Heating Emergency Power System Engines with Heat Pumps

A Study in Energy Efficiency for Emergency Backup Generator Internal Combustion Engine Heating

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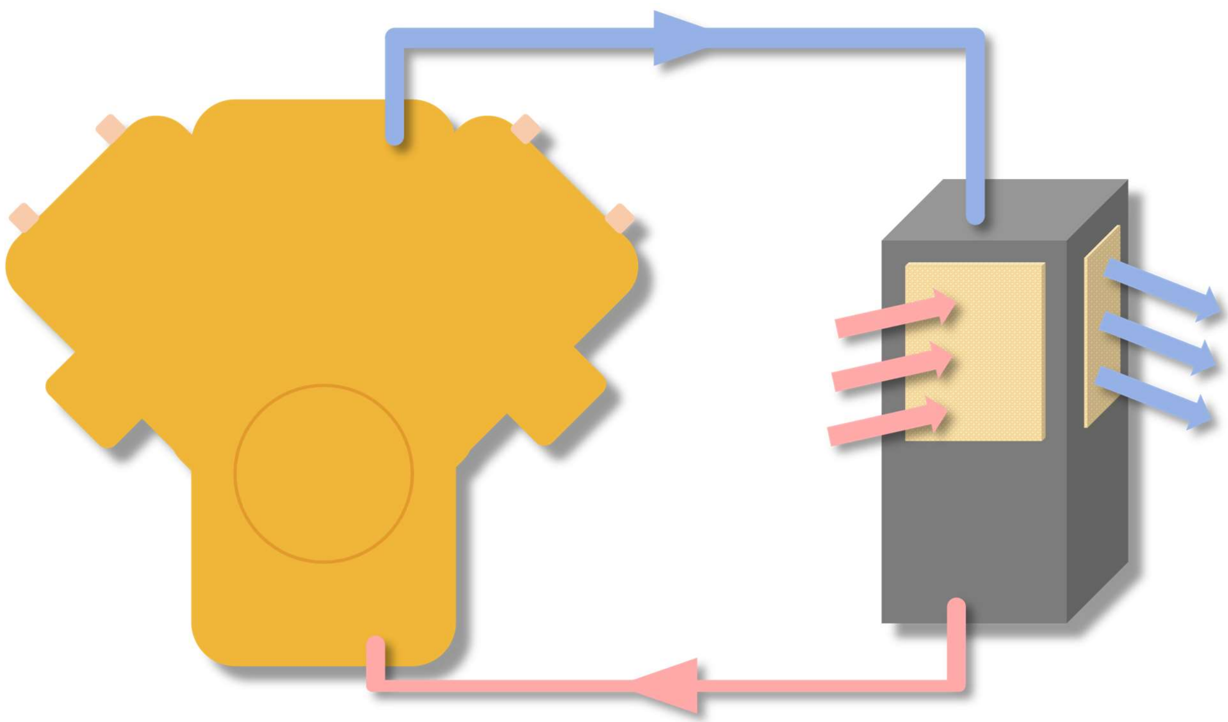

Glossary

COP – Coefficient of Performance; the efficacy of a device to move heat from one substance to another, similar to, but not to be confused with, efficiency

EEM – Energy Efficiency Measure; a device or process the reduces the amount of energy from baseline needed to complete a task

EPS – Emergency Power System; emergency backup electrical power provider

HTX- Heat Transfer; the natural process of heat moving from a hot substance to a cooler substance

ICE – Internal Combustion Engine; primary mover for most emergency power systems (emergency generators)

MTBF – Mean Time Between Failures; statistical prediction of the life of a mechanical and electrical component

NFPA – National Fire Protection Agency of the United States of America; national safety oversight and rule generating agency

OAT – Outside Air Temperature (Dry Bulb); measured by a regional weather station, for this effort, data supplied by the Spokane International Airport

OEM – Original Equipment Manufacturer; parts or equipment originally produced for use by the primary manufacturer, example Cummins or Caterpillar

TMY – Typical Meteorological Year; average climate hourly climate (dry bulb temperature, wet bulb temperature, humidity…) for an average year in a region

~ – Tilda; typically used to indicate that a reported value is an approximate value

Executive Summary

Heat pumps are everywhere, warming homes, offices, providing domestic hot water and now even providing warmth to emergency generator sets keeping them ready to start at a moment's notice. To measure and evaluate the effects of warming the generator's engine with heat pumps, five commercial facilities with 750kW to 2.5MW generators, in or around Spokane Washington USA, were retrofitted with a commercially available generator block heat pump system. Testing revealed that on average heat pumps **reduced** block warming energy consumption by **78%** (22,463 kWh per year per generator) compared to the existing baseline electric resistance heaters. For the average U.S. commercial customer this is a $3,217 /year reduction in operating costs. It would curtail 9.8 tonne of greenhouse gases for customers of a utility with 100% natural gas fired generation or 23.5 tonnes for 100% coal fired generation.

Introduction

The United States of America's National Fire Protection Agency's (NFPA) code 110 for Emergency Power Systems (EPS) requires backup power systems to startup, reach operating speed and transfer load within 10 seconds of losing electric utility services. Internal combustion engines (ICE) are the primary EPS movers; to meet the 10 second requirement ICEs are stored at a ready-to-operate temperature - block heaters are responsible for meeting temperature requirements.

The ready-to-operate temperature requirement is a boon to inefficiency due to differences in temperature between the ICE (warm), the ambient air (not so warm), and subsequent heat transfer (HTX). All energy added to the ICE by the block heater will eventually be lost to the environment.

Block heaters convert electrical energy directly into heat via resistive elements. The element is in contact with the ICE's coolant evenly distributing heat throughout the ICE. Unfortunately, from an energy efficiency standpoint, the warmed ICE then transfers heat to the environment primarily via convection and radiation.

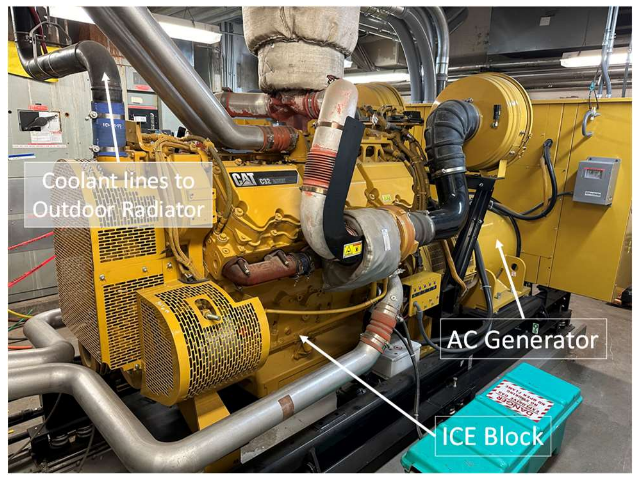

Figure 1: Example test bed enclosed, unheated, 1MW EPS.

Heat pumps do not convert electricity directly to heat. Instead, they use a refrigeration cycle to draw heat from the surrounding ambient air and transfer it, i.e. pump it, to the ICE. Electric resistance heaters are ~100% efficient while a typical air-source heat pump does the same task using ~30% of the heater's energy. A boon for energy efficiency.

This paper describes heat pump ICE heating technology, it's effect on energy consumption, and EPS operations as tested in real world applications.

Internal Combustion Engine Heating Concepts

Electric Resistance Heaters

ICE heaters are electric resistance thermostatically controlled, coolant warming secondary devices mounted externally to the ICE. Coolant flows through hoses which interconnect the heater and ICE. The heater is controlled via a thermostat; it energizes the heater as the ICE rejects heat to the environment and the ICE temperature drops below a specified setpoint.

Heaters typically range in size from 1-9kW with larger applications employing multiple heaters. Heater sizing is directly related to the ICE block's size and the installed environment (indoor, outdoor, temperature controlled). ICE block heat loss is proportional to the exposed surface area (block size) and the temperature difference between the block surface and ambient air.

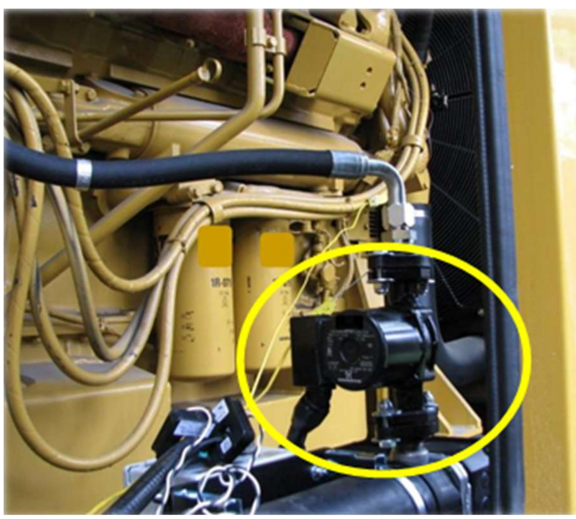

Figure 2: Examples of an ICE heater in an outdoor application.

Pumping Heat

Like a domestic heat pump water heater, an ICE heat pump uses electricity to operate the compressor to drive a refrigeration cycle moving heat from ambient air to ICE coolant.

The U.S. Department of Energy (DOE)[1] provides an excellent description of air-source heat-pump operation.

The heat pump manufacturer recommends the heat pump be installed as depicted in Figure 3. The OEM provided heater is retained as an auxiliary heater circulating coolant between the heat pump's condenser and the ICE. The OEM heater, either thermosiphon or pump-driven, serves as a pass-through while the heat pump is is operating.

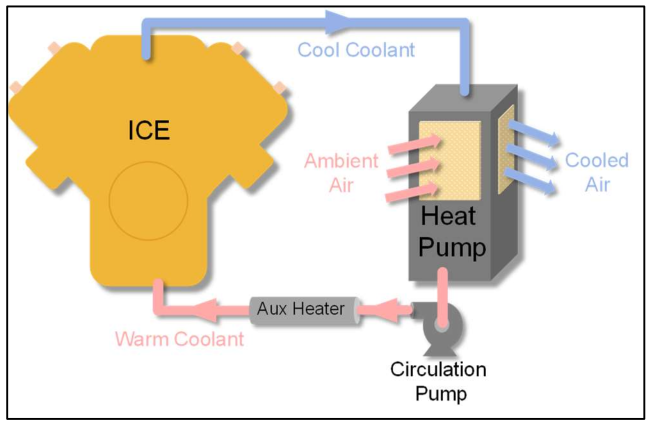

Figure 3: Generalized operational heating system diagram with heat pump, auxiliary (baseline) heater and heat pump controlled coolant circulation pump.

Heating Redundancy

An added benefit of implementing the heat pump system employed during this testing is system redundancy. It is common knowledge that heat pump capacity and efficacy is tied to the ambient air temperature. The system maintains the existing block heater in an auxiliary role, energized when ambient temperatures drop. In most conditions, this configuration adds a level of redundancy to the existing heater, essentially providing an N+1 operational backup as depicted in Figure 3.

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[1] https://www.energy.gov/energysaver/air-source-heat-pumps

At the time of this technology evaluation there appears to be one commercially available ICE heating heat pumping system produced by Hotstart (https://www.hotstart.com/). For testing, HE series devices (see Figure 4) were deployed to selected Avista Utility customer sites and evaluated in real world conditions.

Figure 4: Promotional image of Hotstart's HE ICE heating system. Image care of: https://www.hotstart.com/solutions/energy-efficient-heaters/

Test Procedures and Results

Field Testing

Five Avista Utilities customer sites participated in this effort to compare existing ICE heating technology to heat pump technology. The sites included health care, public safety corrections facility, a university, and data centers. All sites employed 750kW or larger rated EPS and all units were enclosed within facility buildings. The enclosures are a mixture of heated, heated +cooled, and un-conditioned spaces.

The testing involved baseline and reporting periods where heater current draw was measured and logged in variety OAT. Period lengths were selected to record heating energy in wide range of OATs; the periods did not span an entire year but data sets were expansive enough to allow for interpolation and extrapolation of energy use across a Typical Meteorological Year (TMY).

An ONSET HOBO H22 energy data logger with an appropriately sized split-core current transducers (CT) sampled and logged current draw. Enclosure temperature was logged using an ONSET S-TMB-M002 temperature sensor (see Figure 5). Onsite characteristic voltage and power factor measurement conducted using a Fluke 41B power harmonics analyzer (see Figure 6).

Figure 5: Onset H22 data logger, Onset TRMS module, a 15 amp current transducer (CT), and an Onset S-TMB-M002 temperature sensor.

Figure 6: Fluke 41B Power Harmonics Analyzer

Summary of Outcomes

Test sites included two medical facilities, a corrections facility, a college campus, and two data centers. For this document the sites will be denoted as A-E. All EPS were enclosed - two were heated, one was heated and cooled and three were unconditioned. Enclosure temperatures were measured and logged during baseline and reporting periods. OAT history was obtained from local weather stations via www.degreedays.net.

A summary breakdown of the ICE manufacturer and model as well as enclosure type is provided in Table 1.

Table 1: Summary of test points.

Site ID	Site Description	ICE Make	ICE Model	Enclosure Type	Base/Rep Periods
A	Medical Facility	Caterpillar	C32	unheated	Series
B	Corrections Facility	Caterpillar	3512	heated +cooled	Parallel
C	Higher Education	Cummins	KTA-50-G3	heated	Series
D	Data Center	Caterpillar	3516	unheated	Parallel
E	Data Center	Caterpillar	C27	unheated	Parallel

Once the current draw and OAT data is acquired, analysis begins. First, power consumption is calculated using the heater/heat pumps current draw, the characteristic voltage, and power factor measurements, see Table 3.

Table 2: Summary of Site A reporting period, including heat pump supply voltage, power factor, enclosure temperature range, and OAT range.

Site A: Reporting Period Summary		
V_char	208	VAC 1-ph
PF_char	1	-
T_enc_max	55	F
T_enc_min	24	F
T_OAT_max	58	F
T_OAT_min	5	F

Table 3: Truncated example of Site A's reporting period raw current draw, OAT data and power calculation.

	Measured				Calculated		
Date Time, GMT-08:00	°F, Temp Enclosure	°F, Temp OAT KSFF	A, Aux Heater	A, Heat Pump	kW, Aux Heater	kW, Heat Pump	kW, Total
1/17/2024 13:03	35	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	36	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	39	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	39	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	39	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	38	18	31	0	6.5	0.0	6.5
1/17/2024 13:04	37	18	31	0	6.5	0.0	6.5

We can now calculate the average power draw at given OAT, referred to as binning. Table 4 provides an example of the binned analysis.

Table 4: Truncated example of Site A's binned average heat pump and auxiliary heater power draw at various OAT; counts are the number of entries recorded during the period at the given OAT.

Bin: Ave Power vs OAT			
°F, OAT	kW, ave total	°F, enc	Counts
58	0.49	54	720
57	0.57	54	720
56	0.45	53	360
55	0.43	54	360
52	0.61	53	720
51	0.48	53	720
50	0.57	54	360
49	0.49	53	720
48	0.57	51	2,160

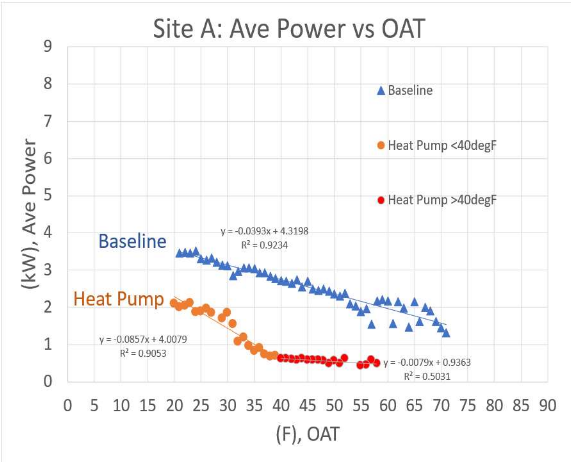


Figure 7: Graph of binned average power consumption; note reporting period's two data sets above and below 40F.

A graphical version is provided in Figure 7; this is where the benefit of the heat pump starts to become clear. Note the heat pump performance curve is shifted down from the baseline curve at the same OAT. Air-source Heat pumps have performance limitations as air temperature drops below 40°F. The auxiliary heater starts to be triggered by the heat pump's controls as the heat pump cannot move enough heat to meet demand; the straight flat curve above 40°F, changes, the slope increases and shifts upward. Eventually, if the ambient temperature dropped far enough, the heat pump performance curve would eventually meet the baseline curve as the heat pump's ability to move heat is negated. Curve fits, shown in Figure 7, based on experimental data, are created and used to predict energy use during a Typical Meteorological Year, reference Table 5 for an example.

Table 5 Truncated example of extrapolation of Site A's annual energy consumption during a TMY for the baseline and EEM systems.

Binning TMY3 Data		Baseline	Reporting
F, OAT	hr, yearly hour at this temp	kWh, annual TMY3 Spokane	kWh, annual TMY3 Spokane
97	3	0.0	0.5
96	0	0.0	0.0
95	5	0.0	1.0
94	19	0.0	3.8
93	0	0.0	0.0
92	22	1.9	4.6
91	0	0.0	0.0
90	38	7.1	8.5
89	0	0.0	0.0
88	37	10.7	8.7
87	0	0.0	0.0
86	30	11.7	7.4
85	71	31.4	17.9
84	0	0.0	0.0

With the TMY extrapolated performance data, annual energy consumption for the baseline and EEM systems are summed and compared. The results for the five sites are presented in Table 6.

Table 6: Summary of testing analysis results.

	Baseline Energy kWh/yr	Heat Pump Energy kWh/yr	Energy Savings kWh/yr	% Reduce Energy
Site A	20,236	4,035	16,201	80%
Site B	36,873	7,318	29,555	80%
Site C	21,588	3,416	18,172	84%
Site D	48,601	11,919	36,682	75%
Site E	16,440	4,737	11,703	71%
Average	**28,748**	**6,285**	**22,463**	**78%**

The heat pump system reduced energy use for all five sites. Total savings varies (11,703-36,682kWh/yr TMY) with enclosure type (conditioned vs unconditioned) and physical size of the ICE; for this effort the heat pump saved an average 22,463 kWh/yr. One a percentage basis, the savings averaged 78% reduction. Details of each site's analysis and results are provided in the appendix.

Effects on the Facility

What effect does a 22,463kWh reduction on energy usage have on a facility? First there are utility costs and secondly there are the utility's reduced Greenhouse Gas (GHG) emissions required to generate energy. Both benefits are variable, depending on each utility's rates and mix of energy resources, respectively.

Cost Savings

The outcomes for a customer served by an electric utility in Great Britain will not match a customer in Mexico City or Spokane Washington USA (see Table 7 for examples of average regional commercial rates).

Table 7: Average U.S. regional electrical energy costs per Energy Information Agency; link to website provided in appendix.

U.S. Region	Ave Commercial Elect Rate
New England	$0.2363 /kWh
Middle Atlantic	$0.1711 /kWh
East North Central	$0.1270 /kWh
West North Central	$0.0984 /kWh
South Atlantic	$0.1126 /kWh
East South Central	$0.1302 /kWh
West South Central	$0.0892 /kWh
Mountain	$0.1075 /kWh
Pacific Contiguous	$0.1938 /kWh
Pacific Noncontiguous	$0.2996 /kWh
U.S. Total	**$0.1309 /kWh**

For example, Table 8 estimates cost savings for the average Avista Washington State large-commercial customer as well as the average U.S. commercial customer. Reference the [2]Avista website and the [3]Energy Information Agency for current rate details. Be aware, rates change often, calculation examples provided are intended to provide an estimate.

Table 8: Summary of results including average annual cost savings for an Avista Washington State large commercial customer.

	Energy Savings kWh/yr	% Reduce Energy	Ave. Avista Cost Savings*	Ave. U.S. Cost Savings**	GHG Reduce*** tonne/yr
Site A	16,201	80%	$1,735 /yr	$2,320 /yr	3.62
Site B	29,555	80%	$3,165 /yr	$4,233 /yr	6.60
Site C	18,172	84%	$1,946 /yr	$2,603 /yr	4.06
Site D	36,682	75%	$3,928 /yr	$5,254 /yr	8.19
Site E	11,703	71%	$1,253 /yr	$1,676 /yr	2.61
Average	**22,463**	**78%**	**$2,405 /yr**	**$3,217 /yr**	**5.01**

*Cost savings based upon Avista large commercial rate schedule WA021; includes demand savings

**Assumed demand rate same as Avista WA021

***GHG emission reduction based upon Avista's resource mix; referfence appendix

The average commercial electric rate for the USA is $0.13/kWh.

Greenhous Gas Reduction

Like rates, resource mixes vary drastically across utilities. Avista is in the Pacific Northwest of the United States where hydro generation is the dominant resource. As of 2024, it is 49% of Avista's mix (Figure 8). Hydro generation emits zero GHGs.

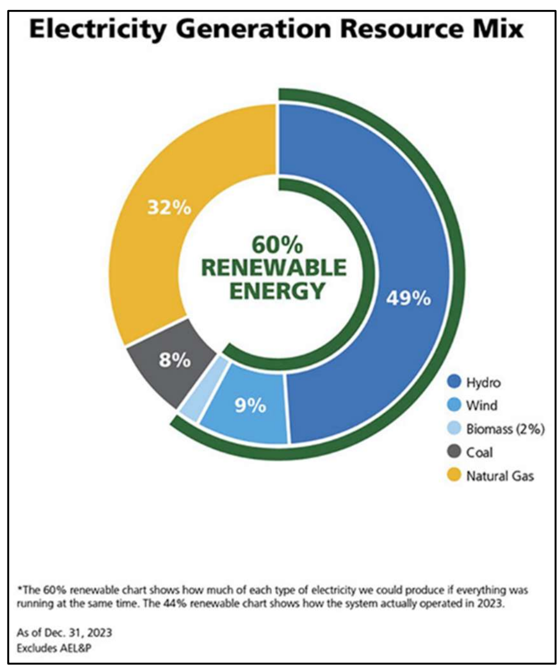


Figure 8: Avista's energy resource mix as of 2024; reference www.myavista.com.

[2] www.myavista.com

[3] https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a

This means that benefits of the heat pump system are not fully realized when compared to a customer served by utility with 100% [4]coal generation, see Table 9.

Table 9: Greenhouse gas reduction for an Avista customer and for comparison emission reduction for customers of utilities with 100% coal fired generation and 100% natural gas fired turbine generation.

	Energy Savings kWh/yr	% Reduce Energy	Avista GHG Reduce tonne/yr	100% Coal GHG Reduce tonne/yr	100% Nat. Gas GHG Reduce tonne/yr
Site A	16,201	80%	3.6	17.0	7.1
Site B	29,555	80%	6.6	31.0	12.9
Site C	18,172	84%	4.1	19.0	7.9
Site D	36,682	75%	8.2	38.4	16.0
Site E	11,703	71%	2.6	12.3	5.1
Average	**22,463**	**78%**	**5.0**	**23.5**	**9.8**

Customer's of a 100% coal burning utility will curtail 23.5 metric tonnes of greenhouse gas emissions with the heat pump; 9.8 tonnes for a 100% natural gas burning utility.

Conclusion

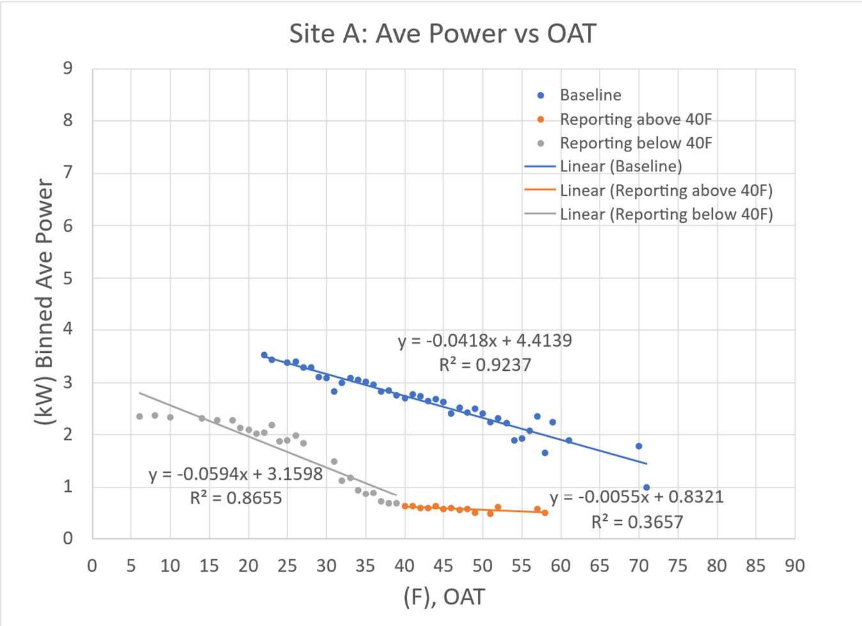
The five heat pump retrofits resulted in noticeable reduction in energy consumption, with performance aligning with heat pump technology in HVAC and water heating applications. Customers with a large (750kW-2.5MW) EPS can benefit from retrofitting the units with this technology.

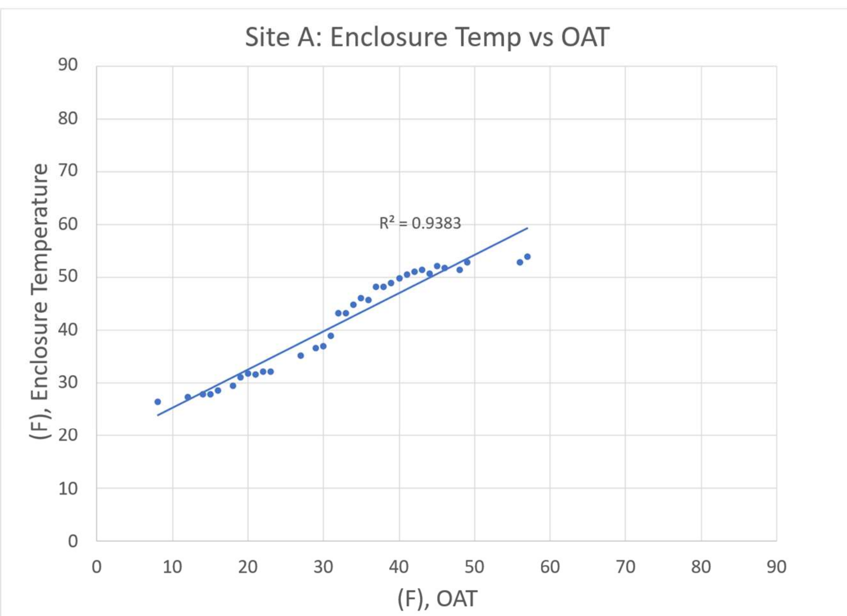
Levi Westra PE CEM CMVP is a Principal Energy Efficiency Engineer at Avista Utilities where he has worked with industrial customers to improve efficiency within their facilities, since 2009. In 2000 Levi graduated from the University of Idaho with a Bachelor's of Science degree in Mechanical Engineering and a Master's of Engineering in Mechanical Engineering from the University of Idaho in 2007.

[4]Average GHG output per kWh for generation of a given fuel type https://www.eia.gov/tools/faqs/faq.php?id=74&t=11

Appendix: Summary of Results for Each Site

	Enclosure Type	ICE Make	ICE Model	ICE Disp (L)	Baseline kWh/TMY	Heat Pump kWh/TMY	Savings kWh/TMY	% Reduce
Site A: Medical	unheated	Caterpillar	C32	32	20,236	4,035	16,201	80%

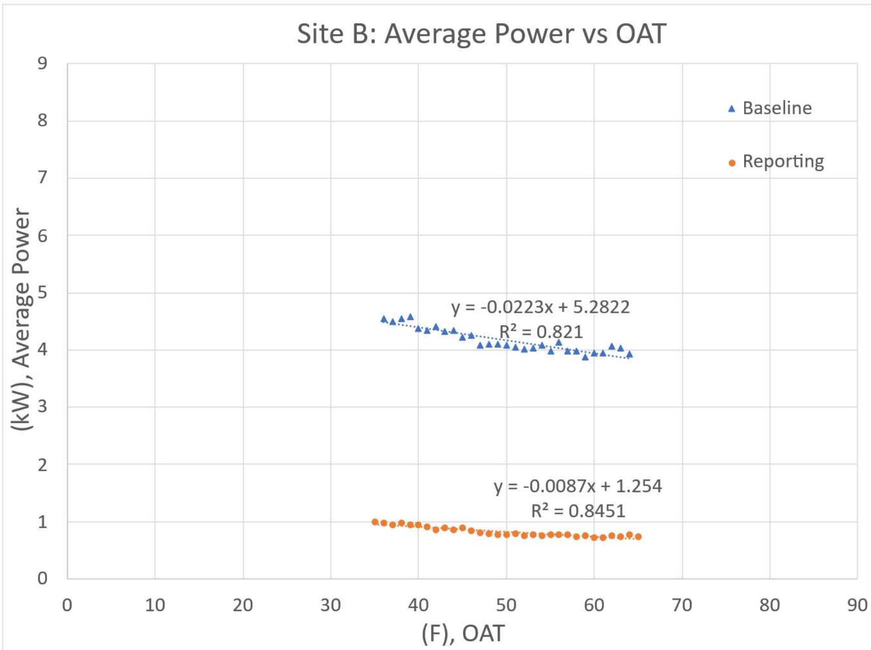


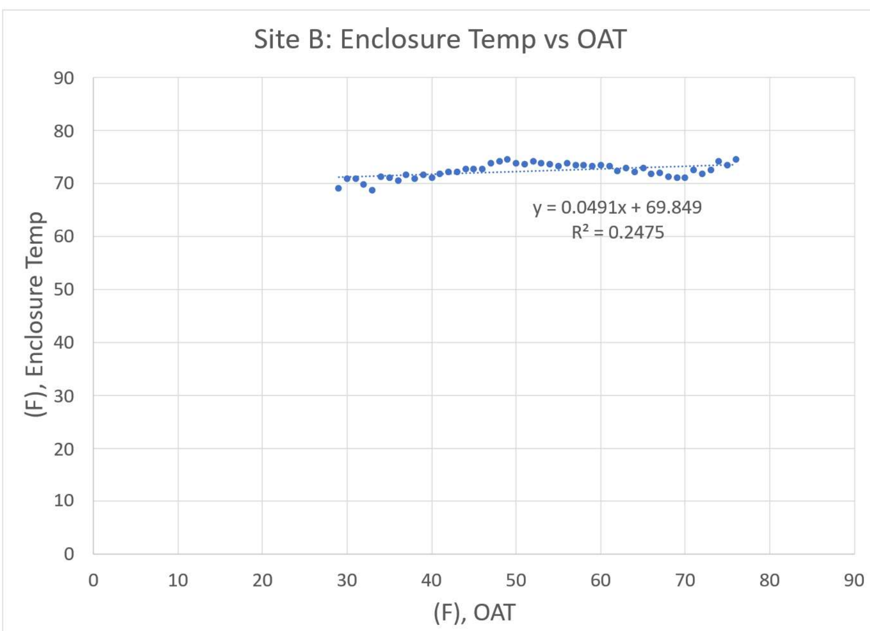


Site A Baseline Ave Power vs OAT		
F, OAT	counts	kW, ave
71	240	1.0
70	540	1.8
61	240	1.9
59	420	2.2
58	300	1.7
57	300	2.3
56	300	2.1
55	420	1.9
54	540	1.9
53	360	2.2
52	780	2.3
51	900	2.2
50	1,020	2.4
49	1,080	2.5
48	1,440	2.4
47	1,320	2.5
46	1,500	2.4
45	1,618	2.6
44	1,140	2.7
43	1,920	2.6
42	1,740	2.7
41	1,200	2.8
40	2,340	2.7
39	2,040	2.8
38	2,160	2.9
37	1,200	2.8
36	1,320	3.0
35	1,020	3.0
34	1,560	3.0
33	780	3.1
32	1,320	3.0
31	1,440	2.8
30	960	3.1
29	600	3.1
28	600	3.3
27	420	3.3
26	240	3.4
25	660	3.4
23	480	3.4
22	300	3.5

Site A Reporting Ave Power vs OAT		
F, OAT	counts	kW, ave
58	720	0.49
57	720	0.57
52	720	0.61
51	720	0.48
49	720	0.49
48	2160	0.57
47	1800	0.55
46	2161	0.59
45	2880	0.58
44	2520	0.63
43	5400	0.58
42	3960	0.59
41	7200	0.63
40	18000	0.63
39	10440	0.68
38	9000	0.68
37	12960	0.72
36	13680	0.89
35	1080	0.87
34	6480	0.94
33	720	1.17
32	3600	1.12
31	3960	1.48
27	720	1.84
26	1080	1.99
25	6480	1.89
24	720	1.88
23	720	2.19
22	3240	2.03
21	2160	2.02
20	2160	2.10
19	690	2.14
18	720	2.27
16	720	2.27
14	1080	2.32
10	720	2.33
8	1080	2.37
6	720	2.35

	Enclosure Type	ICE Make	ICE Model	ICE Disp (L)	Baseline kWh/TMY	Heat Pump kWh/TMY	Savings kWh/TMY	% Reduce
Site B: Corrections	heated+cooled	Caterpillar	3512	51.8	36,873	7,318	29,555	80%

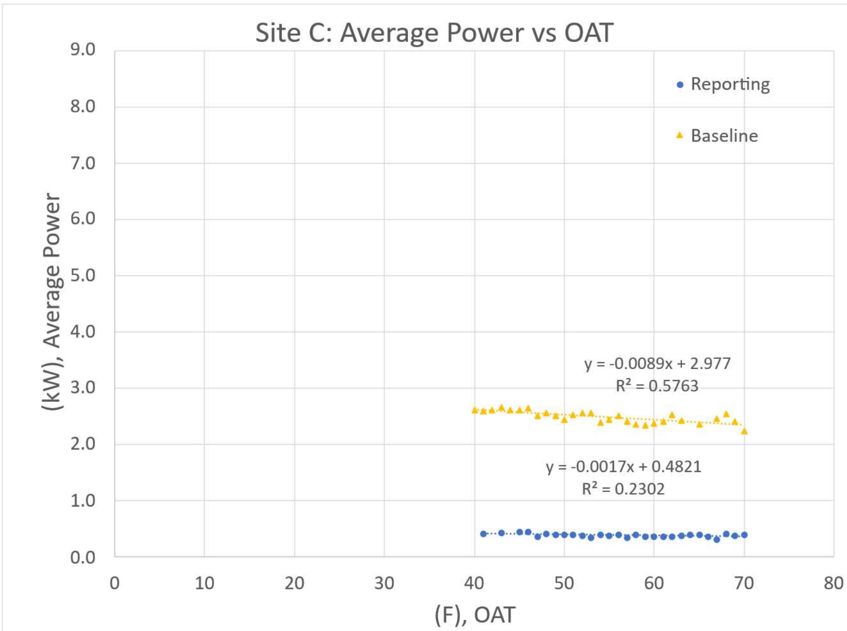


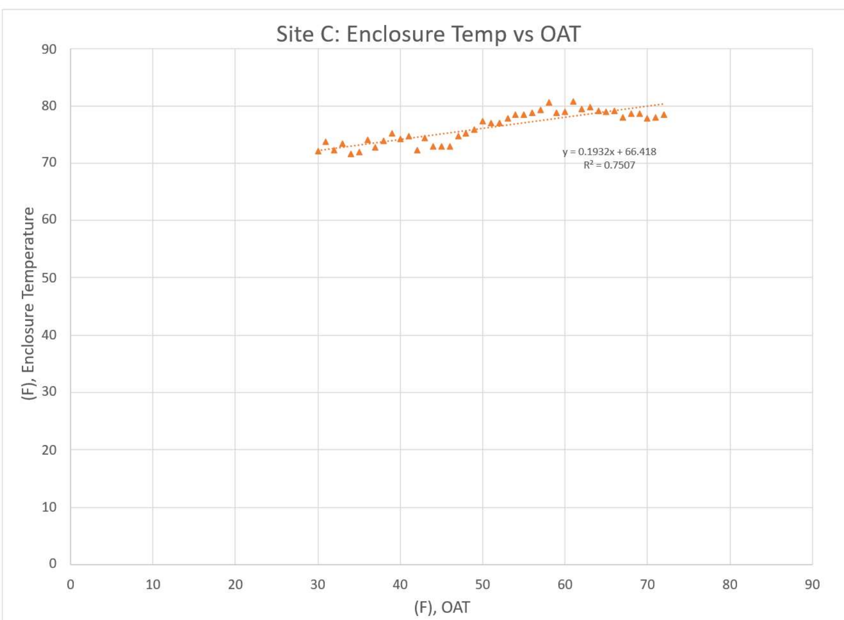


Site B Baseline and Reporting Ave Power vs OAT

F, OAT	F, Enc	kW, base	kW, EEM	Counts
76	74.5	4.43	0.76	180
75	73.4	4.07	0.78	60
74	74.2	4.23	0.76	120
73	72.6	4.43	0.80	600
72	71.9	4.54	0.83	300
71	72.7	4.05	0.78	360
70	71.2	4.32	0.79	300
69	71.0	4.39	0.80	540
68	71.3	4.53	0.80	180
67	72.0	4.40	0.78	180
66	71.9	4.11	0.78	600
65	72.9	3.93	0.74	540
64	72.3	4.04	0.78	600
63	72.9	4.07	0.74	865
62	72.4	3.95	0.75	540
61	73.3	3.94	0.73	1,080
60	73.6	3.88	0.72	540
59	73.3	3.97	0.75	780
58	73.5	3.97	0.74	900
57	73.5	4.13	0.76	840
56	73.8	3.99	0.76	780
55	73.4	4.08	0.77	660
54	73.7	4.03	0.75	1,980
53	73.9	4.01	0.78	1,380
52	74.2	4.05	0.75	1,980
51	73.7	4.09	0.78	1,020
50	73.9	4.10	0.78	1,860
49	74.5	4.09	0.77	2,040
48	74.3	4.08	0.80	1,800
47	73.9	4.25	0.80	1,620
46	72.8	4.22	0.84	1,560
45	72.7	4.34	0.89	2,760
44	72.8	4.33	0.86	960
43	72.3	4.41	0.90	3,180
42	72.3	4.35	0.85	1,320
41	71.9	4.38	0.91	1,620
40	71.1	4.59	0.94	2,340
39	71.7	4.54	0.94	1,500
38	71.0	4.49	0.97	1,215
37	71.7	4.55	0.95	960
36	70.6	4.59	0.98	1,680
35	71.2	4.55	0.99	840
34	71.2	4.51	0.95	1,440
33	68.9	4.95	1.04	360
32	69.8	4.72	1.05	660
31	71.0	4.52	0.97	540
30	70.9	4.43	0.88	360
29	69.1	4.85	1.11	120
28	76.3	3.80	0.64	180
27	68.3	4.17	1.06	60

	Enclosure Type	ICE Make	ICE Model	ICE Disp (L)	Baseline kWh/TMY	Heat Pump kWh/TMY	Savings kWh/TMY	% Reduce
Site C: Higher Ed.	heated	Cummins	KTA-50-G3	50.3	21,588	3,416	18,172	84%





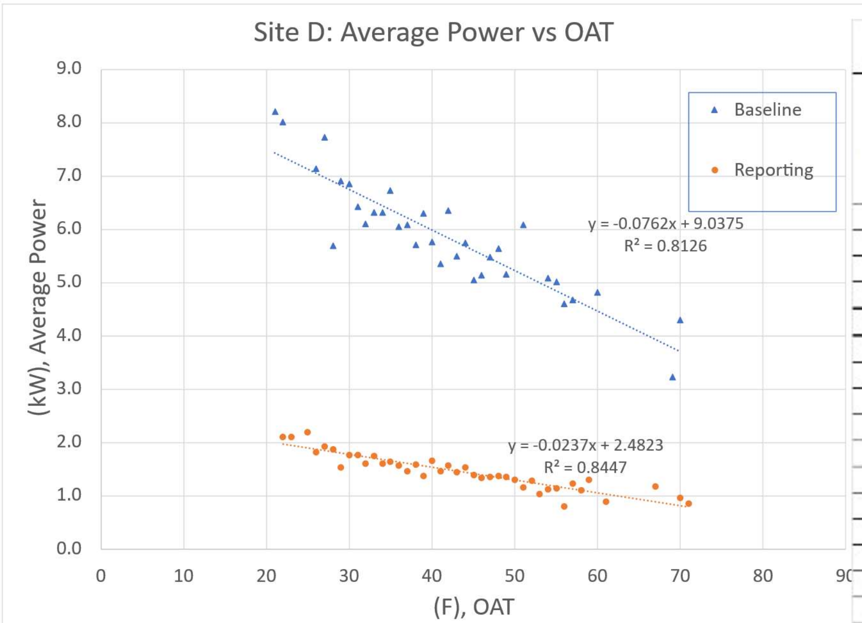
Site C Baseline Ave Power vs OAT

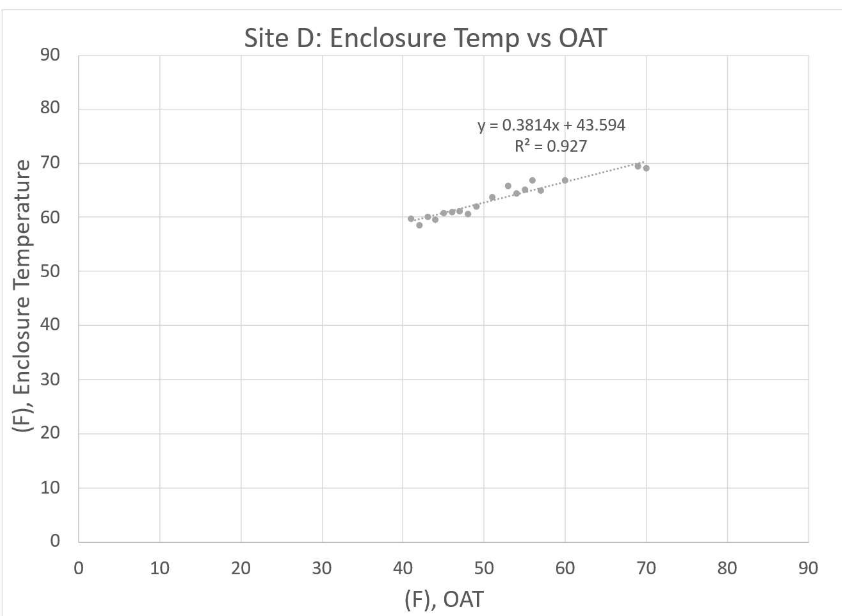
OAT	Ave Power	Counts
76	2.2	120
75	3.0	60
74	2.8	60
72	2.5	360
71	2.8	120
70	2.2	360
69	2.4	360
68	2.5	480
67	2.5	480
66	2.6	660
65	2.4	600
64	2.2	120
63	2.4	1,200
62	2.5	960
61	2.4	540
60	2.4	960
59	2.3	300
58	2.4	1,260
57	2.4	1,380
56	2.5	1,020
55	2.5	1,500
54	2.4	1,380
53	2.6	1,320
52	2.6	2,484
51	2.5	2,160
50	2.4	2,460
49	2.5	3,240
48	2.6	3,120
47	2.5	4,020
46	2.6	3,000
45	2.6	3,600
44	2.6	2,760
43	2.7	5,160
42	2.6	2,880
41	2.6	3,872
40	2.6	5,880

Site C Reporting Ave Power vs OAT

OAT, (F)	P_ave, kW	counts
83	0.27	480
82	0.27	716
81	0.26	840
80	0.31	780
79	0.29	660
78	0.23	660
77	0.32	600
76	0.33	780
75	0.33	420
74	0.36	1,440
73	0.35	840
72	0.35	960
71	0.30	840
70	0.40	1,080
69	0.38	1,800
68	0.41	660
67	0.32	1,380
66	0.37	1,440
65	0.39	1,380
64	0.39	1,620
63	0.38	2,635
62	0.37	1,500
61	0.36	1,620
60	0.37	1,080
59	0.36	1,920
58	0.40	2,400
57	0.35	1,260
56	0.39	2,460
55	0.39	1,440
54	0.40	1,860
53	0.34	840
52	0.39	1,320
51	0.40	960
50	0.40	1,320
49	0.40	900
48	0.41	1,080
47	0.37	600
46	0.44	600
45	0.45	600
43	0.43	300
41	0.41	300

	Enclosure Type	ICE Make	ICE Model	ICE Disp (L)	Baseline kWh/TMY	Heat Pump kWh/TMY	Savings kWh/TMY	% Reduce
Site D: Data Center	unheated	Caterpillar	3516	69	48,601	11,919	36,682	75%





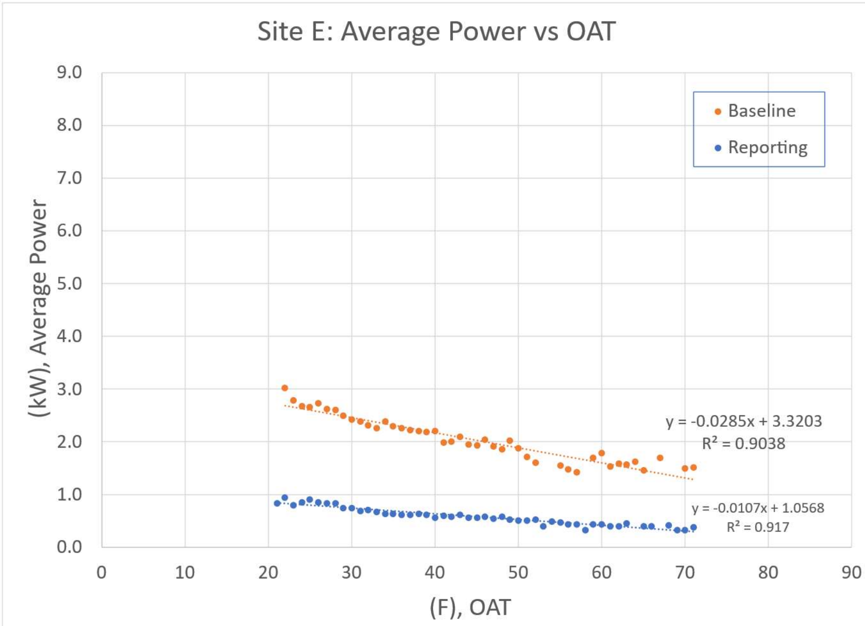
Site D Baseline Ave Power vs OAT

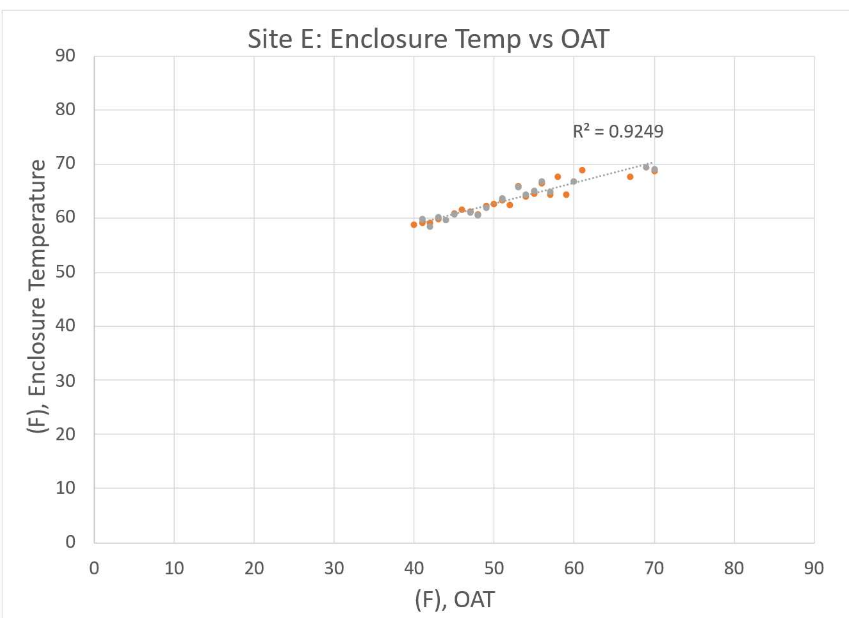
F, OAT	kW, ave power	Counts
70	4.3	9
69	3.2	2
60	4.8	1
57	4.7	4
55	5.0	6
53	2.7	6
51	6.1	16
49	5.2	21
48	5.6	20
47	5.5	28
46	5.1	29
45	5.1	29
44	5.7	23
43	5.5	50
42	6.3	29
41	5.4	29
40	5.8	34
39	6.3	21
38	5.7	39
37	6.1	27
36	6.0	43
35	6.7	20
34	6.3	40
33	6.3	19
32	6.1	19
31	6.4	29
30	6.8	15
29	6.9	14
28	5.7	8
21	8.2	1

Site D Reporting Period Ave Power vs OAT

F, Binning	kW, ave	counts
71	0.86	240
70	0.97	540
67	1.06	240
61	0.93	240
59	1.40	241
58	1.07	300
57	1.23	240
56	0.79	300
55	1.15	360
54	1.12	480
53	1.04	300
52	1.28	960
51	1.11	1,020
50	1.30	1,020
49	1.44	1,200
48	1.30	1,320
47	1.36	1,500
46	1.27	1,380
45	1.41	1,860
44	1.52	1,200
43	1.44	2,700
42	1.61	1,800
41	1.47	2,040
40	1.57	1,740
39	1.37	1,500
38	1.59	1,994
37	1.47	1,380
36	1.55	2,520
35	1.65	1,020
34	1.58	1,980
33	1.77	1,200
32	1.60	1,500
31	1.72	1,500
30	1.76	1,140
29	1.66	660
28	1.75	600
27	1.99	540
26	1.91	240
25	2.12	660
23	2.05	480
22	2.16	300

	Enclosure Type	ICE Make	ICE Model	ICE Disp (L)	Baseline kWh/TMY	Heat Pump kWh/TMY	Savings kWh/TMY	% Reduce
Site E: Data Center	unheated	Caterpillar	C27	27	16,440	4,737	11,703	71%





Site E Baseline Period Ave Power vs OAT

F, OAT	kW, ave power	Counts
71	1.52	240
70	1.50	540
69	1.12	120
68	1.20	120
67	1.71	180
66	1.81	60
65	1.46	120
64	1.64	180
63	1.58	120
62	1.59	60
61	1.55	240
60	1.79	60
59	1.69	240
58	2.07	300
57	1.43	240
56	1.49	287
55	1.56	360
54	1.86	480
53	1.71	300
52	1.61	960
51	1.73	1,020
50	1.88	1,020
49	2.03	1,200
48	1.87	1,320
47	1.92	1,620
46	2.04	1,618
45	1.94	1,920
44	1.96	1,200
43	2.10	2,760
42	2.00	1,800
41	1.99	2,040
40	2.22	1,800
39	2.20	1,500
38	2.21	2,100
37	2.22	1,440
36	2.27	3,000
35	2.30	1,140
34	2.39	2,040
33	2.27	1,200
32	2.32	1,500
31	2.39	1,500
30	2.43	1,140
29	2.49	660
28	2.61	600
27	2.63	540
26	2.74	240
25	2.67	660
24	2.68	120
23	2.78	480
22	3.02	300

Site E Reporting Period Ave Power vs OAT

F, Enc	kW, Total	Counts
71	0.38	500
70	0.33	540
69	0.32	120
68	0.40	300
66	0.39	60
65	0.38	120
64	0.08	180
63	0.44	120
62	0.40	60
61	0.39	240
60	0.42	60
59	0.42	240
58	0.32	300
57	0.43	240
56	0.44	273
55	0.46	360
54	0.48	480
53	0.40	300
52	0.51	960
51	0.50	1,020
50	0.51	1,020
49	0.52	1,200
48	0.58	1,320
47	0.54	1,620
46	0.57	1,558
45	0.57	1,920
44	0.55	1,200
43	0.61	2760
42	0.57	1800
41	0.59	2040
40	0.56	1800
39	0.60	1500
38	0.62	2100
37	0.61	1440
36	0.62	3000
35	0.63	1140
34	0.63	2040
33	0.67	1200
32	0.70	1500
31	0.68	1500
30	0.73	1140
29	0.74	660
28	0.83	600
27	0.82	540
26	0.84	240
25	0.90	660
24	0.84	120
23	0.80	480
22	0.94	300