacity. AHU-2 is a single-zone VAV system that provides 14,500-CFM of air which serves the auditorium. AHU-1 & AHU-2 each have variable frequency drives (VFDs) on the supply and return fans and one DX cooling coil. AHU-1 has a cooling capacity of 46.1-tons with an EER of 11.4. AHU-2 has a cooling capacity of 34.2-tons with an EER of 11.4. AHU-2 has one hydronic heating coil. RTU-1 is a heat recovery unit that provides 4,000-CFM of air which serves the two heating coil units that are in the boys and girls locker rooms. RTU-1 has VFDs on the supply and exhaust fans and an electric heat strip that preheats the outside air before passing through the enthalpy wheel. RTU-1 also has a bypass damper which will recirculate the return air from the locker rooms during off seasonal times when the lockers aren't in excessive use.

CONTROLS

HVAC is controlled by a web based DDC system. Typical heating/cooling setpoints are 70°F/74°F. Night setback is 55°F/80°F (60°F/80°F for RTU-1). The HVAC schedules are set at the beginning of each week and fluctuate depending on theatre performances, community events, and other activities that are planned. The HRU that serves the lockers is typically set to run 24/7 during seasonal sports periods (September through November, March through April). Exhaust fans are controlled by the schedule of the associated AHU.

All units have economizer cooling enabled based on outside temperature. The economizer high/low limit setpoints are typically 50°F/70°F. RTU-1 (lockers) economizer high/low limits are at 34°F/70°F. The minimum OSA damper position is at 0% but is observed to have some leakage (estimated around 5%).

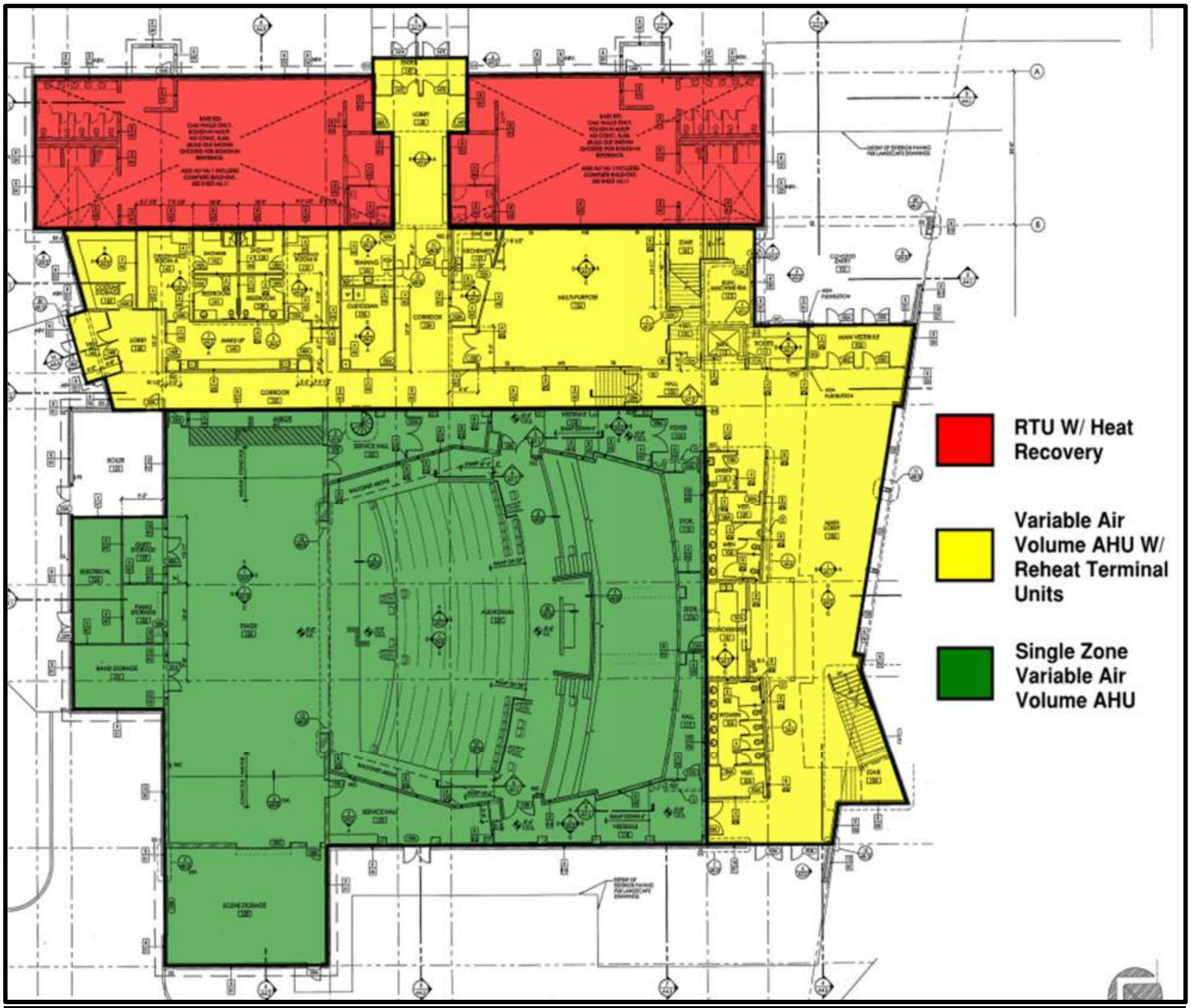
RTU-1 was shown to not be operating correctly based on the control screens and on-site observations. The control screens showed the OSA, EA, and bypass dampers to alternate being open and closed, while on site the OSA damper and bypass dampers were closed. The supply fan was shown to be running at 163.8%, while on site the fan was not operating. The heat recovery wheel was on. The supply fan cannot run efficiently when the OSA and bypass dampers are both closed. Facility staff unsure as to how long RTU-1 has been running this way. Typical operation assumed to be working (supply fan and bypass damper operational).

B-1 operates as the primary boiler while B-2 operates as the secondary boiler. The boilers are locked out when the OSA temperature is greater than 65°F. The hot water pumps are scheduled to be on from 6 am - 6 pm daily.

It was observed on-site that the control screens did not communicate well with the sensors. Multiple sensors showed inconsistent/incorrect data or were not communicating alarms when they should. The following controls issues were noted:

- RTU-1 is not operating correctly.
    - RTU-1 is in occupied mode 24/7 during seasonal sports periods.
    - Night setback is not operational on RTU-1 during seasonal sports periods.
    - Morning warm up is not operational on RTU-1.
- Economizer control logic operates based on OSA temperature only.
- Supply air reset and discharge air temperature controls not working properly.
- DCV is not enabled for AHU-1 and AHU-2.
- AHUs 1-2 & RTU-1 do not bring in code minimum OSA.
- OSA dampers have an estimated 5% leakage.
- AHU-2 supply and return fans run at a constant speed.
- Temperature deadband is less than 5°F minimum.
- Control screen does not show heating coil valve position or hot water pump start/stop for AHU-1 as indicated in mechanical drawings.
- Temperature sensors appear to not be calibrated based on inconsistent values on control screens.
- Damper/fan status alternates between closed/open on control screens.
- Alarms on control screens do not activate when problems occur.

HVAC ZONE MAP



INTERNAL LOADS

Interior lighting consists of LED lights which are controlled by switches and occupancy sensors. The interior heating load from the lights is 0.8 W/ft^2. Lights that are controlled by switches are turned off by 10 PM. Exterior lighting is LED and on a schedule for night use.

DETAILED DESCRIPTION OF PROPOSED MEASURES

EEM 1 – Controls Retro-Commissioning

BASELINE CONDITION

HVAC is controlled by a web based DDC system. Typical heating/cooling setpoints are 70°F/74°F. Night setback is 55°F/80°F (60°F/80°F for RTU-1). The HVAC schedules are set at the beginning of each week and fluctuate depending on theatre performances, community events, and other activities that are planned. The HRU that serves the lockers is typically set to run 24/7 during seasonal sports periods (September through November, March through April). Exhaust fans are controlled by the schedule of the associated AHU.

All units have economizer cooling enabled based on outside temperature. The economizer high/low limit setpoints are typically 50°F/70°F. RTU-1 (lockers) economizer high/low limits are at 34°F/70°F. The minimum OSA damper position is at 0% but is observed to have some leakage (estimated around 5%).

RTU-1 was shown to not be operating correctly based on the control screens and on-site observations. The control screens showed the OSA, EA, and bypass dampers to alternate being open and closed, while on site the OSA damper and bypass dampers were closed. The supply fan was shown to be running at 163.8%, while on site the fan was not operating. The heat recovery wheel was on. The supply fan cannot run efficiently when the OSA and bypass dampers are both closed. Facility staff unsure as to how long RTU-1 has been running this way. Typical operation assumed to be working (supply fan and bypass damper operational).

B-1 operates as the primary boiler while B-2 operates as the secondary boiler. The boilers are locked out when the OSA temperature is greater than 65°F. The hot water pumps are scheduled to be on from 6 am - 6 pm daily.

It was observed on-site that the control screens did not communicate well with the sensors. Multiple sensors showed inconsistent/incorrect data or were not communicating alarms when they should. The following controls issues were noted:

- RTU-1 is not operating correctly.
    - RTU-1 is in occupied mode 24/7 during seasonal sports periods.
    - Night setback is not operational on RTU-1 during seasonal sports periods.
    - Morning warm up is not operational on RTU-1.
- Economizer control logic operates based on OSA temperature only.
- Supply air reset and discharge air temperature controls not working properly.
- DCV is not enabled for AHU-1 and AHU-2.
- AHUs 1-2 & RTU-1 do not bring in code minimum OSA.
- OSA dampers have an estimated 5% leakage.
- AHU-2 supply and return fans run at a constant speed.
- Temperature deadband is less than 5°F minimum.
- Control screen does not show heating coil valve position or hot water pump start/stop for AHU-1 as indicated in mechanical drawings.
- Temperature sensors appear to not be calibrated based on inconsistent values on control screens.
- Damper/fan status alternates between closed/open on control screens.
- Alarms on control screens do not activate when problems occur (Non-energy benefit).

PROPOSED CONDITION

R&W proposes making the following changes to the HVAC sequence of operations and control parameters:

- Reset RTU-1 sequence of operations.
  - Set RTU-1 to operate on an occupied and unoccupied schedule reflecting building occupancy.
  - Enable night setback for RTU-1 during seasonal sports periods.
  - Enable morning warm-up/cooldown for RTU-1. For morning warm-up, close OSA dampers & EA dampers to 0% open. Open bypass damper to 100% open and recirculate conditioned air. For cooldown, open OSA & EA dampers to 100% open and close bypass damper.
- Have economizer control OSA damper position based on:
  - Maintaining MA setpoint/demand for cooling
  - OSA temperature is less than RA temperature
- Enable supply air reset for AHU-1 based on worst case room.
- Enable DCV for AHU-1 & AHU-2 and control it based on CO_2 levels.
- Set OSA damper controls such that they allow code minimum OSA.
- Seal OSA dampers such that there is no leakage when closed.
- Set AHU-2 up as single-zone VAV system.
- Increase temperature deadband to at least 5°F (70°F/74°F to 69°F/74°F)
- Add heating coil valve position and hot water pump start/stop graphic for AHU-1.
- Recalibrate sensors such that they show consistent values on the control screens. Replace faulty sensors.
- Control screens accurately report conditions accurately and communicate alarms (non-energy benefit).

NON-ENERGY SAVINGS DESCRIPTION

None.

TABLE 3: SUMMARY OF EEM 1 VS. EXISTING CONDITION

	kWh Savings	Therm Savings
Estimated Energy Savings	101,072	1,625
Age of Equipment Being Replaced	NA	
Is Existing Equipment Currently Working or Not Working?	NA	
Cost	$34,010 Cost assumed to be $\$1/ft^2$ according to conservative estimates from US Department of Energy (See EEM #1 Cost Estimates Pages 19-20)	
Notes		

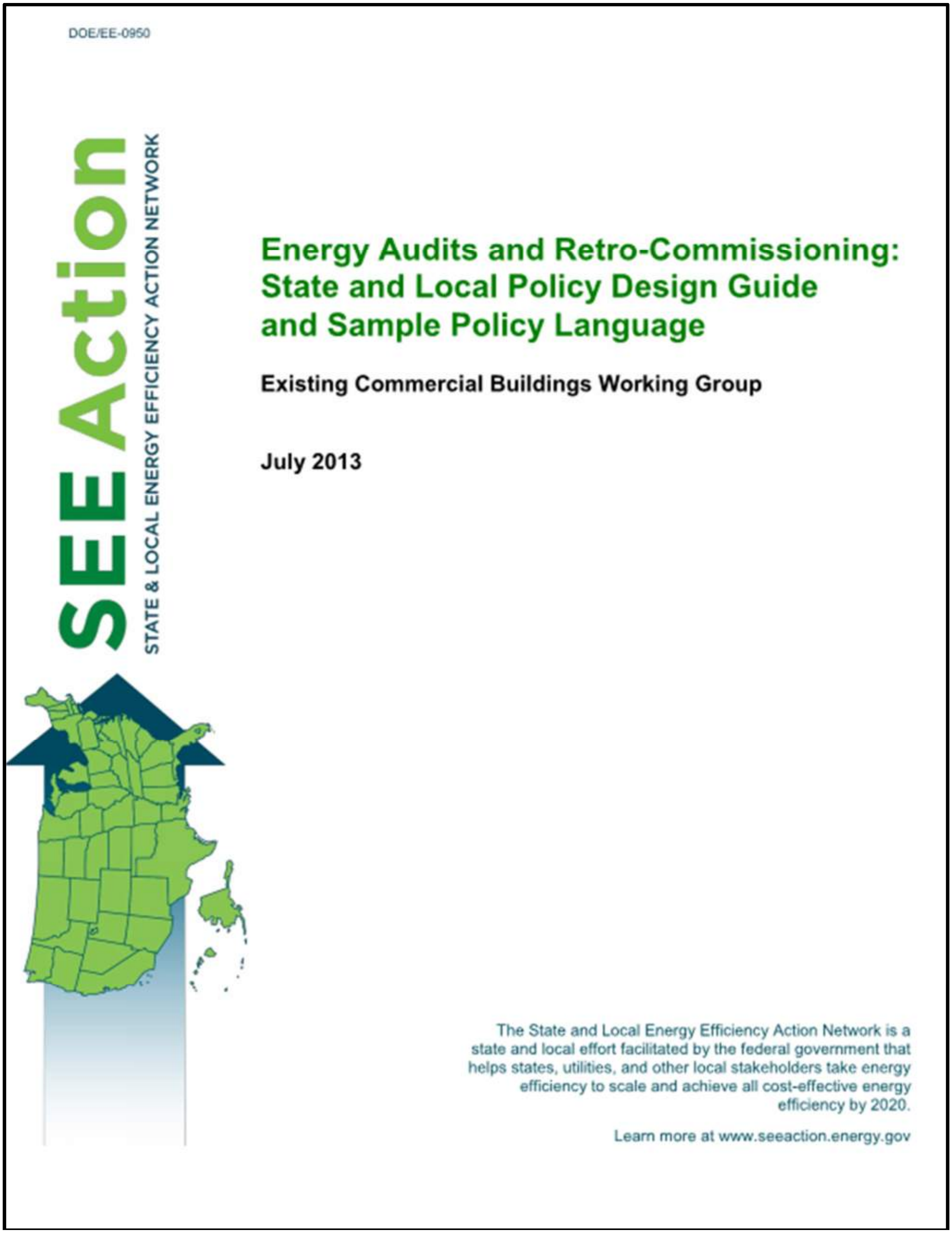
TABLE 4: EEM 1 CONDITIONS

Item	Baseline Condition	Proposed Condition
RTU-1 Scheduling	Running 24/7 during seasonal sports periods (September through November, March through April) *See Schedules>PAC Lockers*	RTU-1 to run on occupied/unoccupied schedule. Schedule to match people occupancy (typical schedule during less busy season assumed to be 8 am – 8 pm) *See Schedules>PAC Lockers EEM*
RTU-1 Night Setback	Night setback for RTU-1 is not operational during seasonal sports periods (September through November, March through April) *See Templates>Thermostat*	Night setback is operational during seasonal sports periods. *See Templates>Thermostat*
RTU-1 Morning Warm-up/Cooldown	Morning Warm-up for RTU-1 is not operational during seasonal sports periods (September through November, March through April) *See Create Systems>Options>Advanced*	Enable morning warm-up (close OSA dampers and open bypass dampers to 100%. Condition air with hot water coils. Turn exhaust fan off). Enable morning cooldown (open OSA dampers and close bypass dampers. Turn exhaust fan on) *See Create Systems>Options>Advanced*
Economizer Controls (AHUs 1-2 & RTU-1)	Economizer control logic not operating in an energy efficient way (assumed to be off). *See Create Systems>Options*	Enable economizer controls when there is a demand for cooling and OSA temperature is less than RA temperature. For RTUs & AHU, have economizer modulate OSA damper position. (Economizer turned on) *See Create Systems>Options*
Supply Air Reset (AHU-1)	Supply air reset not operating correctly. OSA dampers do not modulate to meet discharge air setpoint. Supply air reset off). *See Create Systems>Options>Advanced Options* *See Templates>Thermostat*	Enable supply air reset for AHU-1 based on worst case room. *See Create Systems>Options>Advanced Options* *See Templates>Thermostat*
DCV (AHUs 1-2)	DCV is not enabled. *See Templates>Airflows*	Enable DCV. *See Templates>Airflows*
Code Minimum OSA (AHUs 1-2 & RTU-1)	AHUs 1-2 & RTU-1 do not bring in code minimum OSA. (minimum position assumed 5%) *See Templates>Airflows*	Have minimum OSA damper position/airflow for AHUs 1-2 to be set by DCV controls. Have minimum OSA damper position/airflow for RTU-1 set to match code minimum ventilation requirements outlined in original 2014 mechanical equipment schedules. (AHUs 1-2 min position calculated by Trace DCV. RTU-1 min position at 100%). *See Templates>Airflows*
AHU-2 VAV System	AHU-2 supply and return fans run at a constant speed. *See Create Systems>Fans*	Vary AHU-2 supply and return fan speed based on deviation from room temperature setpoint. Set OSA damper to maintain code minimum airflow when fan speed is slow. *See Create Systems>Fans*
Occupied Heating Setpoint Deadband	Temperature deadband less than code minimum 5°F. (70°F/74°F) *See Templates>Thermostat*	Increase temperature deadband to 5°F. (69°F/74°F) *See Templates>Thermostat*

Energy Calculation Methodology Details:
The energy model was created using Trane Trace 700. Most inputs used in the model calculations were found based on on-site conditions, site personnel, control system screenshots, and the as-built architectural and mechanical drawings. Assumptions were made on items where site personnel were not able to address them, or the available data was insufficient. These items include the OSA damper leakage quantity, economizer controls, and typical weekly occupied/unoccupied scheduling for the HVAC units.

The baseline model was calibrated by comparing the calculated electricity and gas energy to the building's utility history. The main parameters that drove the energy savings were occupied and unoccupied scheduling for RTU-1, enabling DCV for AHUs 1-2, and fixing the economizer and supply air reset controls. This proposed condition results in significant electricity and gas savings. Since the baseline uses ventilation air that is below code minimum, the proposed condition brings code minimum ventilation into the school which results in a gas consumption penalty. Enabling DCV allows for the code minimum ventilation to be reduced when spaces are unoccupied. This also increases the effectiveness of the existing heat recovery systems, both of which reduces the gas consumption penalty.

EEM #1 COST ESTIMATES



DOE/EE-0950

SEE Action
STATE & LOCAL ENERGY EFFICIENCY ACTION NETWORK

Energy Audits and Retro-Commissioning: State and Local Policy Design Guide and Sample Policy Language

Existing Commercial Buildings Working Group

July 2013

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1. Introduction

Commercial buildings consume nearly half of the building energy used in the United States, representing roughly 20% of total U.S. energy consumption and greenhouse gas emissions.[1,2] With energy expenditures averaging more than $2 per square foot ($ft^2$) in commercial and government buildings,[3] energy use is a cost worth managing. Energy audits and retro-commissioning are two strategies that can help building owners manage and reduce this consumption and related costs.

This guide provides information to help state and local policymakers better understand the value of energy audits and retro-commissioning; discussion to help them consider the applicability of policies to drive energy audits and retro-commissioning activity among public and private sector buildings; and resources to draft, enact, and implement policies addressing energy-related assessments of or improvements to existing commercial and public buildings. In recent years, a number of jurisdictions have enacted ordinances or taken other measures to require building owners to conduct energy assessments or "audits" of their facilities, to improve the operating efficiency of existing buildings through "retro-commissioning," or both. This guide distills the experiences of early-adopter jurisdictions into three main elements required for consideration, development, and implementation of the above energy management policies: (1) an introduction to the concepts of energy audits and retro-commissioning; (2) a discussion of key issues for consideration in policy design; and (3) sample language for policy formulation and implementing regulations.

Energy audits can be seen as a starting point to provide building operators with the information they need to make better energy management decisions in the short and long term. A 2011 report notes that "energy audits are a powerful tool for uncovering operational and equipment improvements that will save energy, reduce energy costs, and lead to higher performance. Energy audits can be done as a stand-alone effort but may be conducted as part of a larger analysis across a group of facilities, or across an owner's entire portfolio."[4] Undertaking an energy audit does not, by itself, result in energy savings. Frequently, though, utilities incentivize the cost of an energy audit based on the likelihood that the customer will take audit recommendations and subsequently invest in measures that will result in recommended energy savings.[5]

Moving beyond the audit itself, retro-commissioning is the process of reviewing a building's operations to ensure that all systems are working as designed. Building owners can choose to engage in retro-commissioning on its own, or as a next step to implement the recommendations from an energy audit. Typically focused on low-cost enhancements to operations and maintenance, retro-commissioning can produce whole-building energy savings of 10% to 20% quickly and inexpensively, freeing up funds for more urgent needs.[6,7] At a cost well below $1 per ft^2 (normalized median cost of $0.30 per ft^2 according to a 2009 study)[8] and typical payback in slightly more than one

[1] See U.S. Department of Energy (DOE). *Buildings Energy Data Book*, Chapter 3. (March 2011). http://buildingsdatabook.eren.doe.gov/ChapterIntro3.aspx.
[2] See U.S. Environmental Protection Agency (EPA). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009*, Table ES-8. (April 2011). www.epa.gov/climatechange/emissions/usinventoryreport.html.
[3] See DOE. *Buildings Energy Data Book. Tables 3.3.8 and 3.2.1.* (March 2011). http://buildingsdatabook.eren.doe.gov/ChapterIntro3.aspx.
[4] See DOE. *A Guide to Energy Audits.* (2011). Prepared by Pacific Northwest National Laboratory and Portland Energy Conservation, Inc. www.pnnl.gov/main/publications/external/technical_reports/pnnl-20956.pdf.
[5] For example, Minnesota Energy Resources rebates 50% of the cost of an ASHRAE Level I or II audit after implementation of one of the audit-recommended and custom-program rebate-able energy savings measures. See www.minnesotaenergyresources.com/business/audits.aspx.
[6] See Mills, E. *Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions.* (July 2009). Lawrence Berkeley National Laboratory. http://cx.lbl.gov/documents/2009-assessment/LBNL-Cx-CostBenefit.pdf. Key findings: "*Commissioning is arguably the single-most cost-effective strategy for reducing energy, costs, and greenhouse-gas emissions in buildings today. Energy savings tend to persist well over at least a 3- to 5- year timeframe, but data over longer time horizons are not available. Median commissioning costs: $0.30/ft² and $1.16/ft² for existing buildings and new construction, respectively (and 0.4% of total construction costs for new buildings). Median whole-building energy savings: 16% and 13%. Median payback times: 1.1 and 4.2 years. Median benefit-cost ratios: 4.5 and 1.1, cash-on-cash returns of 91% and 23%.*"
[7] See "Commercial Building Retro-Commissioning Revenue Could Surpass $1.8 Billion in the United States by 2014." (March 24, 2011). www.pikeresearch.com/newsroom/commercial-building-retro-commissioning-revenue-could-surpass-1-8-billion-in-the-united-states-by-2014.
[8] See footnotes 6 and 7, above.

APPENDIX A – SB1149 Measure Life table:

Retro-commissioning: 5 Years

SB 1149 Schools Measure Life [d]

Equipment/Measure	(Years)
Building Envelope	
Double glazed windows (complete units)	30
Retrofit double glazing	20
Triple glazed windows (complete units)	35
Adding storm windows	15
Solar shade films	8
Insulated metal doors	20
Cavity insulation (wall, floor or ceiling)	30
Reduction of window or door area	30
Rigid roof deck insulation	30
Caulking, weather stripping & sealing	10
Exterior door self closers	5
HVAC Components	
Boilers	30
Boiler burners	20
Boiler tune-up optimization	5
Replacement steam traps	6
Ground source heat pump systems	25
Rooftop gas/oil pkgd units	15
Fans, central	25
Air conditioner, rooftop/split	18
Air-to-air packaged heat pumps	16
Water-to-air packaged heat pumps	20
Coils, DX, water or steam	25
Radiant/unit heaters, all types	20
Thermostatic valve	15
Furnaces, gas/oil	20
Chillers, reciprocating	25
Chillers, centrifugal & absorption	30
Cooling towers	35
Heat Recovery Systems	20
Heat Exchangers	25
Damper systems & VAV conversions	20
Low leak dampers	15
Air economizers	15
Automatic boiler flue dampers	15
Ductwork & Piping (new)	30
Duct and pipe insulation/sealing	15

Equipment/Measure	(Years)
HVAC Controls	
DDC systems	15
Local controls: timers, prog. thermostats	15
CO_2, auto faucet or other sensors	10
Pumps, Motors & Drives	
Pumps, base mounted	25
Pumps, inline	20
Premium efficiency motors	25
Variable frequency drives	20
Domestic Hot Water	
Heat pump water heaters	15
Gas or propane water heaters	20
Solar water heaters	15
Faucet flow restrictors, aerators	10
Lighting	
Lighting fixtures, all types	25
Lighting fixture rebuild kits [a]	20
Electronic ballasts	15
Dimming systems	12
Occupancy sensors	10
Lighting control systems (electronic)	15
Linear fluorescent fixture de-lamping [b]	9
Reduced wattage linear fluorescent lamps [c]	9
Screw-in replacement CFL lamps	5
Screw-in replacement LED lamps	12
Kitchen Equipment	
Refrigeration system upgrades	15
Walk-in fan EC motors	15
Reach-in refrigerators/freezers	18
Ice machines	10
Walk-in door self-closers	10
Kitchen cooking equipment	25
Kitchen hood fan VFD and control	18
Other Measures	
Pool covers	10
Solar PV systems	30
Retro-commissioning	5
Vending machine controls	10
Computer power mgmt & LCD monitors	5

APPENDIX B – Baseline

Baseline Monthly Energy Consumption

MONTHLY ENERGY CONSUMPTION

By rw engineering

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 1	**PAC**												
Electric													
On-Pk Cons. (kWh)	20,660	19,353	28,779	28,911	23,358	22,814	24,677	24,680	31,024	31,213	29,151	22,272	306,894
On-Pk Demand (kW)	72	75	76	80	81	85	89	89	85	79	76	73	89
Gas													
On-Pk Cons. (therms)	769	525	612	442	301	110	0	0	269	497	672	669	4,866
On-Pk Demand (therms/hr)	6	4	4	4	3	2	2	2	4	4	4	4	6

Energy Consumption

Building	56,430	Btu/(ft2-year)
Source	134,446	Btu/(ft2-year)
Floor Area	27,184	ft2

Environmental Impact Analysis

CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

Project Name:
Dataset Name: MADRAS PAC V3.TRC

TRACE® 700 v6.3.4 calculated at 03:30 PM on 01/31/2020
Alternative - 1 Monthly Energy Consumption report Page 1 of 2

Baseline Energy Consumption Summary

ENERGY CONSUMPTION SUMMARY

By rw engineering

	Elect Cons. (kWh)	Gas Cons. (kBtu)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 1					
Primary heating					
Primary heating		486,564	31.7 %	486,564	512,172
Other Htg Accessories	14,416		3.2 %	49,202	147,620
Heating Subtotal	**14,416**	**486,564**	**34.9 %**	**535,765**	**659,792**
Primary cooling					
Cooling Compressor	56,987		12.7 %	194,496	583,545
Tower/Cond Fans	14,758		3.3 %	50,368	151,120
Condenser Pump			0.0 %	0	0
Other Clg Accessories	840		0.2 %	2,867	8,603
Cooling Subtotal....	**72,585**		**16.2 %**	**247,731**	**743,268**
Auxiliary					
Supply Fans	159,242		35.4 %	543,492	1,630,640
Pumps	337		0.1 %	1,149	3,447
Stand-alone Base Utilities			0.0 %	0	0
Aux Subtotal....	159,579		35.5 %	544,641	1,634,088
Lighting					
Lighting	60,315		13.4 %	205,854	617,623
Receptacle					
Receptacles			0.0 %	0	0
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	**306,894**	**486,564**	**100.0 %**	**1,533,992**	**3,654,772**

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Project Name:
Dataset Name: MADRAS PAC V3.TRC

TRACE® 700 v6.3.4 calculated at 03:30 PM on 01/31/2020
Alternative - 1 Energy Consumption Summary report page 1

APPENDIX C – EEM 1

EEM 1 Monthly Energy Consumption

MONTHLY ENERGY CONSUMPTION

By rw engineering

------- Monthly Energy Consumption -------

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**EEM 1**												
Electric													
On-Pk Cons. (kWh)	14,953	13,508	15,693	13,984	16,150	19,091	21,313	21,265	20,626	16,885	16,316	16,036	205,820
On-Pk Demand (kW)	50	51	57	71	74	81	85	86	80	69	63	50	86
Gas													
On-Pk Cons. (therms)	767	411	397	183	72	22	0	0	92	245	470	582	3,241
On-Pk Demand (therms/hr)	10	9	4	3	3	2	1	1	3	3	4	9	10

Energy Consumption

Building	37,764	Btu/(ft2-year)
Source	90,082	Btu/(ft2-year)
Floor Area	27,184	ft2

Environmental Impact Analysis

CO2	No Data Available
SO2	No Data Available
NOX	No Data Available

Project Name:
Dataset Name: MADRAS PAC V3.TRC

TRACE® 700 v6.3.4 calculated at 03:30 PM on 01/31/2020
Alternative - 2 Monthly Energy Consumption report Page 2 of 2

EEM 1 Energy Consumption Summary

ENERGY CONSUMPTION SUMMARY

By rw engineering

	Elect Cons. (kWh)	Gas Cons. (kBtu)	% of Total Building Energy	Total Building Energy (kBtu/yr)	Total Source Energy* (kBtu/yr)
Alternative 2					
Primary heating					
Primary heating		324,121	31.6 %	324,121	341,180
Other Htg Accessories	10,579		3.5 %	36,105	108,327
Heating Subtotal	**10,579**	**324,121**	**35.1 %**	**360,226**	**449,507**
Primary cooling					
Cooling Compressor	25,640		8.5 %	87,511	262,559
Tower/Cond Fans	6,328		2.1 %	21,598	64,799
Condenser Pump			0.0 %	0	0
Other Clg Accessories	338		0.1 %	1,152	3,456
Cooling Subtotal....	**32,306**		**10.7 %**	**110,260**	**330,814**
Auxiliary					
Supply Fans	102,406		34.1 %	349,513	1,048,643
Pumps	215		0.1 %	733	2,200
Stand-alone Base Utilities			0.0 %	0	0
Aux Subtotal....	102,621		34.1 %	350,246	1,050,842
Lighting					
Lighting	60,315		20.1 %	205,854	617,623
Receptacle					
Receptacles			0.0 %	0	0
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	**205,820**	**324,121**	**100.0 %**	**1,026,586**	**2,448,786**

* Note: Resource Utilization factors are included in the Total Source Energy value.
** Note: This report can display a maximum of 7 utilities. If additional utilities are used, they will be included in the total.

Project Name:
Dataset Name: MADRAS PAC V3.TRC

TRACE® 700 v6.3.4 calculated at 03:30 PM on 01/31/2020
Alternative - 2 Energy Consumption Summary report page 1