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CO_2 VENTILATION CONTROL

Things to Consider

- How can you determine if active CO_2 control via your ventilation system is a legitimate option for your facility?
- What are the acceptable levels of ventilation and how are they determined?
- Why should you bother? – economic and energy incentives
- Three case studies – Virginia, Tennessee, Washington

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Is CO_2 Control for You?

- Does your HVAC system incorporate an economizer control system?
- Do summertime temperatures get above 85 degrees?
- Do wintertime temperatures get below 45 degrees?
- Is the cost of heating fuel greater than $11.50/MBTU?
- Is the cost of electricity greater than $0.08/kWh?
- Is there less than 30 ft^2/person in the HVAC zone when fully occupied?
- Is the HVAC zone less than fully occupied 40% or more of the time?

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Acceptable Levels of Ventilation

- ASHRAE Standard 62
  - Sets minimum outside air volumetric flow rates (cfm) based upon number of occupants within space, square footage of space, and effectiveness of the ventilation system serving the space
  - Outside air amounts target the amount necessary to maintain CO_2 levels within the space at no more than 700 ppm above outside air levels (Appendix C of Standard 62)
- UFC Guidelines - Federal
  - Primarily refer to ASHRAE standards
- State and Local Guidelines

ASHRAE 62 Example

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(Continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values			Air Class
						Occupant Density (see Note 4)	Combined Outdoor Air Rate (see Note 5)		
	cfm/person	L/s•person	cfm/ft^2	L/s•m^2		#/1000 ft^2 or #/100 m^2	cfm/person	L/s•person	
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	-	-	0.12	0.6	B	-			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
[illegible]			0.06	0.3	B	-			2

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Why bother? – economic and energy incentives

- Conditioning of ventilation air can account for as much as 50% of the energy requirements of HVAC systems in many climates
- Any reduction in the amount of ventilation air to be processed results in a decrease in energy consumption
- Any decrease in energy consumption results in an economic savings

Three Case Studies

- Virginia – Naval Amphibious Base Little Creek
  - Norfolk, VA
  - Building 3607, Galley
- Tennessee – Naval Support Activity, Mid-South
  - Millington, TN
  - Building 767, Conference Center
- Washington – Naval Base Kitsap
  - Bremerton, WA
  - Building 1017, Gymnasium

Virginia - Little Creek Building 3607 Galley

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Washington – Kitsap Building 1017 Gymnasium

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Tennessee - Mid-South Building 767 Conference Center

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Analysis

- Virgina – Naval Amphibious Base Little Creek
  - Norfolk, VA

Outside Air Calculations per ASHRAE 62.1-2004

OUTSIDE AIR CALCULATIONS: ASHRAE 62-2004 AREA & PEOPLE

Utilization of Equation 11: Taylor, May 2006, "CO2 Based DVC Using 62.1-2004", ASHRAE Journal Article.

Total outside air flow at the air handler based on CO2 concentration difference

$$V'ot = \frac{Ra*Az}{Ez - \frac{Rp * (Cr-Coa)}{8400*m}} \qquad \text{EQ 11}$$

Calulation of space CO2 levels and volumetric flowrate of OA at min and max occupancy.

To determine MAX CO2 use EQ. 13 Taylor, May 2006 ASHRAE Journal

$$Cr = Coa + \frac{8400*Ez*m}{Rp + \frac{Ra*Az}{Pz}} \qquad \text{EQ 13}$$

Little Creek Bldg. 3607, Enlisted Dining, AHU-1 & AHU-2

	MIN	MAX	
INPUT VARIABLES			**Bold values with yellow highlight are inputs**
Ra	**0.18**	0.18	Room area ventilation rate, (cfm/ SF), ASHRAE 62, Table 2
Az	**1508**	1508	Occupied Square footage (SF)
Rp	**7.5**	7.5	Ventilation rate per person (cfm/person)., ASHRAE 62, Table 2
Pz	0	**100**	Number of people in the occupied space
Occupiable Square Feet		2250	14.25 Square foot per person
CONSTANTS			**Bold border:blue highlight = values based on site conditions**
Ez	1	1	Effectiness of the ventilation system, 1 = Ceiling supply diffusers
Coa	400	400	CO2 in outside air, (ppm), Actual measurement or estimate
constant	8400	8400	Conversion factor of 0.0084 cfm/met/person, (ppm*met*person/cfm).
met	1	1	Metabolic generation of CO2 per person, unit is (met), (1.0 for restful state.)
CALCULATED OUTPUTS			
V'ot	271	1021	Calculated by EQ. 11, OA volumetric flowrate, (CFM)
OA Space	271	271	OA required for the space square footage, (CFM)
OA People	0	750	OA required for the people occupying the space, (CFM)
Total OA	271	1021	Calculated OA volumetric flowrate, (CFM)
REPORTING VALUES			
	MIN	MAX	**These values are applied to both AHU-1 and AHU-2**
Cr, Room CO2	400	1222	Room CO2 concentrations, EQ. 13, Taylor, May 2006 ASHRAE Journal
Total OA	271	1021	Calculated OA volumetric flowrate, (CFM)

Total OSA for space with:

0 Occupants – 271 cfm
100 Occupants – 1021 cfm

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System Component Energy Breakdown – Virginia – Air Cooled Chiller System

SYSTEM COMPONENT ENERGY EVALUATION<------Little Creek, Norfolk, VA

ENERGY COST		
Electricity	$0.03035	$/kWh
Natural Gas	$12.08	$/Million Btu

Steam Coil		
Steam		
Boiler efficiency		
Steam cost per Btu	$0.0000351	$/Btu

			6.66867E-05	gpm/Btu	

CHILLED WATER SYSTEM		
Chiller		
Chiller	170	Tons
Power	180	kW
Chiller efficiency	1.06	kW/Ton
Energy cost per ton	$0.03	$/Ton hr

			CHWP	2.32	gpm/ton

Chilled Water Pump			AHU-1	AHU-2	AHU-3	AHU-4
Flow	394	gpm	98	98	84	103
Head	65	feet H_2O	16	16	12	10
Conversion	3960		3960	3960	3960	3960
Pump Efficiency	0.75		0.75	0.75	0.75	0.75
Drive Efficiency	0.95		0.95	0.95	0.95	0.95
Motor Efficiency	0.95		0.95	0.95	0.95	0.95
MHP	9.55	hp	0.58	0.58	0.38	0.38
Conversion	0.746	kW/hp	0.746	0.746	0.746	1.746
Power consumed	7.13	kW	0.44	0.44	0.28	0.67
Energy cost per hour	$0.22	$/hr	$0.01	$0.01	$0.01	$0.02
Energy cost per ton		$/ton	$0.0003	$0.0003	$0.0002	$0.0005

Chilled Water pump Costs			$0.0003	$0.0003	$0.0002	$0.0005

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System Component Energy Breakdown – Tennessee - Water Cooled Chiller System

SYSTEM COMPONENT ENERGY EVALUATION ------Mid-South, Millington, TN

ENERGY COST		
Electricity	$0.08550	$/kWh
Natural Gas	$12.41	$/Million Btu

HOT WATER SYSTEM					
Boiler					
Boiler efficiency	0.8		<----See FEMP (Federal Energy Management Program)		
Boiler cost per Btu	$0.0000155	$/Btu	6.667E-05	gpm/Btu	
Hot Water Pump			AHU-1	AHU-2	AHU-3
Flow	180	gpm	51	49	34
Head	80	feet H_2O	5	5	5
Conversion	3960		3960	3960	3960
Pump Efficiency	0.75		0.75	0.75	0.75
Drive Efficiency	0.95		0.95	0.95	0.95
Motor Efficiency	0.95		0.95	0.95	0.95
MHP	5.37	hp	0.10	0.09	0.06
Conversion	0.746	kW/hp	0.746	0.746	0.746
Power consumed	4.01	kW	0.07	0.07	0.05
Pump energy cost per hour	$0.34	$/hr	$0.01	$0.01	$0.00
Energy cost per Btu		$/Btu	7.93E-09	7.93E-09	7.93E-09

CHILLED WATER SYSTEM					
Chiller					
Chiller	210	Tons	CHWP	2.00	gpm/ton
Power	200	kW	CWP	3.00	gpm/ton
Chiller efficiency	0.95	kW/Ton			
Energy cost per ton	$0.08	$/Ton hr			

Cooling Tower		
Fan motor	15	hp
Cooling tons	210	Tons
Cooling tower energy per ton of cooling	0.07	hp/Ton
kW/Hp	0.746	kW/hp
kW	0.05	kW/Ton
Energy cost per ton	0.0046	$/Ton hr

Chilled Water Pump			AHU-1	AHU-2	AHU-3
Flow	420	gpm	158	158	104
Head	70	feet H_2O	5	5	5
Conversion	3960		3960	3960	3960
Pump Efficiency	0.75		0.75	0.75	0.75
Drive Efficiency	0.95		0.95	0.95	0.95
Motor Efficiency	0.95		0.95	0.95	0.95
MHP	10.97	hp	0.29	0.29	0.19
Conversion	0.746	kW/hp	0.746	0.746	0.746
Power consumed	8.18	kW	0.22	0.22	0.14
Energy cost per hour	$0.70	$/hr	$0.02	$0.02	$0.01
Energy cost per ton		$/ton	$0.0002	$0.0002	$0.0002

Condenser Water Pump			AHU-1	AHU-2	AHU-3
Flow	630	gpm	237	237	156
Head	70	feet H_2O	70	70	70
Conversion	3960		3960	3960	3960
Pump Efficiency	0.75		0.75	0.75	0.75
Drive Efficiency	0.95		0.95	0.95	0.95
Motor Efficiency	0.95		0.95	0.95	0.95
MHP	16.45	hp	6.19	6.19	4.07
Conversion	0.746	kW/hp	0.746	0.746	0.746
Power consumed	12.27	kW	4.62	4.62	3.04
Energy cost per hour	$1.05	$/hr	$0.39	$0.39	$0.26
Energy cost per ton		$/ton	$0.0050	$0.0050	$0.0050

Condenser + Chilled Water Pump Costs			$0.0052	$0.0052	$0.0052

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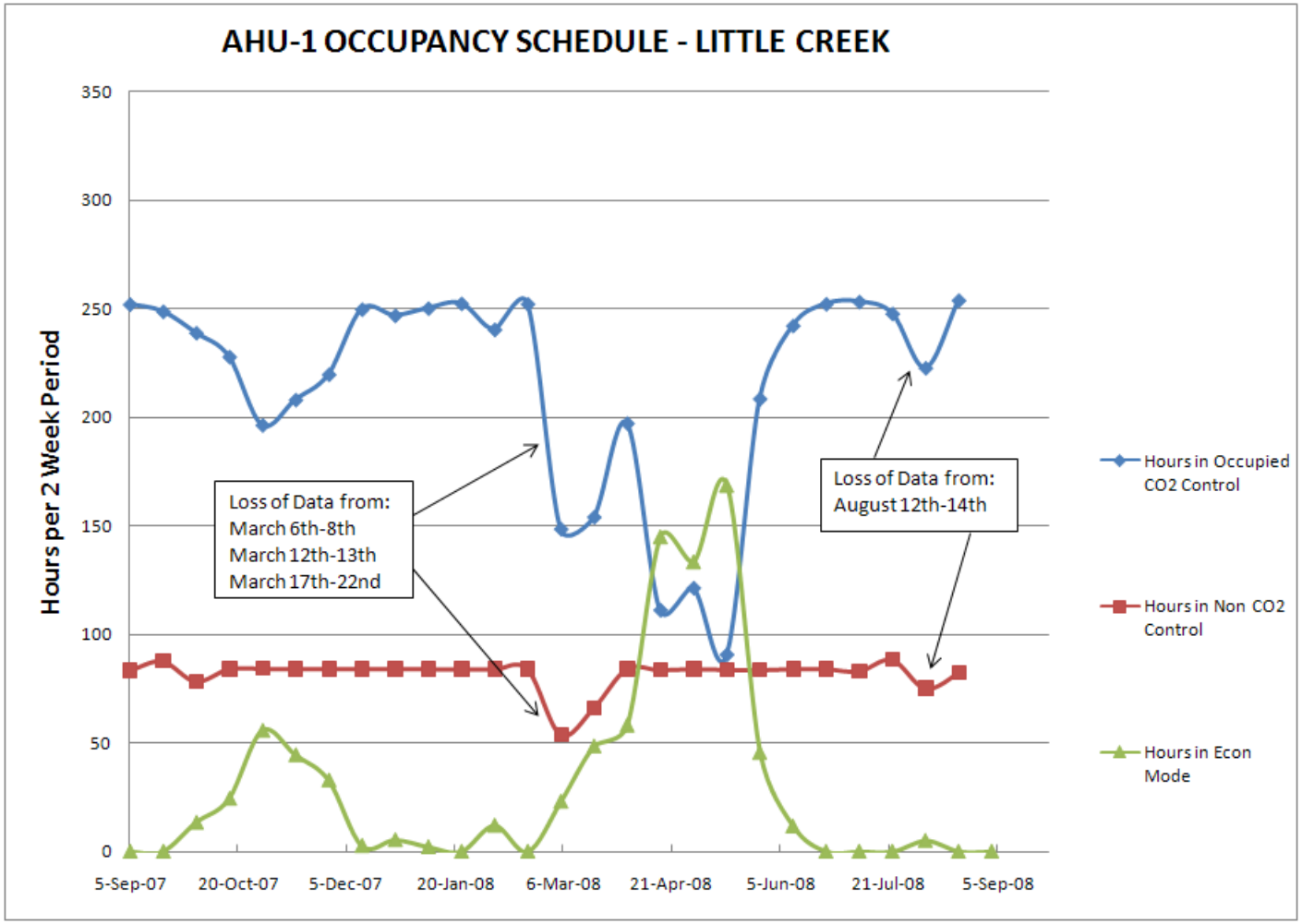
Occupancy Schedule - Virginia



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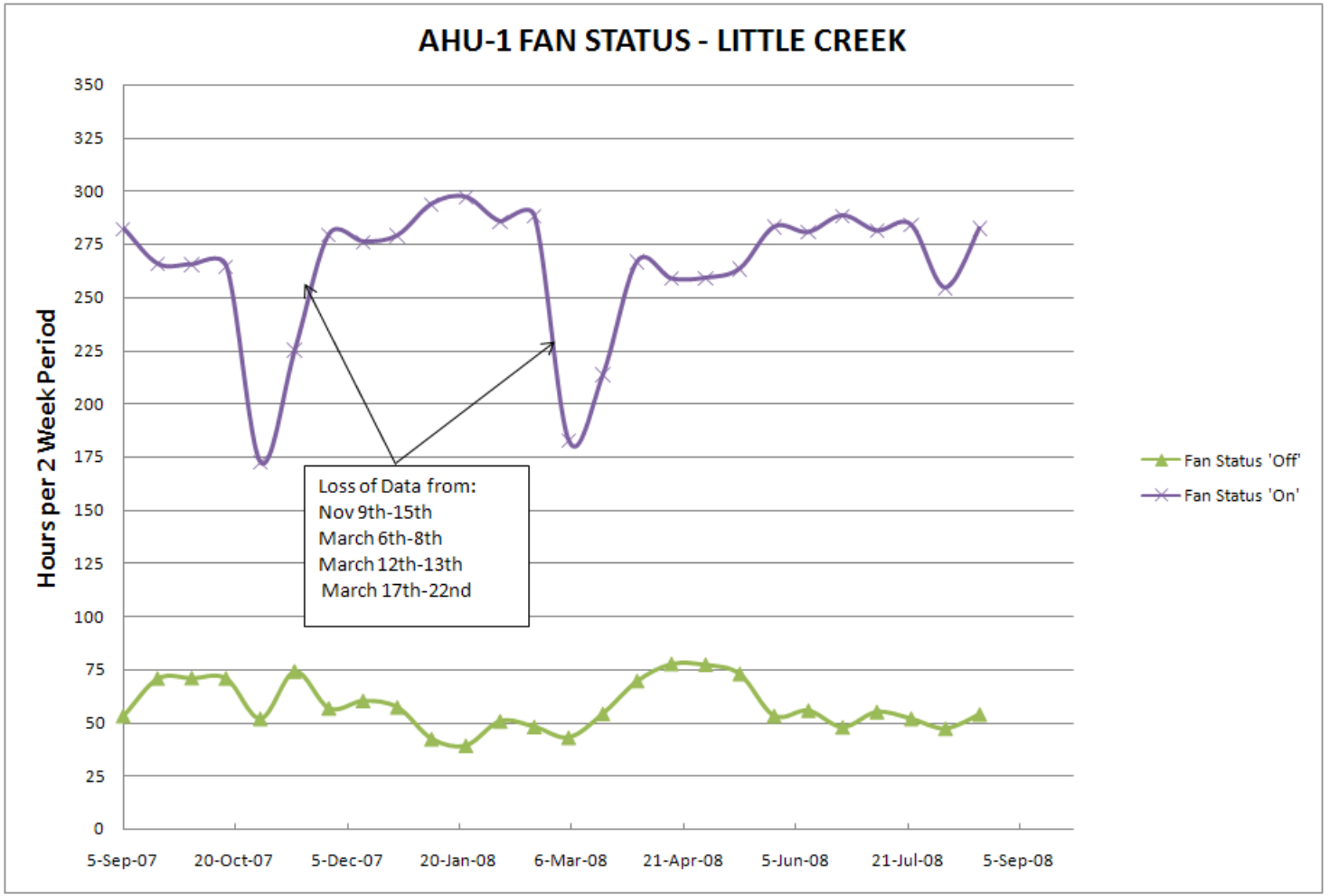
Performance Results - Virginia

- Fan Operation (On/Off)
- CO2 Measured Concentration Levels
- Ventilation Air Cooling Load
- Ventilation Air Heating Load
- Ventilation Air Flow Rates

Fan Status - Virginia



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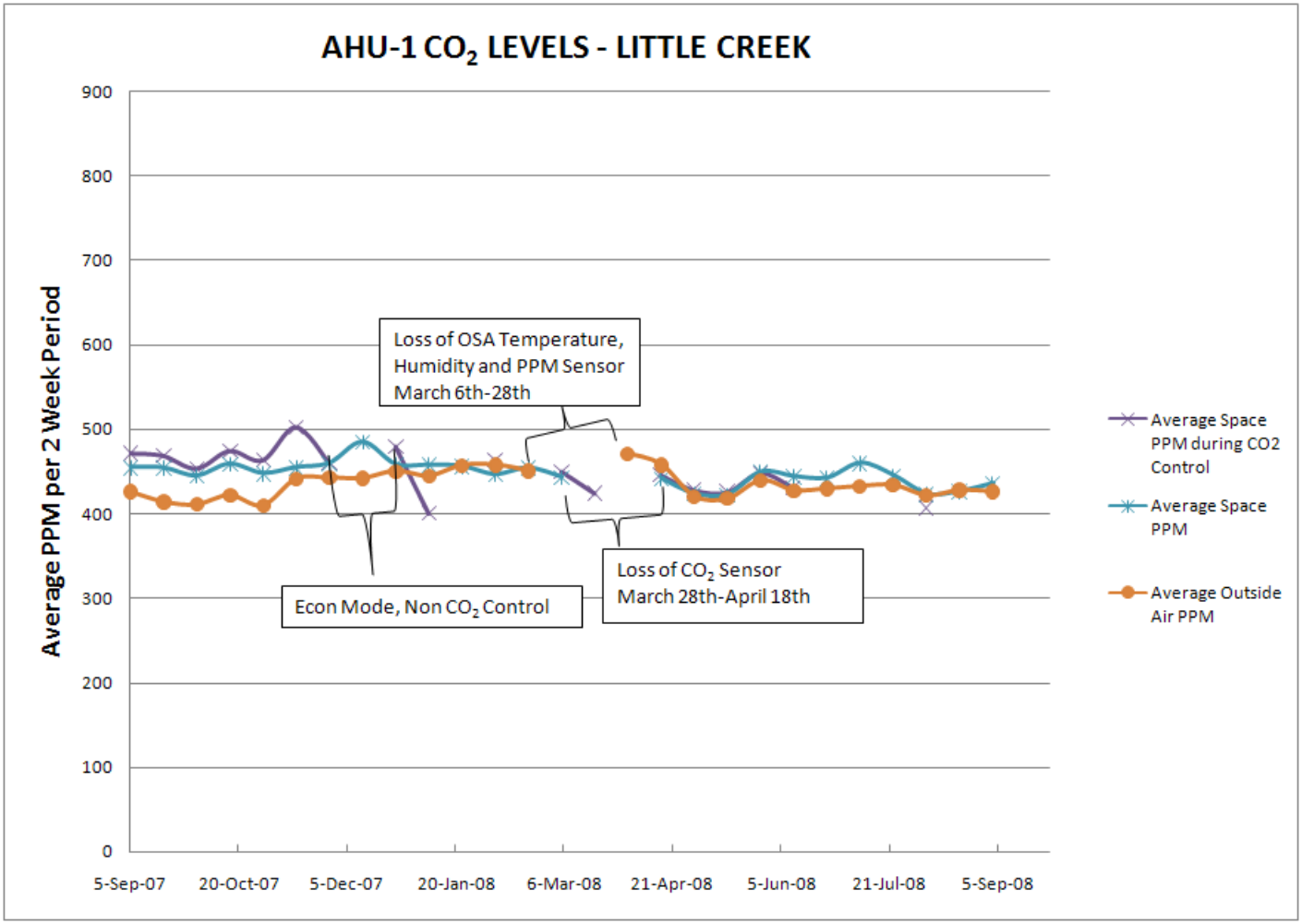
CO_2 Measured Concentration Levels - Virginia



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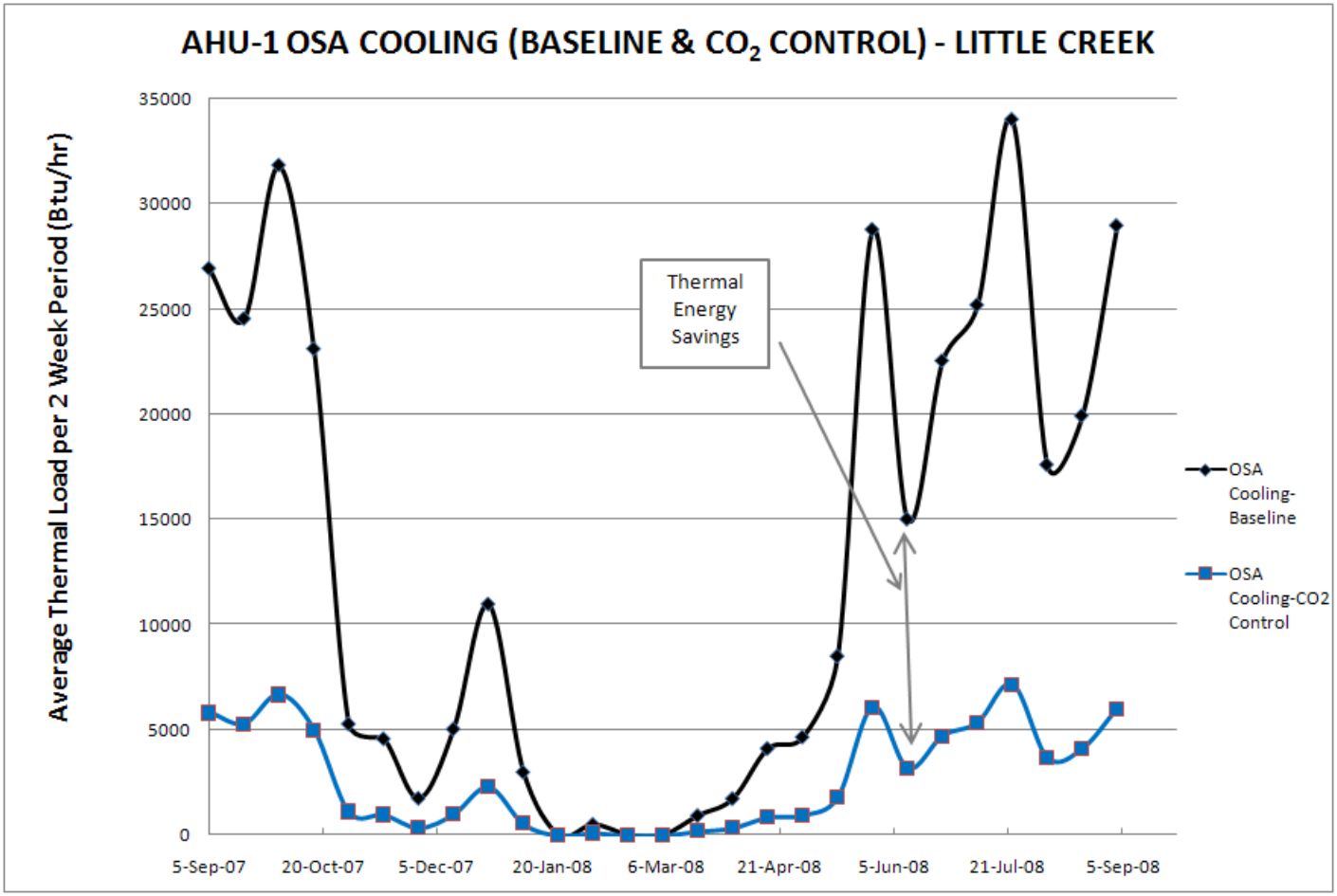
Ventilation Air Cooling Load - Virginia



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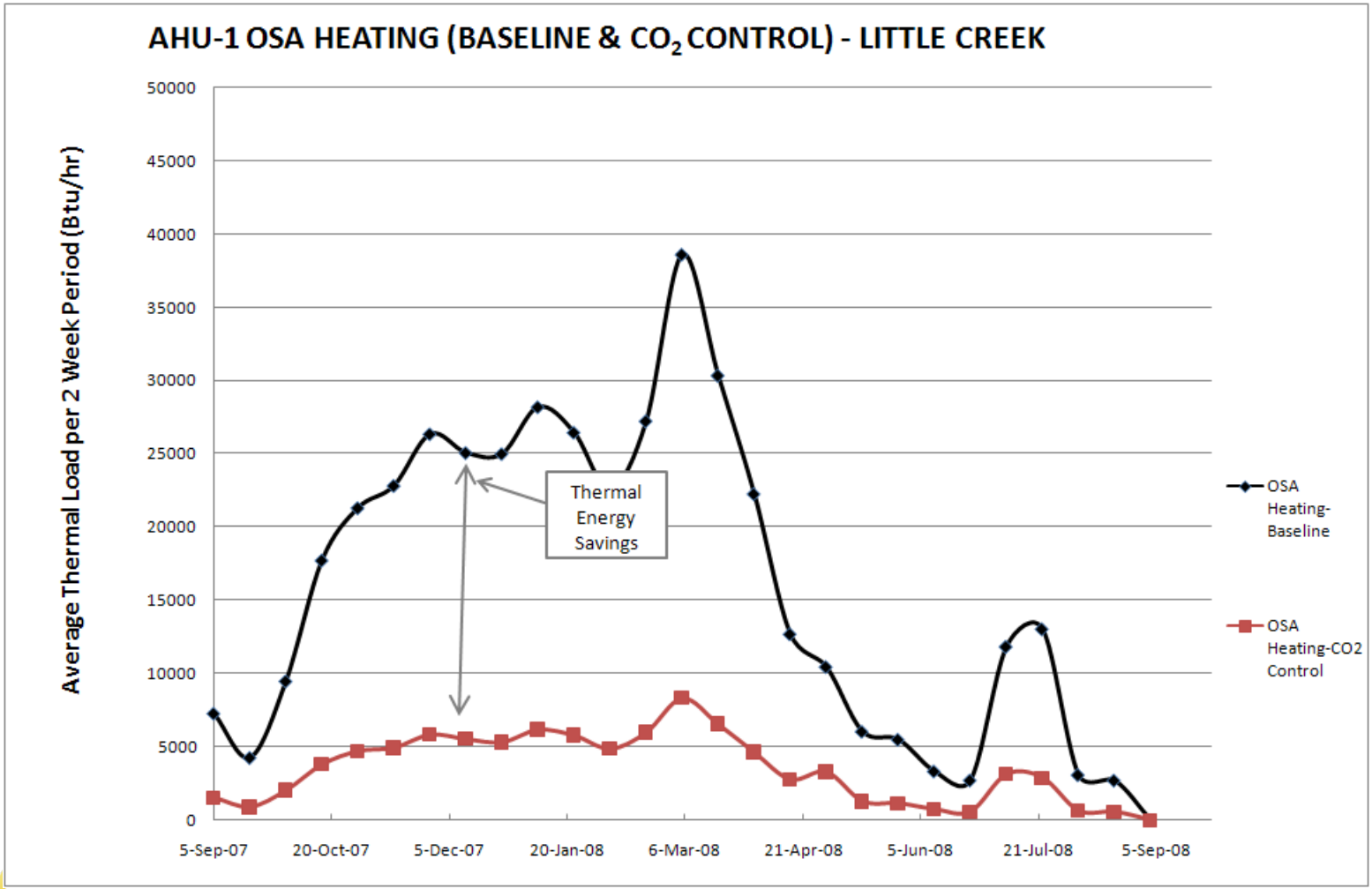
Ventilation Air Heating Load - Virginia



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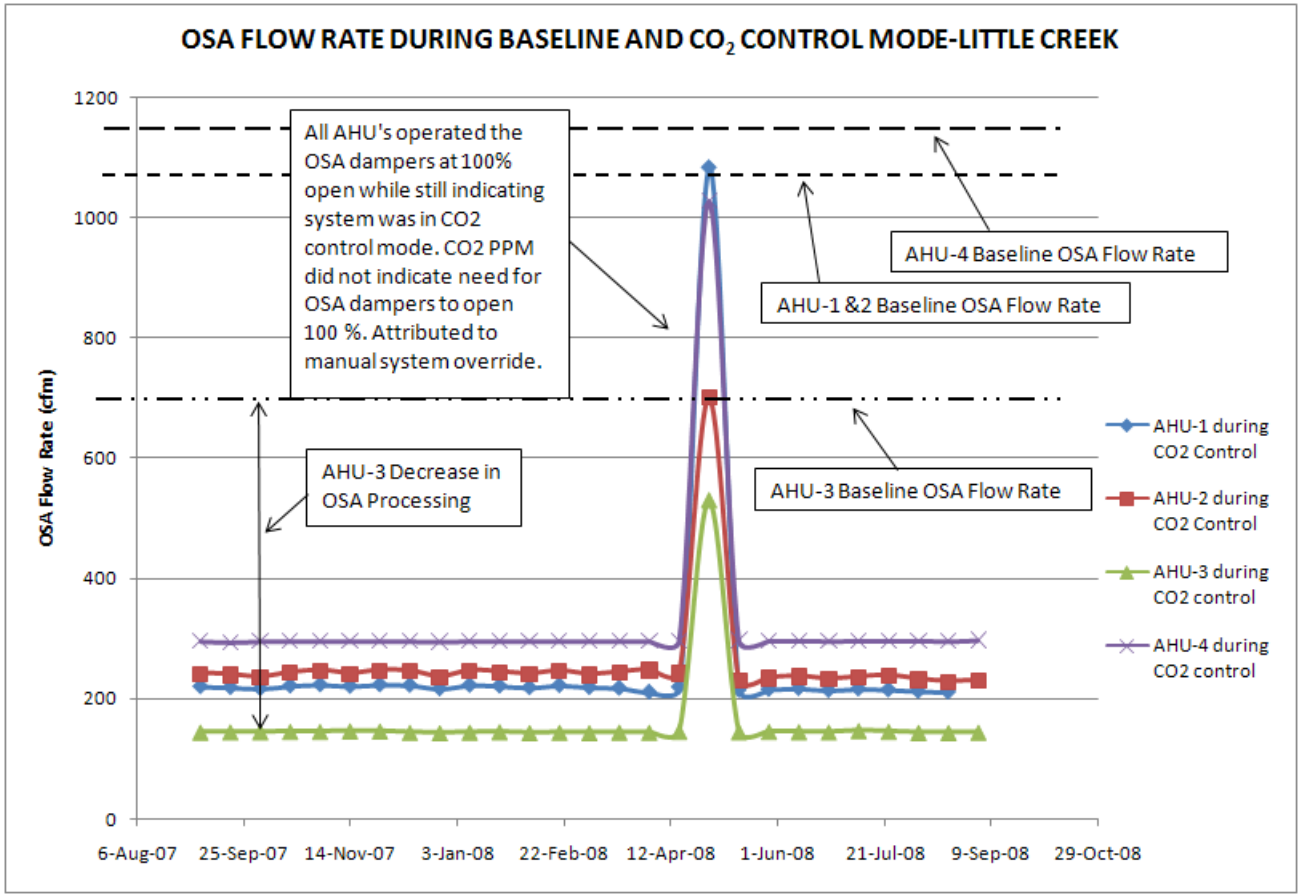
Ventilation Air Flow Rates - Virginia



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Performance Results – All Sites

- CO_2 Controlled Hours
- Savings per CO_2 Controlled Hour
- Annual Savings
- Payback in Years – non weather corrected
- Energy Manager Decision Calculator
- Test Site Evaluation Scores
- Payback based on Evaluation Scores

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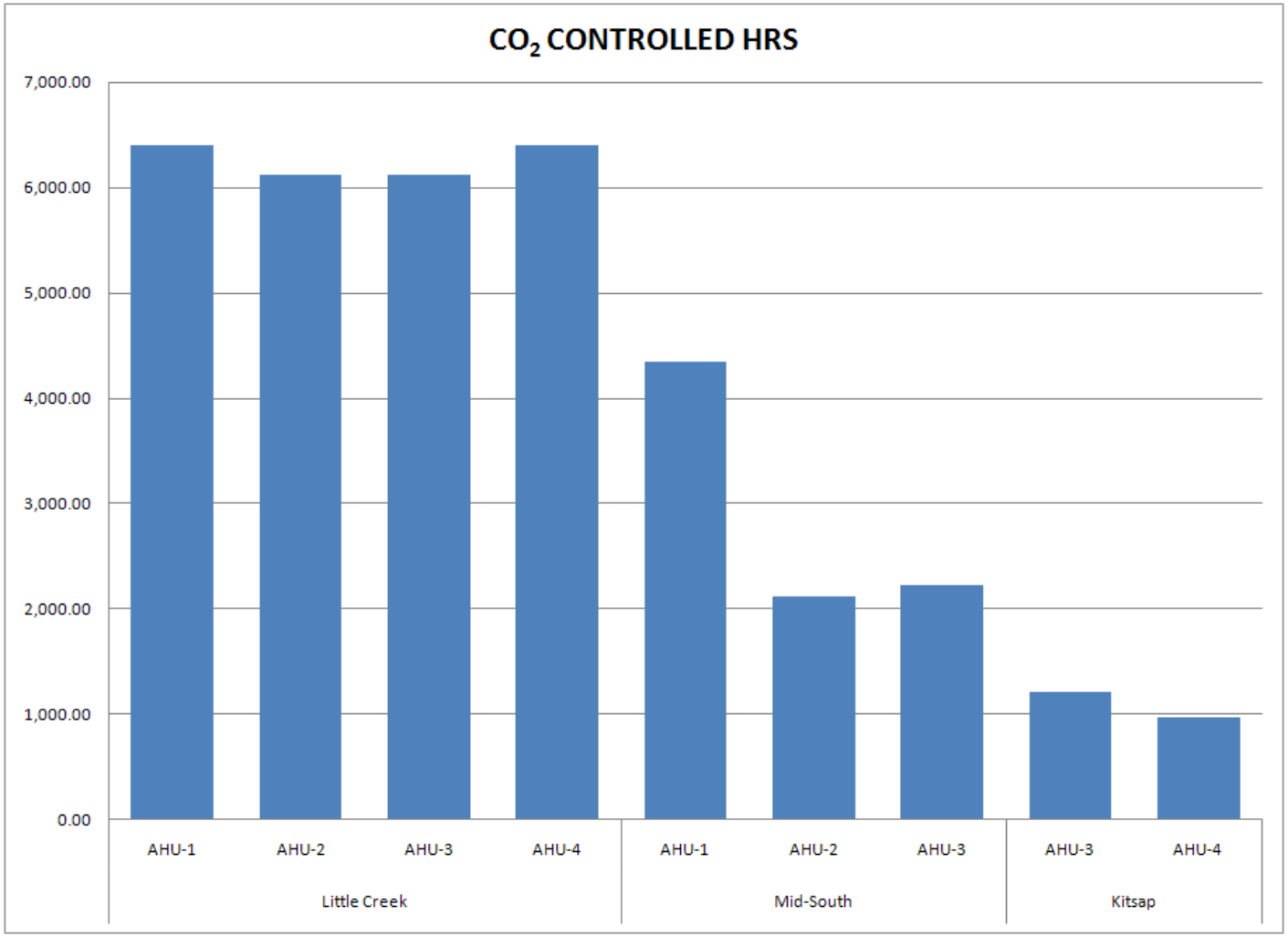
CO_2 Controlled Hours – All Sites



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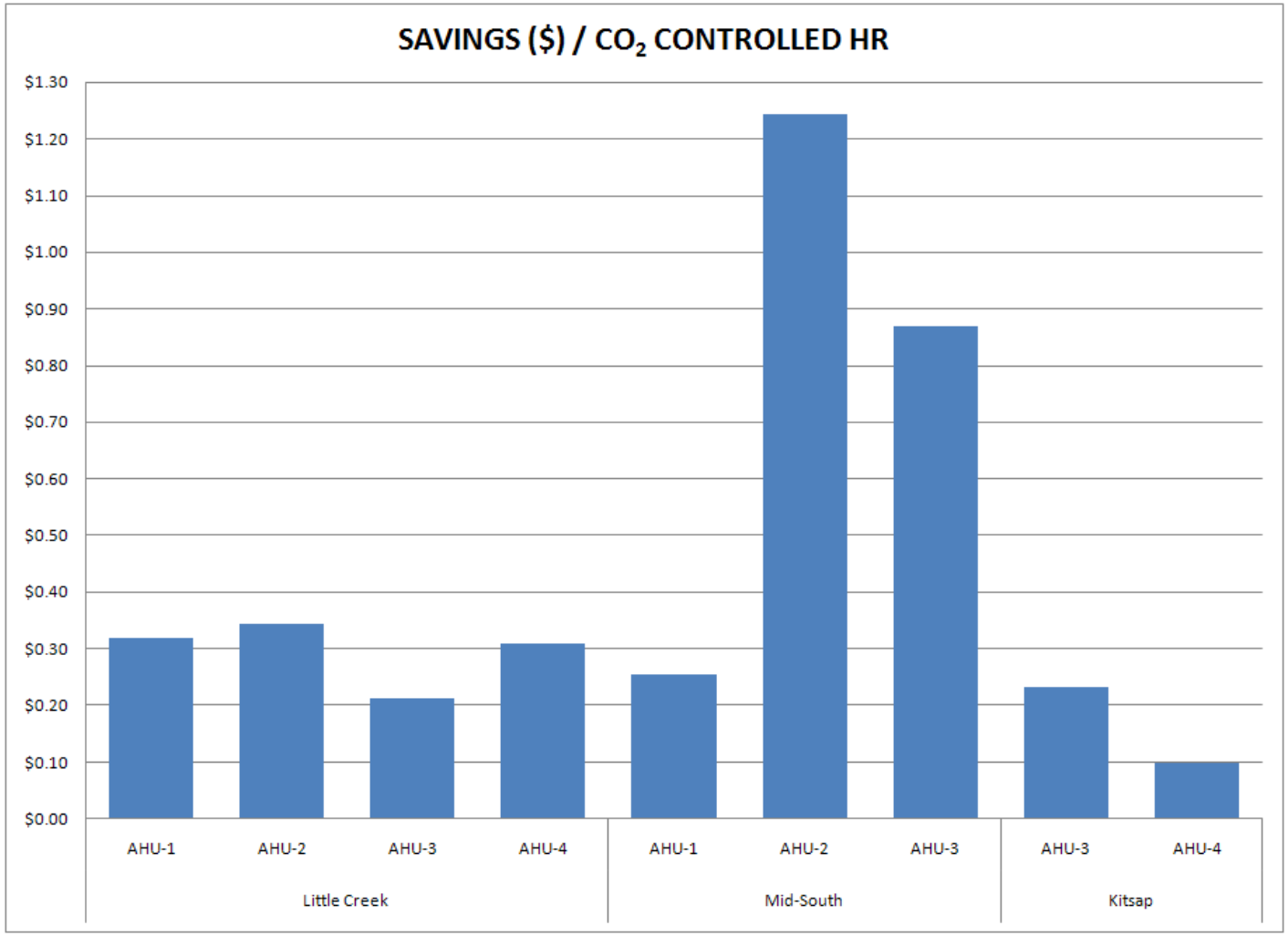
Savings per CO_2 Controlled Hour – All Sites



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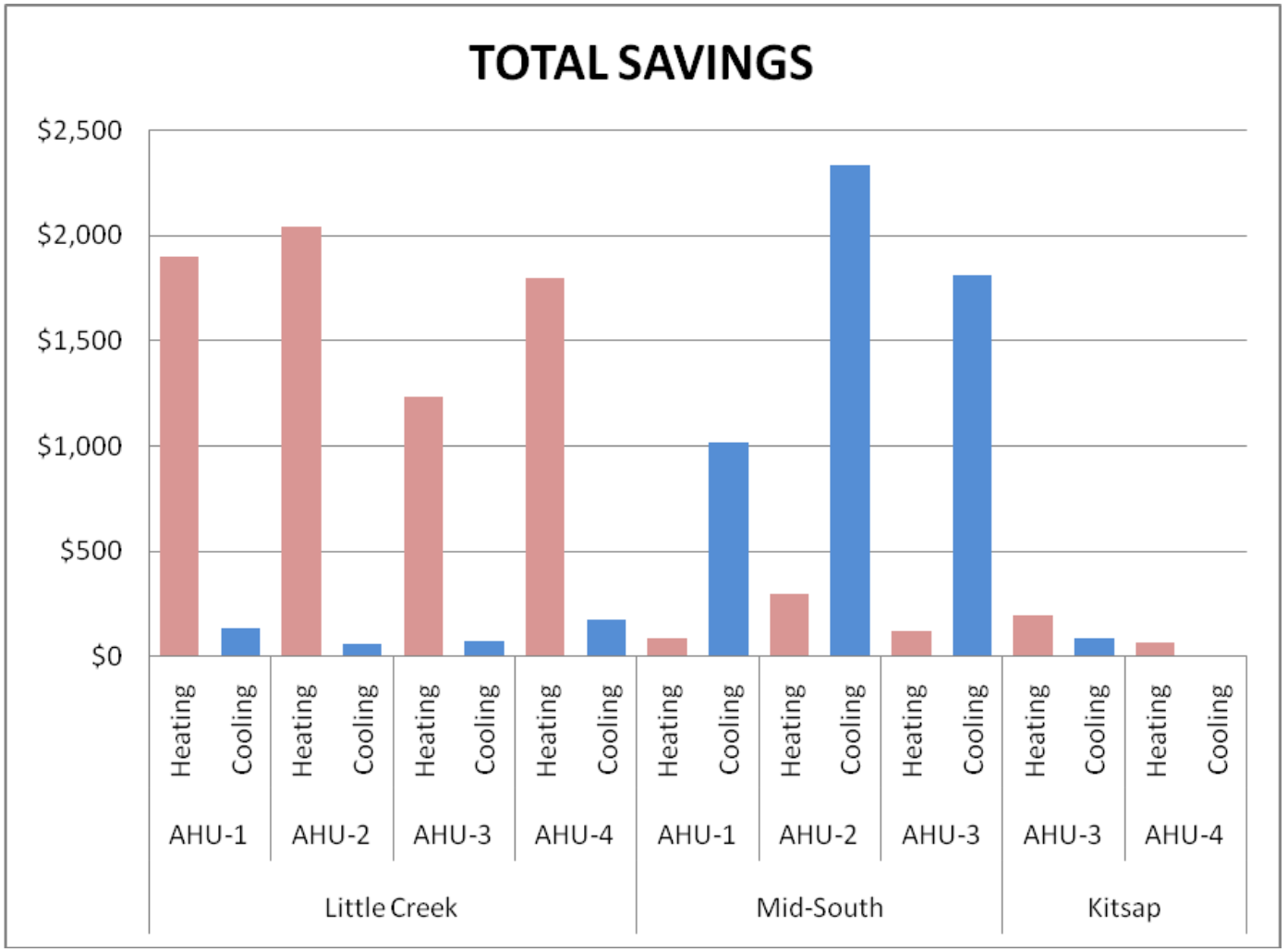
Annual Savings – All Sites



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Payback in Years – All Sites, Non Weather Corrected

	Total Installed Cost	Annual Total Savings	Payback (yrs)
Little Creek	$ 18,373	$ 7,427	2.5
Mid-South	$ 35,500	$ 5,682	6.3
Kitsap	$ 19,685	$ 348	56.6

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Energy Manager Decision Calculator – Should I Install or Not?

- If the total score is **<19**, the candidate facility is **not a good candidate** for this technology.
- If the total score is **19 - 25**, it is definitely **worth further investigation**.
- If the total score is **> 26**, it is a strong indicator of a **good candidate** for this technology.

CO_2 HVAC Controls Decision Calculator					
	Score				
Variable	**1**	**2**	**3**	**4**	**5**
CDD	<1000	1000 - 1250	1250 - 1750	1750 - 2000	>2000
HDD	<3000	3000 - 4000	4000 - 5000	5000 - 6000	>6000
Cost of heating fuel (per MBTU)	<$11	$11 - $11.50	$11.50 - $12	$12 - $12.50	>$12.50
Cost of Electricity (per kWh)	<5¢	5¢ - 6¢	8¢ - 9¢	7¢ - 10¢	>10¢
Efficiency of Heating System	>75%	65% - 75%	55% - 65%	45% - 55%	<45%
COP of Cooling System	>5	4 - 5	3 - 4	2 - 3	<2
Max SF/person in HVAC zone	>60	50 - 60	30 - 50	20 - 30	<20
% of time zone < 50% occupied	<25%	25% - 40%	40% - 55%	55% - 75%	>75%

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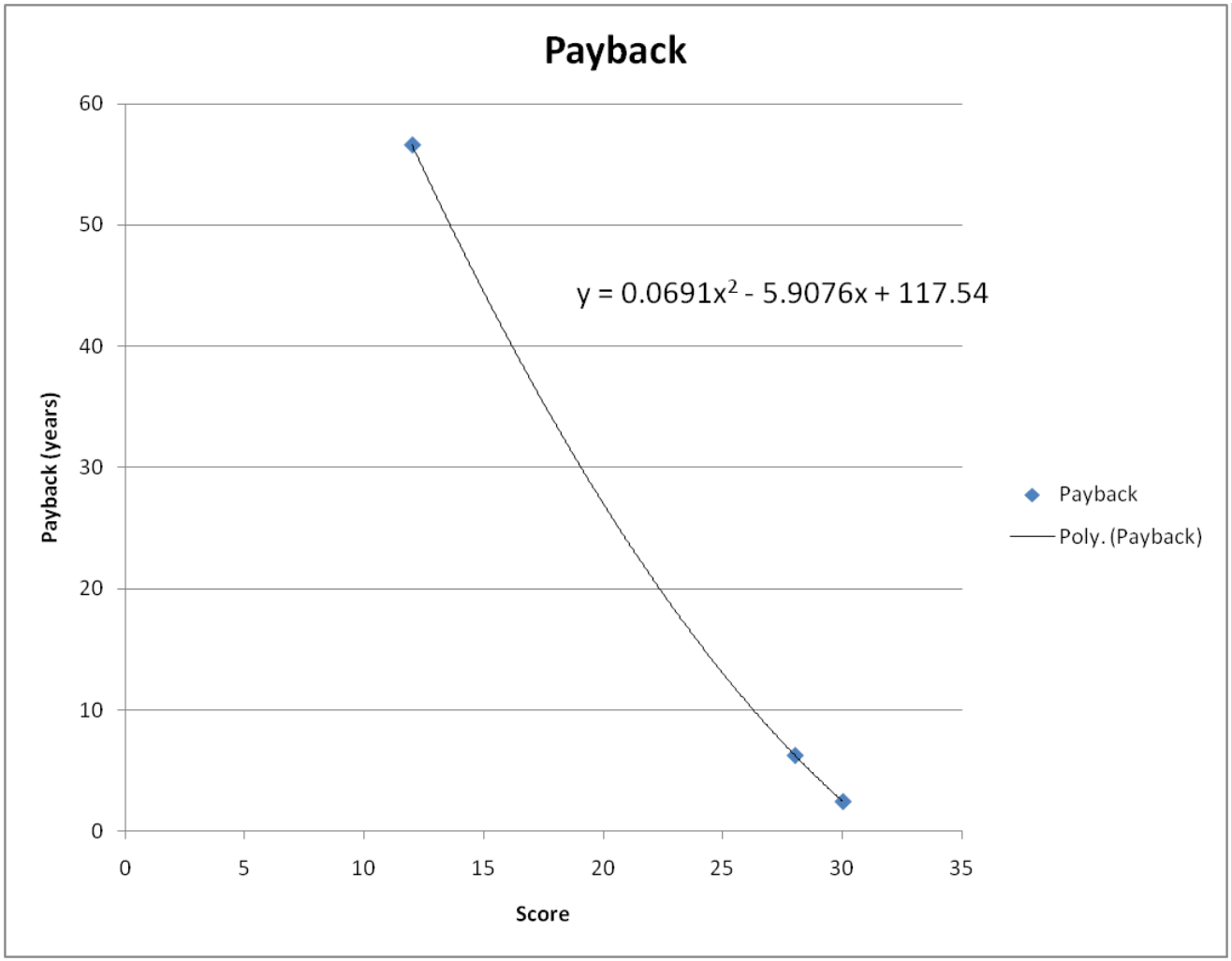
Test Site Evaluation Scores

- For the three sites included in this evaluation, the scores are:

Variable	Kitsap		Little Creek		Mid-South	
	Value	Score	Value	Score	Value	Score
CDD	393	1	2108	5	2094	5
HDD	4784	3	3066	2	3542	2
Cost of heating fuel (per MBTU)	$10.51	1	$12.08	4	$12.41	5
Cost of Electricity (per kWh)	$0.04	1	$0.03	1	$0.09	4
Efficiency of Heating System	0.8%	1	0.35%	5	0.8%	1
COP of Cooling System	3.5	3	3.5	3	3.5	3
Max SF/person in HVAC zone	100	1	15	5	20	4
% of time zone < 50% occupied	0.25%	1	0.8%	5	0.6%	4
Totals		**12**		**30**		**28**

Payback Based on Evaluation Score



Score	Payback
1	111.7
2	106.0
3	100.4
4	95.0
5	89.7
6	84.6
7	79.6
8	74.7
9	70.0
10	65.4
11	60.9
12	56.6
13	52.4
14	48.4
15	44.5
16	40.7
17	37.1
18	33.6
19	30.2
20	27.0
21	24.0
22	21.0
23	18.2
24	15.6
25	13.0
26	10.7
27	8.4
28	6.3
29	4.3
30	2.5
31	0.8
32	-0.7
33	-2.2
34	-3.4
35	-4.6
36	-5.6
37	-6.4
38	-7.2
39	-7.8
40	-8.2

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Conclusion

- Questions/Comments?

- Thanks for Support
  - NAVFAC TechVal Program
  - Site Energy Managers and Personnel

Supporting Slides