Technical Analysis Study

JEFFERSON COUNTY SCHOOL DISTRICT
WARM SPRINGS K-8 ACADEMY
50 CHUKAR RD
WARM SPRINGS, OR 97761

PROJECT: ETECPS1542521956

SPONSORED BY: ENERGY TRUST OF OREGON
EXISTING BUILDINGS

ELECTRIC UTILITY: PACIFIC POWER
GAS UTILITY: N/A

SUBMITTED BY:
R&W ENGINEERING, INC.

2/3/20
VERSION # 2

CONTACTS

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DISCLAIMER

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 Warm Springs K-8 Academy at 50 Chukar Rd in Warm Springs, OR. The facility was built in 2014, is single story, and contains a total floor area of 88,106 square feet. The energy efficiency measure (EEM) affects the entire building. Using data from the last three years, the average annual electrical usage for the building was 867,400 kWh. This translates to an Energy Use Index of 46.6 kBtu/ft^2/year. The EUI for this building is 55% 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. The recommendations are expected to reduce the building's electricity consumption by 39%.

NOTE: The retro-commissioning measure will propose energy efficient changes to the HVAC sequence of operations but will not fix mechanical issues such as refrigerant leaks and compressor failures that the school district has described. The energy and cost savings that are provided assumes the VRF system is operating correctly. R&W has seen other VRF systems with similar mechanical problems to this school that were caused by such things as fitting failure, pipe sizing and layout problems, and trapping of refrigerant. R&W recommends the district pursue corrections to ensure the building HVAC system operates as originally intended.

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 $/Therm
	$ 0.084			$ 1.61

		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	Therms/ Yr	MBtu/Yr	%	kBtu/SF/Yr	$/Yr	$/Yr	$/Yr	$/Yr	$	Yrs	1/Yrs	Yrs	Yes/No
1	Controls Retro-Commissioning	0	338,374	0	-292	1,125,332	27.4%	-12.8	$28,525	$0	-$470	$28,055	$88,106	*3.1*	*0.3*	5	Yes
	TOTAL EEM Energy Savings	0	338,374	0	-292	1,125,332	27.4%	-12.8	$28,525	$0	-$470	$28,055	$88,106	*3.1*	0.3		

	Peak Demand	Electric	Natural Gas	All Other	Energy Total	% of Baseline	EUI	Cost Electricity	Cost Natural Gas	Cost All Other Fuels	Cost Total
	KW	kWh/Yr	therms/ Yr	therms/ Yr	MBtu/Yr	%	kBtu/SF/Yr	$/Yr	$/Yr	$/Yr	$/Yr
TOTAL Baseline Energy Usage		867,400		11,450	4,104,600	100.0%	46.6	73,122		19,686	97,929
TOTAL Proposed Energy Usage		529,026		11,742	2,979,268	72.6%	33.8	44,597		20,156	69,874

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, PGE $0.0883

Natural Gas: Avista $0.93, Cascade $0.63, NW Natural $0.77

** 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 Page 17).

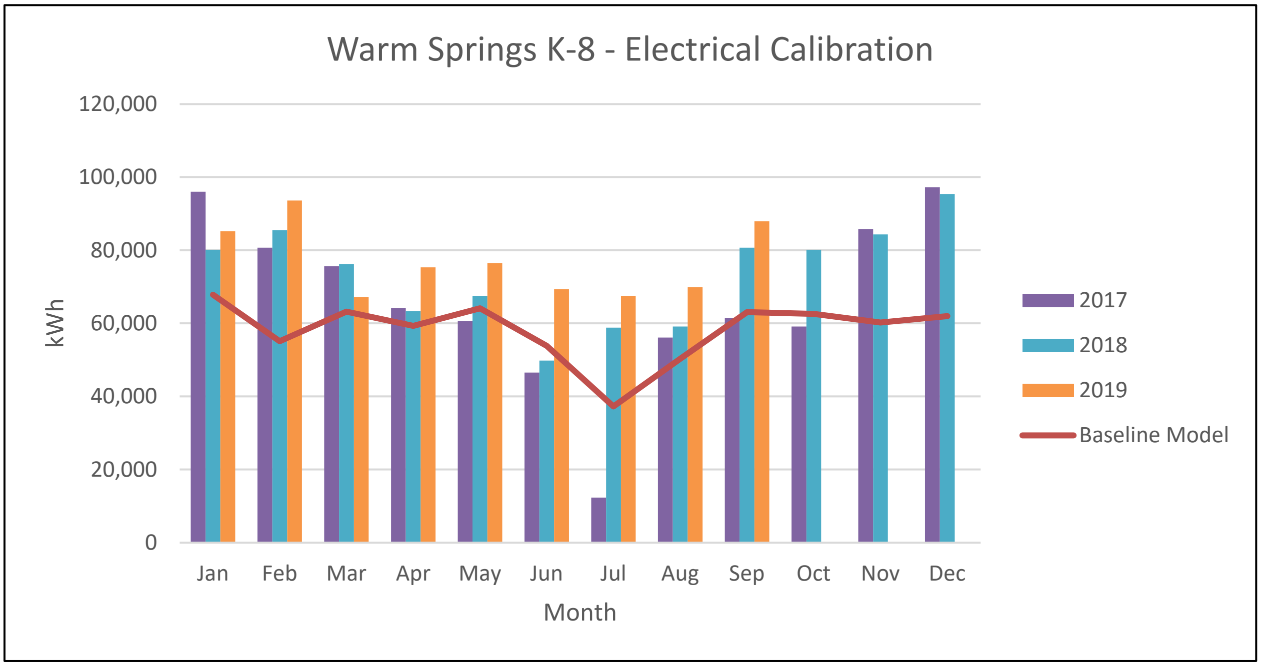
*** Simple Payback is a measure of how quickly your investment in the measure will pay for itself and does not include any potential incentive and/or non-energy benefits.

**** 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.

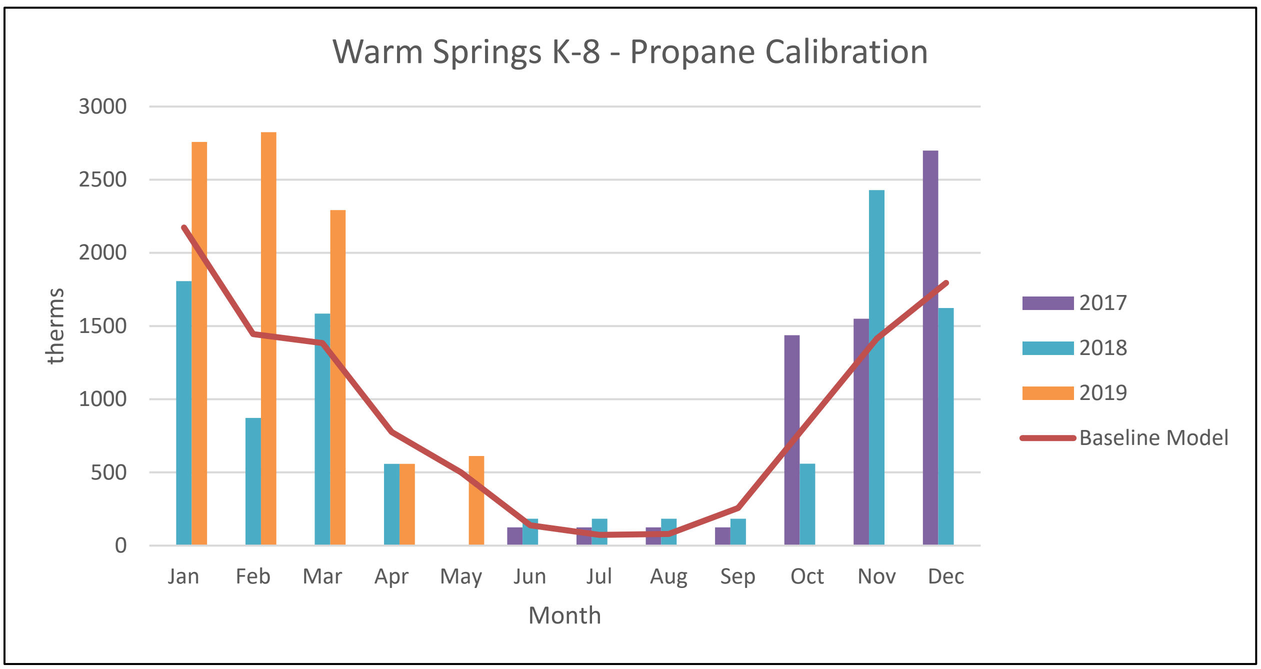
HISTORICAL ENERGY USE

TABLE 2: HISTORICAL BUILDING ENERGY USE

Beginning Year: 2016	End Year: 2019							
	Electricity			All Other Fuels (Propane)			Total	
Month/Year*	Electricity Use (kWh)	Electricity Use (MBtu)	Electricity Cost ($)	All Other Fuel Use (Therm)	All Other Fuel Use (MBtu)	All Other Fuel Cost ($)	Total Energy Use (MBtu)	Total Energy Cost ($)
10/2016	57,300	195,508	$4,830				195,508	$4,830
11/2016	73,800	251,806	$6,221				251,806	$6,221
12/2016	102,300	349,048	$8,624				349,048	$8,624
01/2017	96,000	327,552	$8,093				327,552	$8,093
02/2017	80,700	275,348	$6,803				275,348	$6,803
03/2017	75,600	257,947	$6,373				257,947	$6,373
04/2017	64,200	219,050	$5,412				219,050	$5,412
05/2017	60,600	206,767	$5,109				206,767	$5,109
06/2017	46,500	158,658	$3,920				158,658	$3,920
07/2017	12,300	41,968	$1,037				41,968	$1,037
08/2017	56,100	191,413	$4,729				191,413	$4,729
09/2017	61,500	209,838	$5,184				209,838	$5,184
1st Year Totals	**786,900**	**2,684,903**	**$66,336**				**2,684,903**	**66,336**
10/2017	59,100	201,649	$4,982	1,437	143,747	$ 2,551	345,396	$7,533
11/2017	85,800	292,750	$7,233	1,550	155,038	$ 3,043	447,787	$10,276
12/2017	97,200	331,646	$8,194	2,698	269,843	$ 5,419	601,489	$13,613
01/2018	80,100	273,301	$6,752	1,807	180,685	$ 3,653	453,986	$10,406
02/2018	85,500	291,726	$7,208	873	87,254	$ 1,764	378,980	$8,972
03/2018	76,200	259,994	$6,424	1,585	158,478	$ 2,131	418,472	$8,555
04/2018	63,300	215,980	$5,336	558	55,815	$ 677	271,795	$6,013
05/2018	67,500	230,310	$5,690		-		230,310	$5,690
06/2018	49,800	169,918	$4,198		-		169,918	$4,198
07/2018	58,800	200,626	$4,957		-		200,626	$4,957
08/2018	59,100	201,649	$4,982	733	73,292	$ 1,145	274,941	$6,128
09/2018	80,700	275,348	$6,803	-	-		275,348	$6,803
2nd Year Totals	**863,100**	**2,944,897**	**72759**	**9,804**	**980,404**	**$ 17,833**	**4,069,048**	**93,143**
2-Year Average (Baseline Energy Usage)	**825,000**	**2,814,900**	**$69,547.50**	**9,804**	**980,404**	**$ 17,833**	**2,814,900**	**$79,739**
10/2018	80,100	273,301	$6,752	559	55,916	$ 904	329,217	$7,657
11/2018	84,300	287,632	$7,106	2,428	242,823	$ 4,060	530,454	$11,167
12/2018	95,400	325,505	$8,042	1,623	162,330	$ 2,732	487,835	$10,774
01/2019	85,200	290,702	$7,182	2,758	275,799	$ 4,642	566,502	$11,824
02/2019	93,600	319,363	$7,890	2,825	282,497	$ 4,631	601,860	$12,522
03/2019	67,200	229,286	$5,665	2,292	229,235	$ 3,734	458,521	$9,399
04/2019	75,300	256,924	$6,348	558	55,833	$ 879	312,757	$7,226
05/2019	76,500	261,018	$6,449	611	61,140	$ 862	322,158	$7,311
06/2019	69,300	236,452	$5,842				236,452	$5,842
07/2019	67,500	230,310	$5,690				230,310	$5,690
08/2019	69,900	238,499	$5,893				238,499	$5,893
09/2019	87,900	299,915	$7,410				299,915	$7,410
3rd Year Totals	**952,200**	**3,248,906**	**80,270**	**13,097**	**1,309,658**	**21,540**	**4,614,480**	**102,715**
3-Year Average (Baseline Energy Usage)	**867,400**	**2,959,569**	**$ 73,122**	**11,450**	**1,145,031**	**$19,686**	**4,104,600**	**$ 97,929**



Warm Springs K-8 - Electrical Calibration
120,000
100,000
80,000
60,000
40,000
20,000
0
kWh
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2017
2018
2019
Baseline Model



Warm Springs K-8 - Propane Calibration
3000
2500
2000
1500
1000
500
0
therms
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
2017
2018
2019
Baseline Model

	Electric Use (kWh)			Propane (Therm)		
	Baseline	Model	% Deviation	Baseline	Model	% Deviation
Jan	87,100	67,834	-22.1%	2,282	2,174	-4.8%
Feb	86,600	55,089	-36.4%	1,849	1,445	-21.8%
Mar	73,000	63,168	-13.5%	1,939	1,384	-28.6%
Apr	67,600	59,282	-12.3%	558	776	39.0%
May	68,200	64,104	-6.0%	611	500	-18.2%
Jun	55,200	53,830	-2.5%	154	139	-9.7%
Jul	46,200	37,275	-19.3%	154	74	-51.9%
Aug	61,700	50,297	-18.5%	154	80	-48.0%
Sep	76,700	63,063	-17.8%	154	257	66.9%
Oct	65,500	62,593	-4.4%	998	835	-16.4%
Nov	81,300	60,204	-25.9%	1,989	1,413	-29.0%
Dec	98,300	61,958	-37.0%	2,161	1,795	-16.9%
Total	867,400	698,697	-19.4%	13,004	10,872	-16.4%

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. The electrical non-modeled energy uses include plug loads, exterior lighting, kitchen equipment, split-system AC units (not tied into the VRF system), electric unit heaters, and bathroom exhaust fans. The gas non-modeled energy uses include domestic hot water, kitchen equipment, and gas unit heaters. Since propane is purchased in gallons and consumed over time, the propane use was averaged during the summer months (June – September).

BUILDING OCCUPANCY

Typical Daily Occupancy					
Indicate Building/Area	**Hours/Day**	**Days/Week**	**Weeks/Year**	**Annual Hrs**	**% of Bldg Used**
Classrooms	12	5	36	2160	48%
Corridors	12	5	36	2160	14%
Kitchen	8	5	36	1440	3%
Gymnasium	12	5	36	2160	12%
Locker Rooms	8	5	36	1440	4%
Library	12	5	36	2160	2%
Admin Offices	12	5	36	2160	4%
Restrooms	12	5	36	2160	3%
Cafeteria	12	5	36	2160	6%
Storage	12	5	36	2160	4%
Is building ever partially occupied?	**Yes**				
Indicate Use	**Additional Hours/Day**	**Days/Week**	**Weeks/Year**	**Annual Hrs**	**% of Bldg Used**
Classrooms	2	2	36	144	50% of classrooms
Corridors					
Kitchen					
Gymnasium	4	4	36	576	12%
Locker Rooms	4	4	36	576	4%
Library	2	2	36	144	2%
Admin Offices	2	2	36	144	50% of admin offices
Restrooms					
Cafeteria					
Storage					

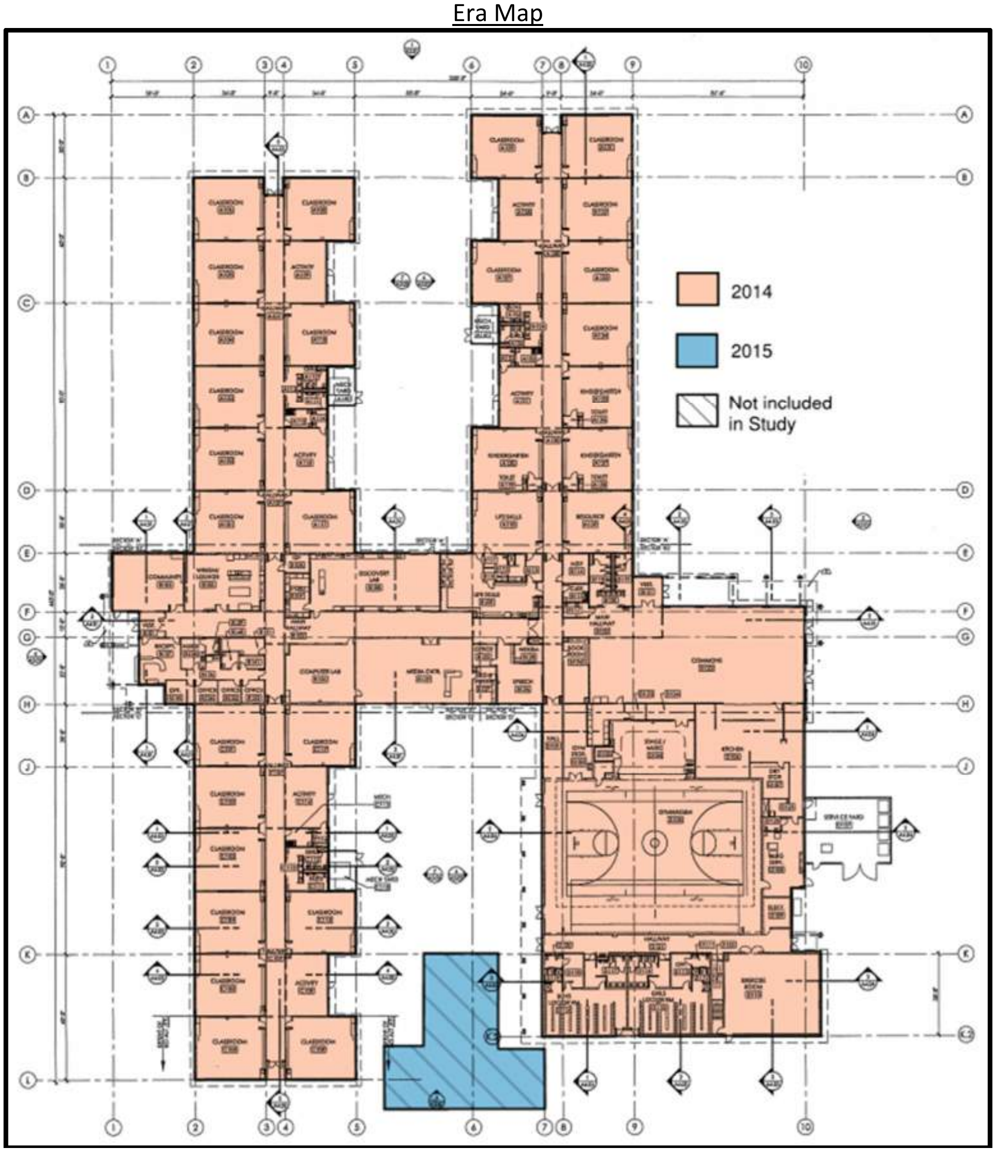
BUILDING OCCUPANCY NARRATIVE

The table above represents average building occupancy. The building is used regularly after typical school hours and has sports events that run in the evening. Summer school hours change each year, but classes typically occur during August.

FACILITY OVERVIEW

The Warm Springs K-8 Academy is located at 50 Chukar Rd in Warm Springs, OR. The school was originally constructed in 2014 with one classroom remodel in 2015. The building is single story. There is a full cooking kitchen. The building has an estimated floor area of 88,106 square feet. During the school year (September to June) the school is occupied for 12 hours a day from about 7 am to 7 pm by approximately 650 students and 97 staff. The gymnasium areas are used for sports practices throughout the school year until 10 pm on weeknights. In the summer the school is used for a variety of activities, including summer school (varies each year), sports camps and other community events. Interior lighting consists of LED which are controlled by switches and occupancy sensors. Exterior lighting is LED and are controlled by photocells. The HVAC system consists of a variable refrigerant flow (VRF) system with ventilation provided by multiple heat recovery units (HRUs), air handling units (AHUs), rooftop units (RTUs), and one make-up air unit (MAU). There are six outdoor heat pump units that distribute refrigerant to indoor fan coil units (FCUs). The HVAC system is controlled by a web-based direct digital control (DDC) system. The domestic hot water system consists of two high efficiency condensing propane boilers. See below for additional details on building's energy using systems. The figure below shows a floor plan of the building with the era of each remodel/new construction.

Era Map



Building Envelope

The exterior walls of the building are composed of plywood sheathing, 2x4 wood framing with batt insulation, and gypsum board. Some exterior walls have 4'' of CMU veneer on the lower half of the wall (*U – 0.064). The majority of the roof is sloped and composed of asphalt composition shingles, wood framing, and batt insulation. Parts of the school have membrane roofing with rigid insulation (*U – 0.048). Windows are tinted, double pane with aluminum frames (*U – 0.45, SC – 0.40). Most windows do have interior shading devices throughout which are used. There is an eave that provides light shading around the school. 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 these doors have tinted, double pane windows.

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

Front office

Classroom Wing

Gym/Multipurpose Room

Central Admin

WATERSIDE HVAC SYSTEM

The heating and cooling for the building is provided by a VRF system composed of six outdoor heat pumps (HP-01 – HP-06) which distribute refrigerant flow to fan coil units located throughout the school. Each heat pump is composed of three inverter compressors which provide staged heating or cooling. The heating capacity and COP of each heat pump from HP-1 – HP-05 is 360-MBH and 3.2. The heating capacity and COP of HP-06 is 334-MBH and 3.2. The cooling capacity and IEER of each heat pump from HP-01 – HP-05 is 26.7-tons and 15.6. The cooling capacity and IEER of HP-06 is 24.8-tons and 16.9.

Domestic hot water is provided by two high efficiency condensing propane hot water heaters with an input of 200-MBH, each and an efficiency of 99%. Hot water is distributed by a fractional hp recirculation pump that is controlled by the DDC system.

AIR SIDE HVAC SYSTEM

Ventilation air is provided by five HRUs (HRUs 1-5), one AHU (AHU-1), two RTUs (RTUs 1-2), and one MAU (MAU-1) which were all installed in 2014. HRUs 1-3 each serve 5,280-CFM of ventilation air to multiple FCUs located in the classroom wings. HRU-4 serves 7,860-CFM of ventilation air to multiple FCUs located in the central admin areas and music rooms. These FCUs are ducted and located in the ceiling plenum which pull air from the occupied spaces and condition the air to maintain the room setpoint. HRU-5 is a single zone unit that serves 2,540-CFM to the locker room. HRUs 1-5 have variable speed drives on their supply and exhaust fans, although the fans run at a constant speed. AHU-1 serves 3,000-CFM to the wrestling room. RTU-1 serves 1,855-CFM to the kitchen. RTU-2 serves 18,000-CFM to the multipurpose room. MAU-1 serves 2,670-CFM to the kitchen.

HRUs 1-5, AHU-1, and RTUs 1-2 have backup propane gas heat exchangers. HRUs 1-3 have a heating input of 225-MBH. HRU-4 has a heating input of 400-MBH. HRU-5 has a heating input of 150-MBH. AHU-1 has a heating input of 250-MBH. RTU-1 has a heating input of 120-MBH. RTU-2 has a heating input of 1,080 MBH. All propane heating units have an efficiency of 80%. RTU-1 has a DX cooling coil with a capacity of 5-tons and an EER of 13.

CONTROLS

HVAC is controlled by a web-based DDC system installed in 2014. Typical heating/cooling setpoints are 70°F/74°F. There is no night setback. The HRUs, RTUs, and AHU are in occupied mode 24/7. The heat pumps are scheduled to be in occupied mode from 4:30 am – 6:00 pm, M-F. Exhaust fans are on when outside air temperature is between 50°F – 70°F. Sensors were observed to show inconsistent values on the control screens.

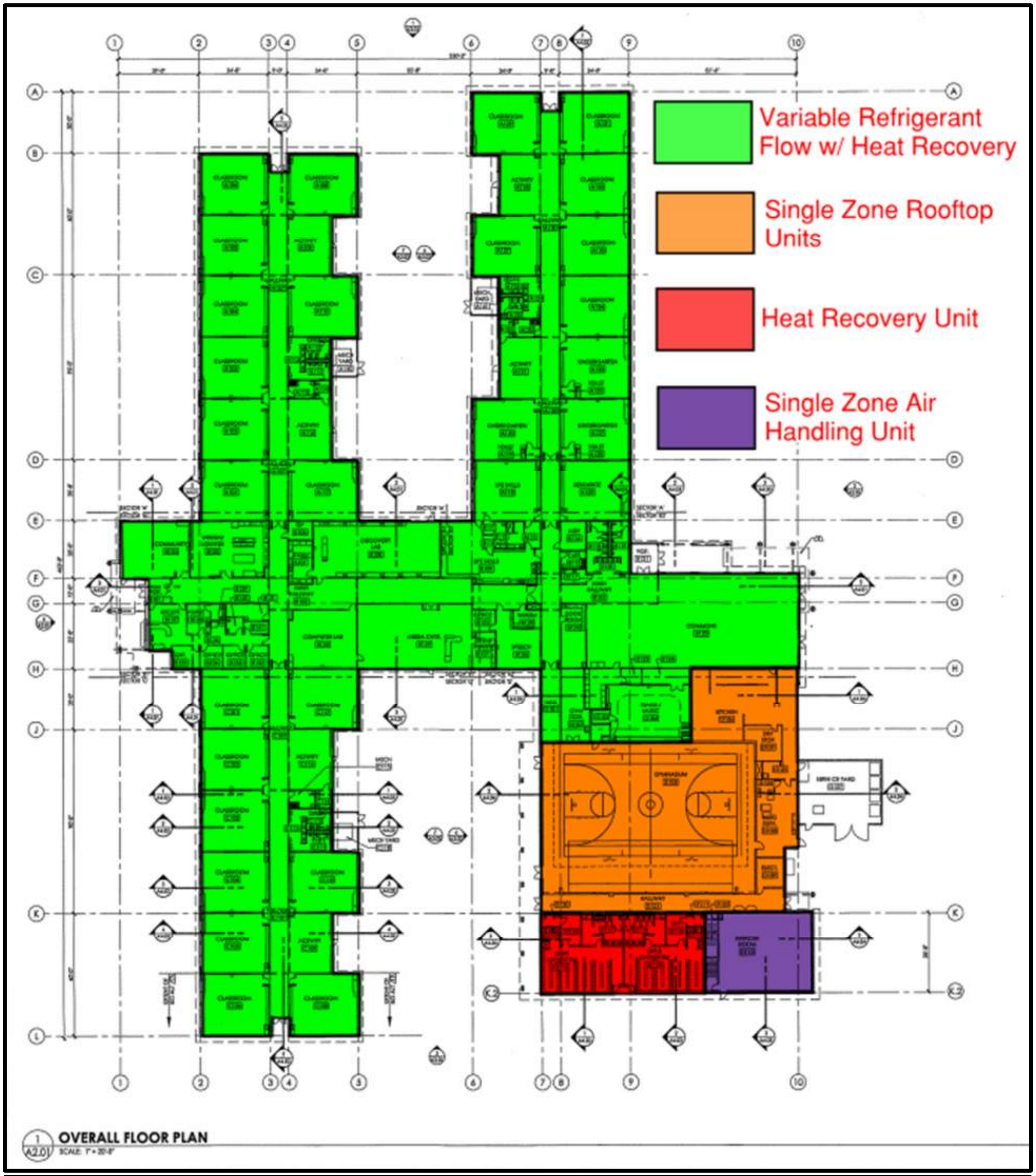
Outside air dampers were observed to be leaking, even when closed. Per facility personnel, the minimum outside air damper position is at 0%, although the typical leakage is estimated to be around 10% (as observed by control temperatures). The control screens show RTU-1 & RTU-2 to have more leakage than other AHUs (estimated around 15%). All units have economizer cooling enabled based on outside air temperature. The economizer low limit/high limit setpoints are 50°F/70°F and modulate the outside air dampers. The HRUs economizer controls also modulate the OSA dampers. The HRUs reset the supply air temperature based on heating demand. Typical reset schedule is 81.5°F to 50°F. The supply and return fans do not vary their speed and are set at 100% and 86%, respectively.

There is a morning warm-up and night setback sequence of operations but is not operational due to the HRUs, RTUs, and AHU operating in occupied mode 24/7. The facility maintenance team was unsure whether the VRF system utilized night setback, so it was assumed to not be functional.

By observing the controls screens, discussion with district personnel, and going on-site, the following items were noted:

- HRUs, RTUs, and AHUs are in occupied mode 24/7.
- VRF schedule does not match building occupancy.
- Night setback is not enabled.
- Morning warm up is not enabled.
- Economizer control logic operates based on OSA temperature only.
- HRUs, RTUs, and AHU are not bringing in code minimum OSA.
- OSA dampers have an estimated 10% leakage (15% for RTU-1 & RTU-2).
- RTU-2 and AHU-1 supply and return fans run at a constant speed.
- Temperature deadband is less than 5°F code minimum.
- Temperature sensors appear to not be calibrated based on inconsistent values on control screens.
- Alarms on control screens do not activate when problems occur (Non-energy benefit).

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 controlled by photocells.

DETAILED DESCRIPTION OF PROPOSED MEASURES

EEM 1 – Retro-Commissioning BASELINE CONDITION

HVAC is controlled by a web-based DDC system installed in 2014. Typical heating/cooling setpoints are 70°F/74°F. There is no night setback. The HRUs, RTUs, and AHU are in occupied mode 24/7. The heat pumps are scheduled to be in occupied mode from 4:30 am – 6:00 pm, M-F. Sensors were observed to show inconsistent values on the control screens.

Outside air dampers were observed to be leaking, even when closed. Per facility personnel, the minimum outside air damper position is at 0%, although the typical leakage is estimated to be around 10% (as observed by control temperatures). The control screens show RTU-1 & RTU-2 to have increased leakage than other AHUs (estimated around 15%). All units have economizer cooling enabled based on outside air temperature. The economizer low limit/high limit setpoints are 50°F/70°F and modulate the outside air dampers. The HRUs economizer controls also modulate the OSA dampers. The HRUs reset the supply air temperature based on heating demand. Typical reset schedule is 81.5°F to 50°F. The supply and return fans do not vary their speed and are set at 100% and 86%, respectively.

There is a morning warm-up and night setback sequence of operations but is not operational due to the HRUs, RTUs, and AHU operating in occupied mode 24/7. The facility maintenance team was unsure whether the VRF system utilized night setback, so it was assumed to not be functional.

By observing the controls screens, discussion with district personnel, and going on-site, the following items were noted:

- HRUs, RTUs, and AHUs are in occupied mode 24/7.
- VRF schedule does not match building occupancy.
- Night setback is not enabled.
- Morning warm up is not enabled.
- Economizer control logic operates based on OSA temperature only.
- HRUs, RTUs, and AHU are not bringing in code minimum OSA.
- OSA dampers have an estimated 10% leakage (15% for RTU-1 & RTU-2).
- RTU-2 and AHU-1 supply and return fans run at a constant speed.
- Temperature deadband is less than 5°F code minimum.
- Temperature sensors appear to not be calibrated based on inconsistent values 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:

- Set HRUs, RTUs, and AHUs to operate on an occupied and unoccupied schedule reflecting building occupancy. Set unoccupied scheduling for HRUs, RTUs, and AHUs to match VRF unoccupied scheduling.
- Set VRF schedule to operate during main occupied hours.
- Enable night setback for HRUs, RTUs, and AHUs during unoccupied mode. Use propane for heating during unoccupied hours.

- Enable morning warm up/cool down. For warm up, close OSA dampers and condition air with propane heat. For RTUs and AHUs cool down, open OSA dampers to 100% and bring in cool air. For HRUs, open OSA dampers and bypass dampers to 100% and close face dampers to bring in cool air.
- Have economizer controls modulate OSA damper position for RTUs and AHU and modulate heat recovery bypass/face damper position for HRUs. Have controls logic based on:
    - If there is a demand for cooling
    - OSA temperature is less than RA temperature
- Set OSA damper controls such that they allow code minimum OSA.
- Seal OSA dampers such that there is no leakage when closed.
- Set RTU-2 and AHU-1 up as single-zone VAV systems.
- Increase temperature deadband to at least 5°F.
- Recalibrate sensors such that they show consistent values on the control screens.
- HVAC problems report alarms accurately on control screens (Non-energy benefit).

NON-ENERGY SAVINGS DESCRIPTION

None.

TABLE 3: SUMMARY OF EEM 1 VS. EXISTING CONDITION

	kWh Savings	Therm Savings
Estimated Energy Savings	338,374	-292
Age of Equipment Being Replaced	NA	
Is Existing Equipment Currently Working or Not Working?	NA	
Cost	$88,106 Cost assumed to be $\$1/ft^2$ according to conservative estimates from US Department of Energy (See EEM #1 Cost Estimates Pages 18-19)	
Notes		

TABLE 5: EEM 1 CONDITIONS

Item	Baseline Condition	Proposed Condition
HRU, RTU, AHU Scheduling	HRUs, RTUs, AHU run 24/7. *See Utilization Schedules>People-Warm Springs* *See Create Rooms>Internal Loads* *See Create Systems>Dedicated OA*	HRUs, RTUs, AHU run on occupied/unoccupied schedule. Typical occupied schedule runs from 6 AM – 6 PM, M-F. Schedule for HRU-5 (locker room) and RTU-1 (kitchen) from 7 AM – 3 PM, M-F. *See Schedules>People-Warm Springs EEM* *See Schedules>People-Warm Springs Kitchen/Lockers* *See Create Rooms>Internal Loads*
VRF Scheduling	VRF runs from 4:30 AM – 6 PM *See Utilization Schedules>People-Warm Springs Indoor FCU* *See Create Systems>Fans* *See Equipment Schedules>VRF Warm Springs* *See Create Plants>Cooling Equipment>Controls*	VRF runs from 6 AM – 6 PM (Typical classroom occupancy). *See Create Systems>Fans* *See Equipment Schedules>VRF Warm Springs EEM* *See Create Plants>Cooling Equipment>Controls*
Night Setback	Night setback not enabled. *See Templates>Thermostat*	Enable night setback (55°F/80°F) on HRUs, RTUs, and AHU. Keep VRF system off during unoccupied hours. *See Templates>Thermostat*
Morning Warm-up/Cooldown	Morning warm-up not enabled *See Create Systems>Options>Advanced*	Enable morning warm-up (close OSA dampers and condition air with propane heat. For RTUs & AHU cool down, open OSA dampers to 100% and bring in cool air. For HRUs, open OSA dampers & bypass dampers to 100% and close face dampers to bring in cool air). *See Create Systems>Options>Advanced*
Economizer Controls	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. For HRUs, have economizer modulate bypass/face damper position. (Economizer turned on) *See Create Systems>Options*

Code Minimum Ventilation	HRUs, RTUs, and AHU have minimum OSA damper position at 0%. (Due to damper leakage, HRUs & AHU minimum position at 10%, RTU-1 & RTU-2 at 15%. Room ventilation served by HRUs shown as 0.036 CFM/ft^2 which is 10% of combined HRU & FCU CFM). *See Templates>Airflows*	Have minimum OSA damper position/airflow set to match code minimum ventilation requirements outlined in original 2014 mechanical equipment schedules (HRUs – 100% open so room ventilation is 0.364 CFM/ft^2 for HRUs 1-4, HRU-5 – 1,900 CFM, RTU-1 – 875 CFM, RTU-2 – 2,300 CFM, AHU-1 – 580 CFM). Reduce fan speed for HRU-5 to provide 1900-CFM (power changed from 1.6-kW to 1.14 kW). *See Templates>Airflows* *See Create Systems>Fans*
OSA dampers	HRUs, RTUs, and AHU leak air when closed (HRUs & AHU minimum position at 10%, RTU-1 & RTU-2 at 15%). *See Templates>Airflows*	Seal OSA dampers such that there is no leaking when closed (fixes unoccupied ventilation & morning warm-up/cooldown ventilation. Minimum OSA amounts set to code minimum.) *See Templates>Airflows* *See Create Systems>Options>Advanced Options*
RTU-2 & AHU-1 VAV System	RTU-2 and AHU-1 supply and return fans run at a constant speed. *See Create Systems*	Vary RTU-2 and AHU-1 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*
Temperature 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, VRF/FCU unoccupied night setback, and the condition of the VRF system.

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 the HRUs, RTUs, and AHU. This proposed condition results in significant electricity 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. This does increase the effectiveness of the existing heat recovery system, which reduces the gas consumption penalty.

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	**Warm Springs**												
Electric													
On-Pk Cons. (kWh)	67,834	55,089	63,168	59,282	64,104	53,830	37,275	50,297	63,063	62,593	60,204	61,958	698,699
On-Pk Demand (kW)	366	366	361	185	189	204	213	301	200	292	365	366	366
Gas													
On-Pk Cons. (therms)	2,174	1,445	1,384	776	500	139	74	80	257	835	1,413	1,795	10,873
On-Pk Demand (therms/hr)	4	3	3	2	2	1	0	0	2	3	3	3	4

Energy Consumption

Building	42,056	Btu/(ft2-year)
Source	100,529	Btu/(ft2-year)
Floor Area	82,555	ft2

Environmental Impact Analysis

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

Project Name:
Dataset Name: WARM SPRINGS K-8.TRC

TRACE® 700 v6.3.4 calculated at 02:21 PM on 12/13/2019
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	17,757	1,087,274	33.1 %	1,147,878	1,326,328
Other Htg Accessories			0.0 %	0	0
Heating Subtotal	**17,757**	**1,087,274**	**33.1** %	**1,147,878**	**1,326,328**
Primary cooling					
Cooling Compressor	24,571		2.4 %	83,861	251,608
Tower/Cond Fans	3,296		0.3 %	11,249	33,751
Condenser Pump			0.0 %	0	0
Other Clg Accessories	3,369		0.3 %	11,499	34,501
Cooling Subtotal....	**31,236**		**3.1** %	**106,609**	**319,860**
Auxiliary					
Supply Fans	476,530		46.8 %	1,626,398	4,879,681
Pumps			0.0 %	0	0
Stand-alone Base Utilities			0.0 %	0	0
Aux Subtotal....	476,530		46.8 %	1,626,398	4,879,681
Lighting					
Lighting	173,175		17.0 %	591,047	1,773,317
Receptacle					
Receptacles			0.0 %	0	0
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	**698,698**	**1,087,274**	**100.0** %	**3,471,932**	**8,299,188**

* 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: WARM SPRINGS K-8.TRC

TRACE® 700 v6.3.4 calculated at 02:21 PM on 12/13/2019
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**												
Electric													
On-Pk Cons. (kWh)	38,100	33,743	41,670	32,089	32,217	23,157	3,315	18,898	29,825	34,720	37,529	35,060	360,323
On-Pk Demand (kW)	362	356	291	180	179	161	166	240	162	253	353	363	363
Gas													
On-Pk Cons. (therms)	2,296	1,588	1,742	739	323	0	0	0	190	767	1,689	1,830	11,164
On-Pk Demand (therms/hr)	16	13	12	10	6	5	4	4	5	11	13	14	16

Energy Consumption	
Building	28,420 Btu/(ft2-year)
Source	58,929 Btu/(ft2-year)
Floor Area	82,555 ft2

Environmental Impact Analysis	
CO2	No Data Available
SO2	No Data Available
NOX	No Data Available

Project Name:
Dataset Name: WARM SPRINGS K-8.TRC

TRACE® 700 v6.3.4 calculated at 02:21 PM on 12/13/2019
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	14,329	1,116,390	49.7 %	1,165,295	1,321,878
Other Htg Accessories			0.0 %	0	0
Heating Subtotal	**14,329**	**1,116,390**	**49.7 %**	**1,165,295**	**1,321,878**
Primary cooling					
Cooling Compressor	11,421		1.7 %	38,981	116,955
Tower/Cond Fans	1,422		0.2 %	4,853	14,561
Condenser Pump			0.0 %	0	0
Other Clg Accessories	2,313		0.3 %	7,894	23,684
Cooling Subtotal....	**15,156**		**2.2 %**	**51,728**	**155,199**
Auxiliary					
Supply Fans	157,662		22.9 %	538,101	1,614,465
Pumps			0.0 %	0	0
Stand-alone Base Utilities			0.0 %	0	0
Aux Subtotal....	157,662		22.9 %	538,101	1,614,465
Lighting					
Lighting	173,175		25.2 %	591,047	1,773,317
Receptacle					
Receptacles			0.0 %	0	0
Cogeneration					
Cogeneration			0.0 %	0	0
Totals					
Totals**	**360,323**	**1,116,390**	**100.0 %**	**2,346,171**	**4,864,859**

* 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: WARM SPRINGS K-8.TRC

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Alternative - 2 Energy Consumption Summary report page 1