Smart Vehicle Controllers Pilot Program Data Analysis

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Prepared by

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Project Background:
Diesel vehicle engine blocks are commonly heated for a quick and smoke-free start-up during the cold weather. These heating devices are typically an immersion type heater that uses 110 Volt single phase resistive elements that are energized anytime the electrical plug is 'plugged in' to an outlet. During the winter season, these vehicle heaters are plugged in and energized whenever the vehicle is parked.

Smart Vehicle Controllers in Study:

	
IPLC Controller: This controller is hardwired and replaces the existing outlet already in place for plugging in the vehicle. http://iplc.com/m210	**Control-X:** This controller is an extension cord with a controller box in-line, it replaces the operator's existing extension cord. http://eleproducts.com/controllers/products.php

Control Design Strategy:
IPLC: The IPLC unit takes a temperature measurement every 4.5 minutes and utilizes that temperature to energize the heater a certain programmed percentage based on the ambient temperature. i.e. If the ambient temperature setting for 30°F is programmed to run the heater 80% of the time at that temperature, then the heater will run 80% of the next 4.5 minutes or 3.6 minutes ON and .9 Minutes OFF.

Control-X: The Control-X unit can utilize either an adjustable schedule to energize the heater or can utilize the ambient temperature to energize the heater. When the temperature function is used an adjustable on/off time will cycle the power. i.e. The temperature program can be set to run 30 Minutes ON and then 60 Minutes off at temperatures below 30°F

Project Objective:
The objective of this analysis was to verify that the controllers operated as expected. The data collected for this project was between March and April, 2014. We monitored six buses that are considered 'field trip buses' so they did not have a set schedule. Our test plan was as follows:

1. Install four IPLC controllers
2. Install one Control-X (CX) controller
3. Install six CT loggers in the electrical panel that provides power to the six buses in this study. One bus will be the Control bus with no controls.
4. Install two ambient air temperature loggers, one at the panel and one at the controllers.
5. Program three of the IPLC controllers with different control parameters and keep one IPLC & one Control X at its factory default parameters.

The units were programmed as follows:

Bus Barn Field Trip Buses				Temp Scale		
Bus #	Control Type	Serial #	Initial Plug-in Delay Time	Temp Scale	On %	Other Notes:
Control	None	N/A	No Delay	N/A	N/A	N/A
16	IPLC	119204	Default: 2.5 Hours	Below -12° (100%)	Above 23° (0%)	Follows Linear sloped line
39	IPLC	119207	No Delay	Below 32° (100%)	Above 60° (0%)	Follows Linear sloped line
61	IPLC	119203	No Delay	Below 60° (100%)	Above 60° (0%)	On/Off control at 60°
7	IPLC	119206	No Delay	Below 40° (100%)	Between 60°-40° (20%); Above 60° (0%)	Follows Linear sloped line
58	Control X	N/A	No Delay	Below 39° (30 min on and 20 min off cycle)	Above 39° (60 min on and 120 min off cycle)	N/A

CONTROL BUS:

This bus had no controls and was plugged in whenever the bus was parked at the lot. The heater energizes 100% when plugged in.

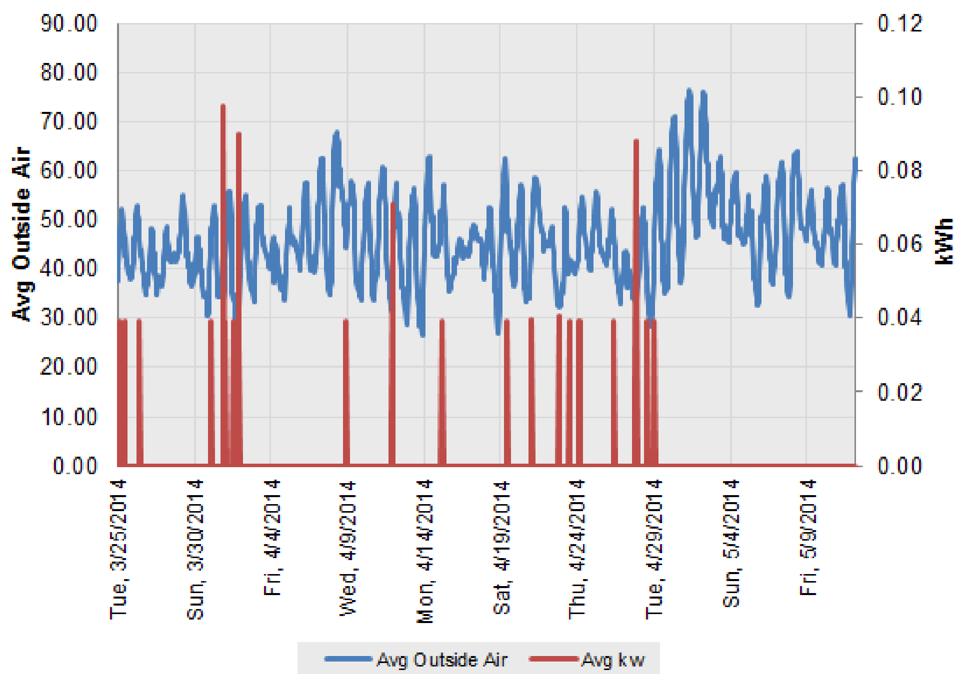
The bus data shows that it was unplugged 5 times over the 48 day period with the heater running 100% of time when plugged in with no relation to OSA temp.

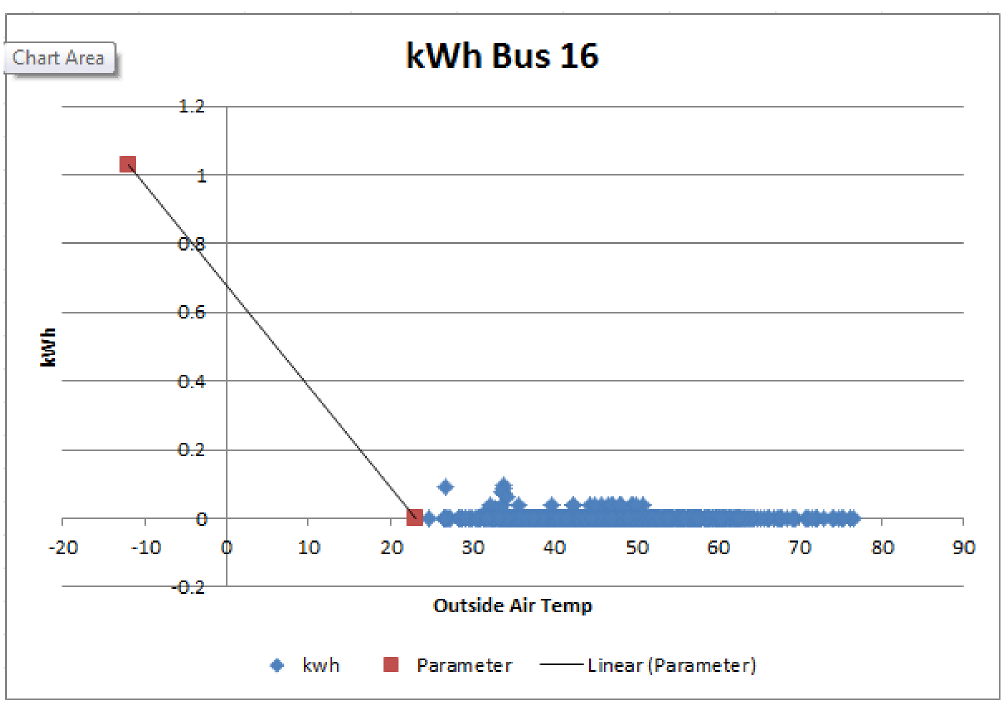
Total kWh for 33 Days: 961 kWh, ~$77 at $0.08/kWh

Bus 16 IPLC:

This bus utilized the IPLC default settings and the temperature from March to May only dropped below the minimum temperature of 23°F a few times; so the heater only energized approximately 1% of logging period. The data shows that the controller is working.

Total kWh for 33 Days: 1.45 kWh, ~$0.13 at $0.08/kWh



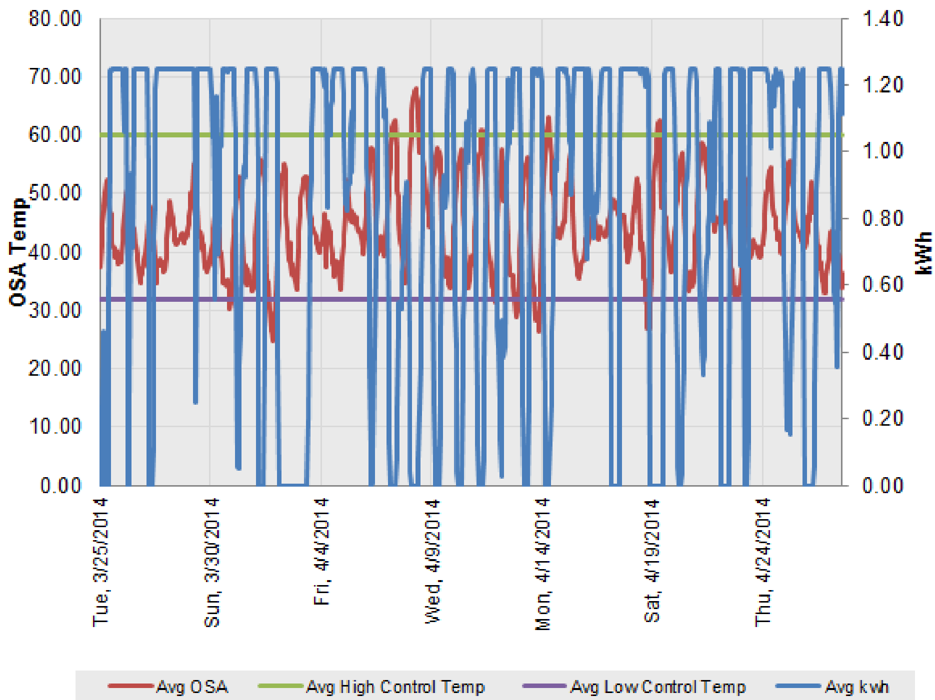


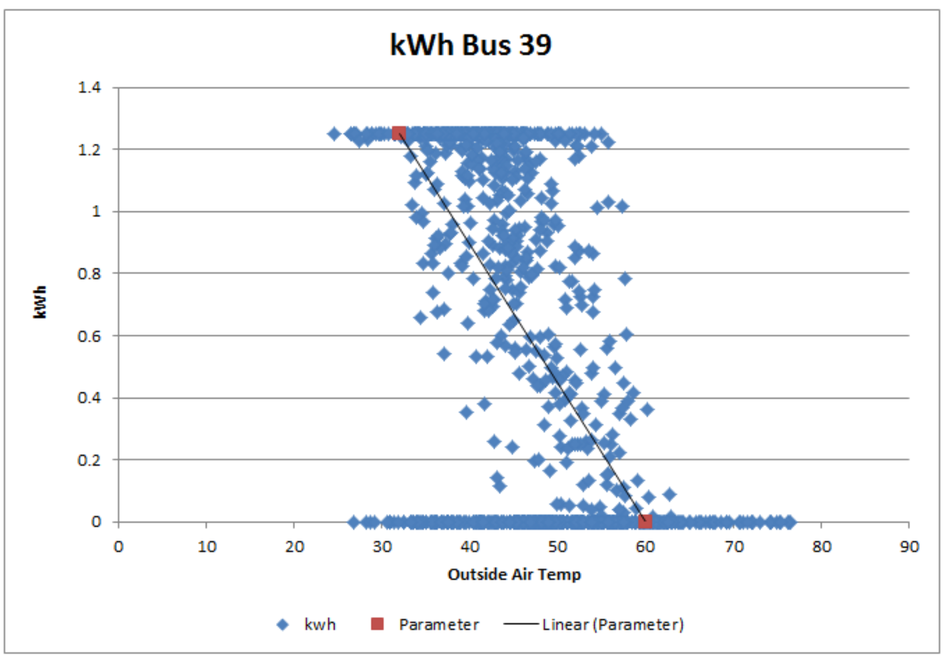
BUS 39 IPLC:

This bus utilized the IPLC controller with modified temperature control settings

Parameters: Follows a linear run time (4.5 minutes) from 32°F (100% on) to 60°F (0% on)

Total kWh for 35 Days: 655 kWh, ~$52.00 at $0.08/kWh



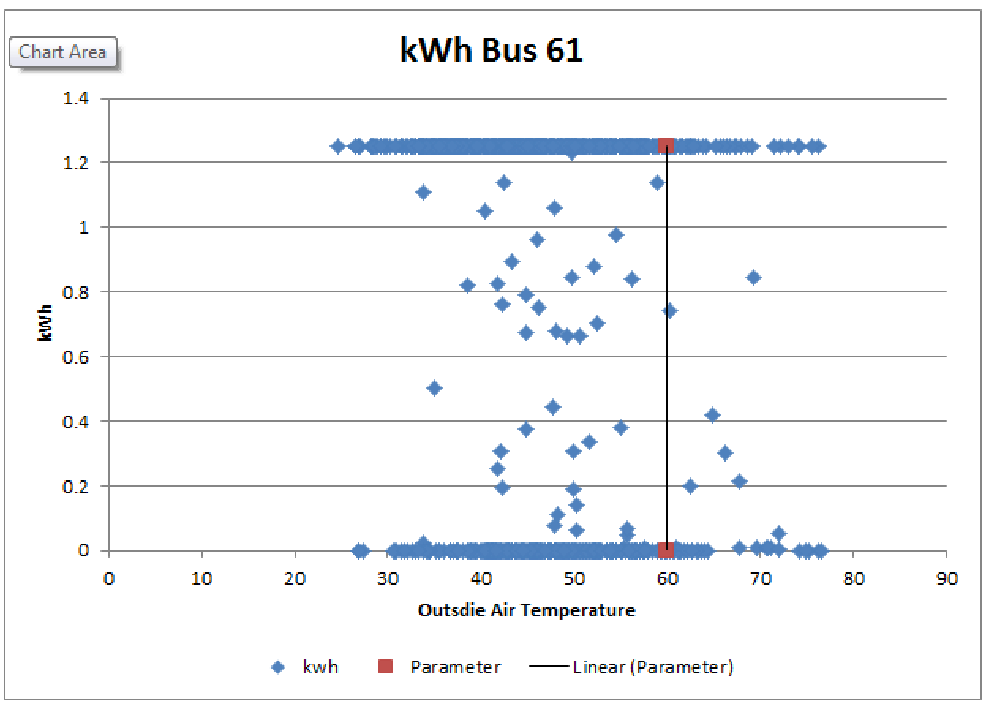


BUS 61 IPLC:

This bus utilized the IPLC controller with modified temperature control settings.

Parameters: Below 60°F heater will cycle ON, Above 60°F heater will cycle OFF.

Total kWh for 35 Days: 840 kWh, ~$67.00 at $0.08/kWh

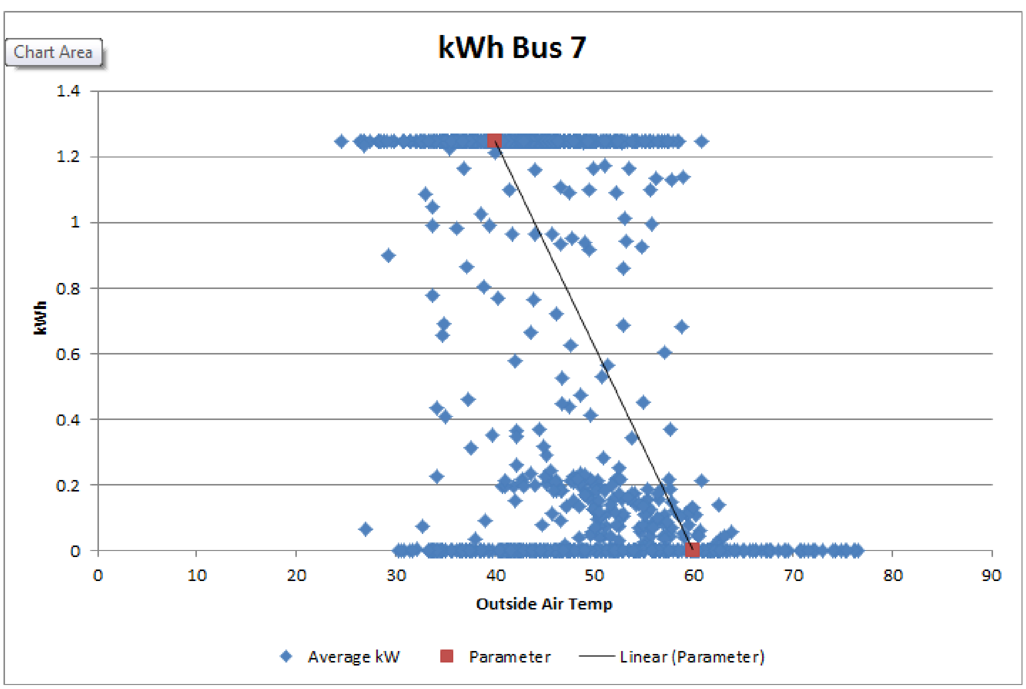


<u>Bus 7 IPLC:</u>

This bus utilized the IPLC controller with modified temperature control settings.

Parameters: Follows a linear run time (4.5 minutes) from below 40°F (100% on) & between 40 °F to 60°F (follows a linear sloped line) & above 60°F (0% on)

Total kWh for 35 Days: 713 kWh, ~$57.00 at $0.08/kWh

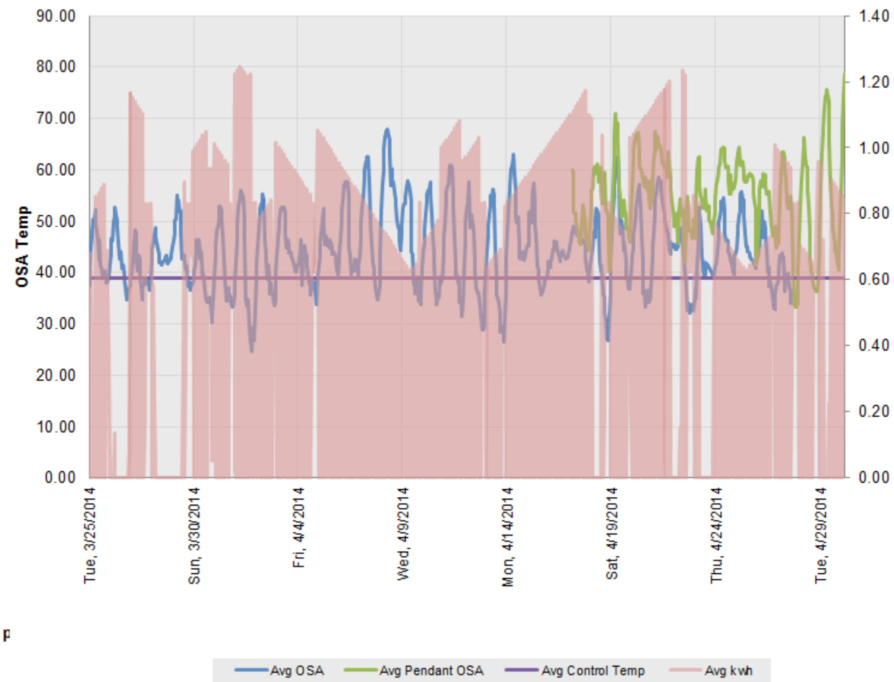


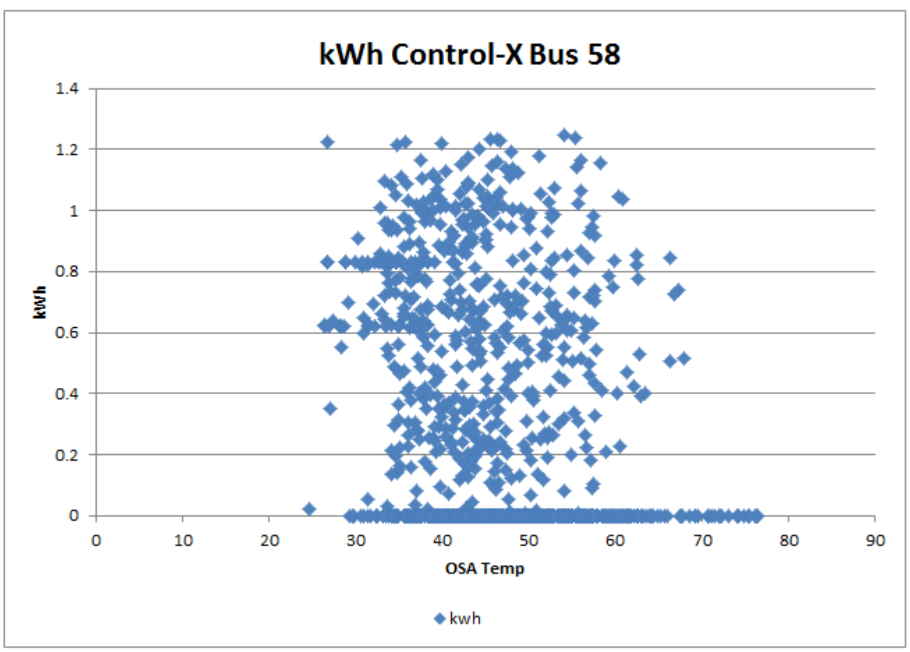
Bus 58 Control X:

This bus utilized the Control-X unit and was controlled via ambient temperature with modified control settings.

Parameters: Below 39°F heater will cycle for 30 minutes ON/20 minutes OFF. Above 39°F heater will cycle 60 minutes ON/120 minutes OFF.

Total kWh for 35 Days: 345.4 kWh, ~$28.00 at $0.08/kWh





Summary of Usage for Each Bus Heater

Bus Barn Field Trip Buses				Temp Scale	
Bus #	Control Type	Usage for the Test Period (33-35 Days)	Temp Scale	On %	Other Notes:
Control	None	**961 kWh**	N/A	N/A	N/A
16	IPLC	**1.45 kWh**	Below -12° (100%)	Above 23° (0%)	Follows Linear sloped line
39	IPLC	**655 kWh**	Below 32° (100%)	Above 60° (0%)	Follows Linear sloped line
61	IPLC	**840 kWh**	Below 60° (100%)	Above 60° (0%)	On/Off control at 60°
7	IPLC	**713 kWh**	Below 40° (100%)	Between 60°-40° (20%); Above 60° (0%)	Follows Linear sloped line
58	Control X	**345.4 kWh**	Below 39° (30 min on and 20 min off cycle)	Above 39° (60 min on and 120 min off cycle)	N/A

Data-Mate (IPLC Program Tool) Downloaded Data:

This summary table is data taken directly from the IPLC controller units.

3/25/14 to 5/12/14								
Bus#	Heater Load (kW)	Power On Time (Days)	Power On Time (Hrs)	Plug In Time (HRS)	kWh without IPLC	kWh with IPLC (Actual)	Plug In Counts	Savings %
16	1.048	47.93	1150.32	368.94	386.71	1.45	21	99.63%
39	1.126	47.98	1151.52	698.14	793.44	627.03	12	20.97%
61	1.107	47.98	1151.52	820.41	911.9	895.06	19	1.85%
7	1.225	47.94	1150.56	928.43	1137.79	884.12	15	22.29%

Definition of Terms:

Bus #: Specific bus that was monitored.

Heater Load(kW): Calculated heater load based on power measurements.

Power On Time (Days & HRS): Time since IPLC controller was installed and line power established.

Plug In Time (HRS): Time when a bus extension cord was plugged into IPLC outlet.

kWh without IPLC: Multiplies the plug in time by the heater load to estimate usage without any controls.

kWh with IPLC (Actual): Actual energy use with control parameters.

Plug In Counts: Number of times the bus extension cord was unplugged and plugged back in.

Savings %: Savings from kWh without IPLC vs. kWh with IPLC (Actual).

Comparing Different Profiles for the IPLC & Control-X to TMY Data:

TMY data taken from weather station located at Fairchild AFB in Spokane, WA.

Schedule Assumptions:

Schedule	Leave	Return	Plug In Delay
Morning	7:00 AM	9:00 AM	2 Hours (IPLC Only)
Afternoon	2:00 PM	4:00 PM	2 Hours (IPLC Only)

1. Assume heater sizes of 1.2 kW
2. Not plugged in over the summer
3. Left plugged in over the weekends

Profile & Usage Descriptions:

Control Type	Annual kWh Usage Per Bus	kWh Rate	Energy Usage Cost	% Savings	Heater Load (kW)	Temperature at 100% ON	Temperature at 0% ON	Notes
No Controls	5,857	$ 0.080	$ 468.58	N/A	1.2	When Plugged In	When Unplugged	Linear
Profile Default IPLC	67	$ 0.080	$ 5.39	99%	1.2	-12°F	23°F	Linear
Profile Default Control X	2,992	$ 0.080	$ 239.36	49%	1.2	11°F	39°F	Cycles
Profile A IPLC	1,480	$ 0.080	$ 118.38	75%	1.2	0°F	50	Linear
Profile B IPLC	3,473	$ 0.080	$ 277.86	41%	1.2	32°F	50	Linear
Profile C Control X	650	$ 0.080	$ 52.00	89%	2.2	-12°F	23°F	Cycles

Control X Profiles:

Profile Default Control X			
Temp Range (°F)		On (minutes)	Off(Minutes)
<12		100% ON	0% OFF
12	15	120	20
16	19	105	20
20	23	90	20
24	27	75	20
28	31	60	20
32	35	45	20
36	39	30	20
>40		0% ON	100% OFF

Profile C Control X*			
Temp Range (°F)		On (minutes)	Off(Minutes)
<12		100% ON	0% OFF
12	15	120	20
16	19	105	20
20	23	90	20
24	27	OFF	
28	31	OFF	
32	35	OFF	
36	39	OFF	
>39		OFF	

*Profile C Control X has same temperature settings as Profile Default IPLC.

Cost Comparisons:

Controller	Retail Price
IPLC Unit*	$153
Control X Unit	$190

*One Data-mate controller is needed to setup custom profiles and download reports for the IPLC units, Retail $240

Comparison of savings for same schedule as above for IPLC units in Spokane, Seattle, & Missoula:

	Annual kWh Usage Per Bus		
Control Type	Spokane Airport	Seattle Airport	Missoula Airport
No Controls (unplugged above 55°F)	5,857	5,935	6,646
Profile Default IPLC	67	0	148
Profile A IPLC	1,480	581	1,785
Profile B IPLC	3,473	1,588	3,931

	% Savings from No Controls Per Bus		
Control Type	Spokane Airport	Seattle Airport	Missoula Airport
No Controls (unplugged above 55°F)	5,857	5,935	6,646
Profile Default IPLC	99%	100%	98%
Profile A IPLC	75%	90%	73%
Profile B IPLC	41%	73%	41%

Product Feature Comparisons:

1. **<u>Intelligent Parking Lot Controller (IPLC).</u>** This controller is hardwired and replaces the existing outlet already in place for plugging in the vehicle.
    a. The controller features include:
        i. Initial plug-in delay time (factory default setting is 2.5 HRS)
        ii. Programmable heater power based on ambient temperature
        iii. LED light indicators for status & troubleshooting
        iv. Downloadable preformatted data reports. See appendix B for examples.
2. **<u>Control X controller (CX)</u>**. This controller is an extension cord with a controller box in-line, it replaces the operator's existing extension cord.
    a. The controller features include:
        i. Schedule or ambient temperature control
        ii. No installation required, plug and play
        iii. Portable

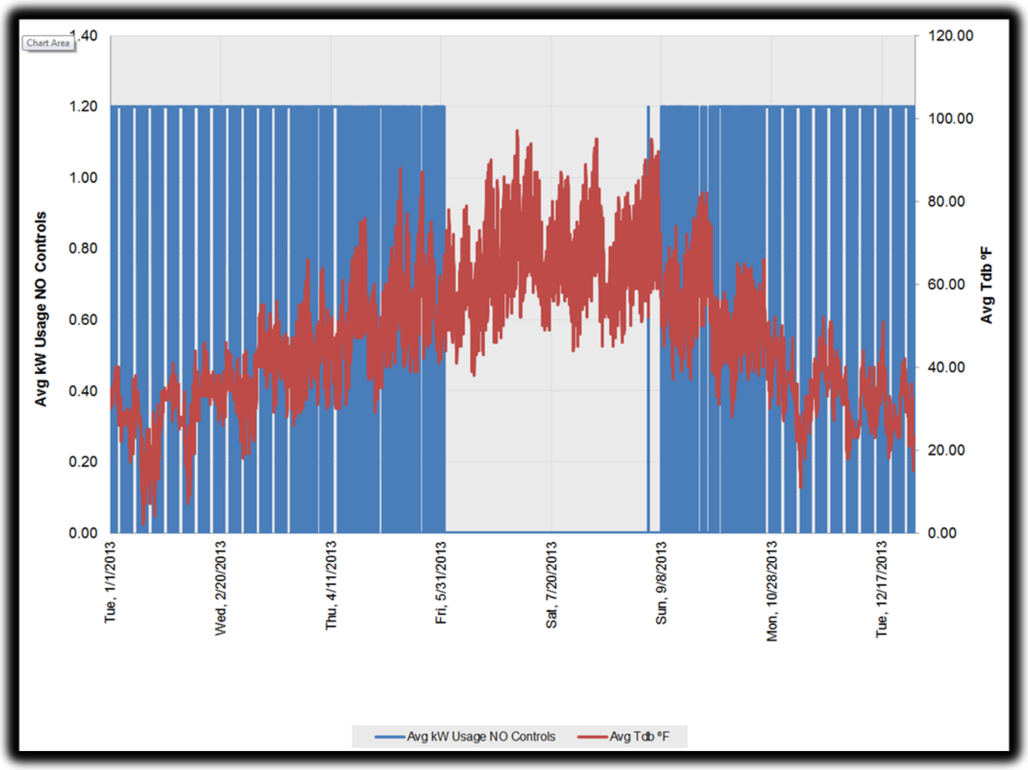
Conclusions:

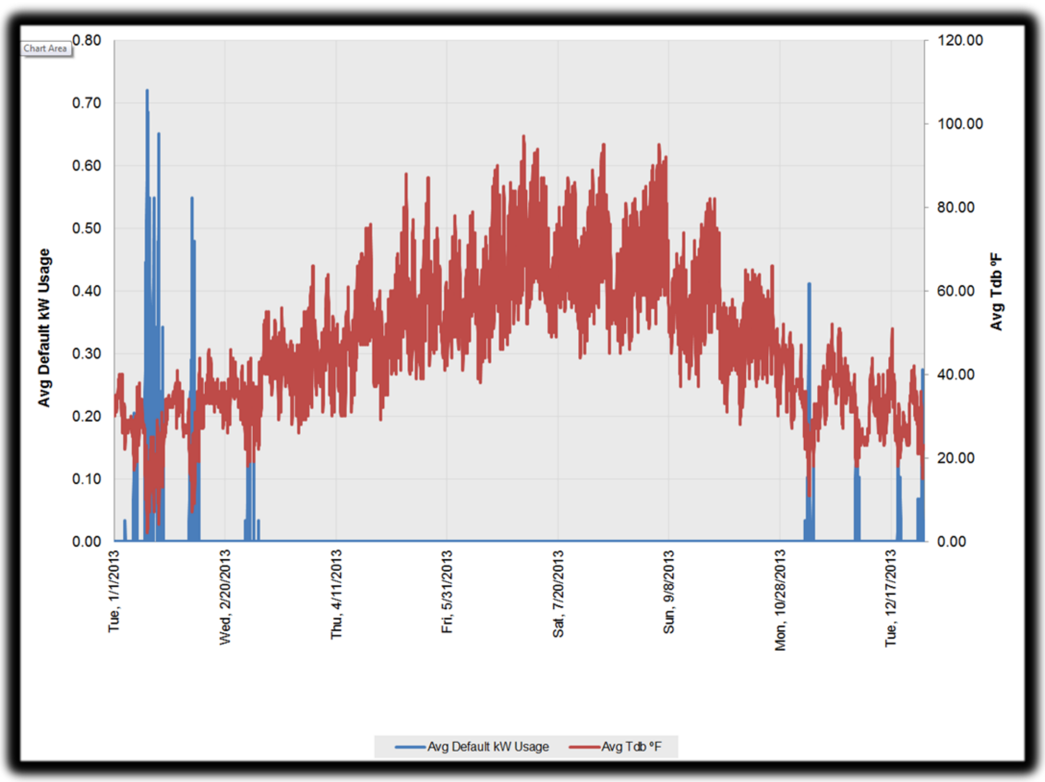
Both heaters show good potential for energy savings with low simple payback durations based on the aggressiveness of the user defined programming. The default programming for both controllers showed the highest savings.

Next Steps:

1. Discuss possibility of installing the IPLC units on 10 normal daily buses for data collection starting next school year.
2. Put together a plan for implementation including tracking bus heater usage and any changes in engine start-up.

Appendix A: TMY IPLC Profile Graphs





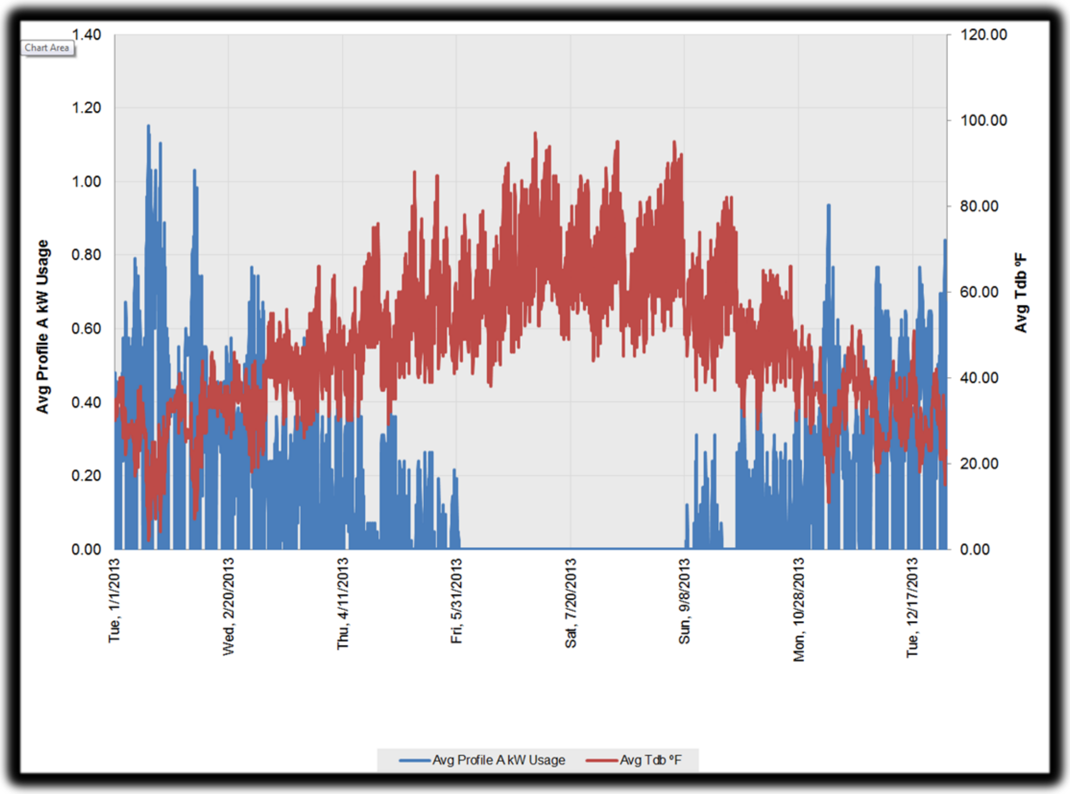
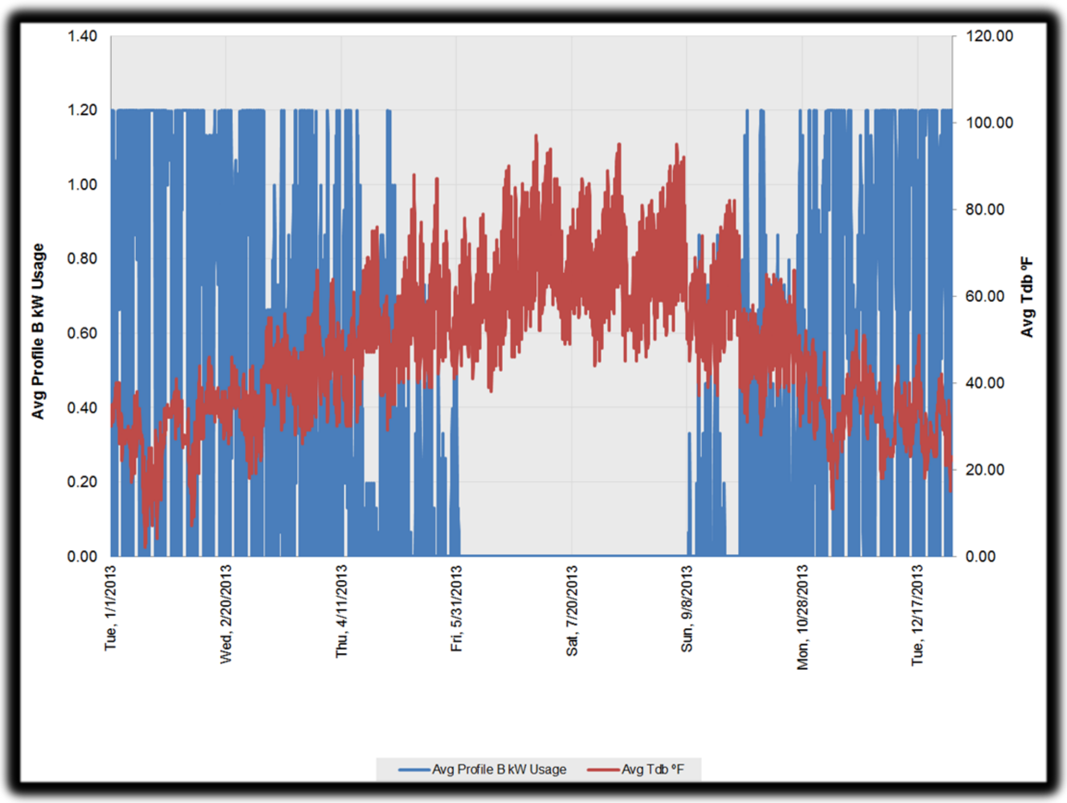
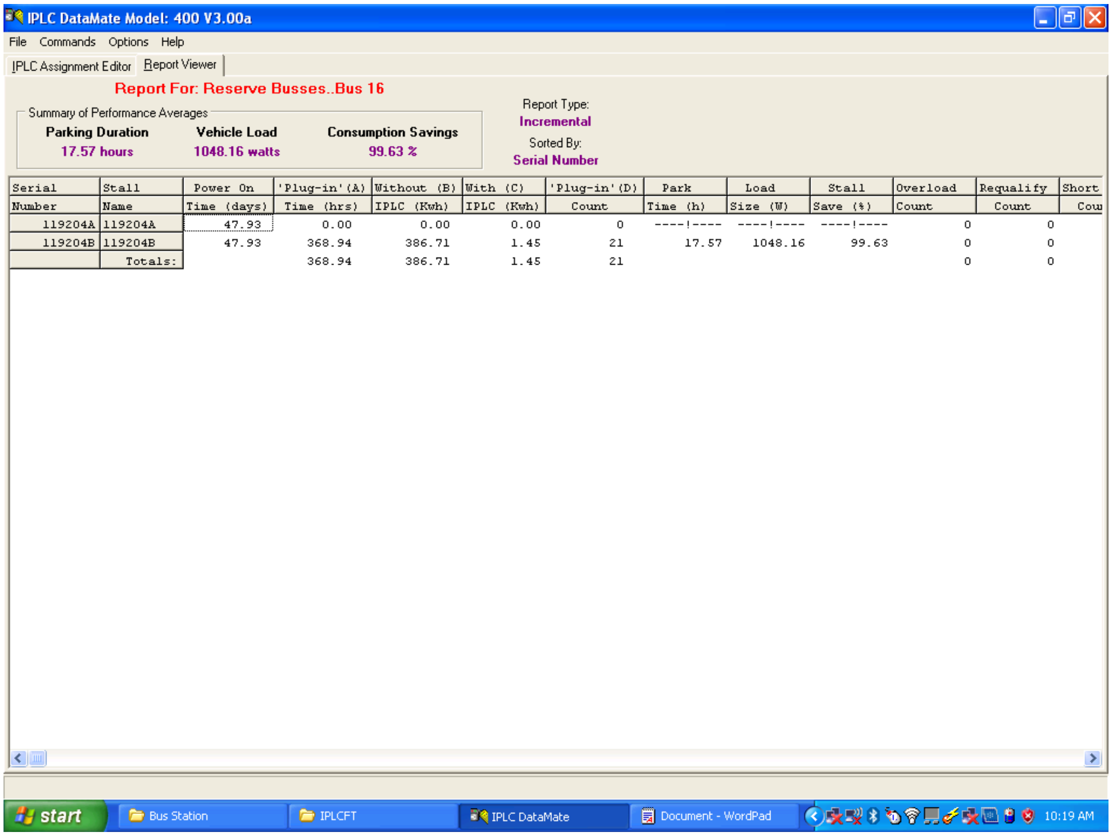


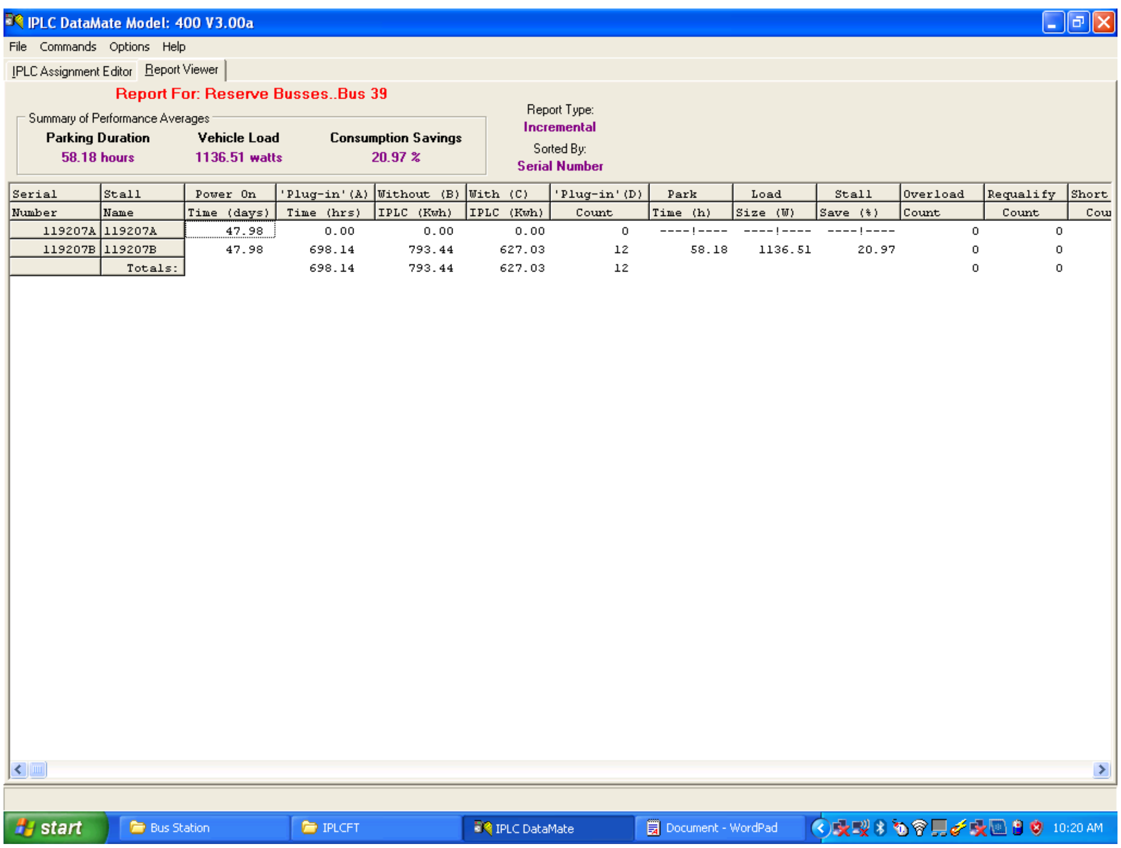
Chart Area
Avg Profile A kW Usage
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Avg Tdb °F
Tue, 1/1/2013
Wed, 2/20/2013
Thu, 4/11/2013
Fri, 5/31/2013
Sat, 7/20/2013
Sun, 9/8/2013
Mon, 10/28/2013
Tue, 12/17/2013
Avg Profile A kW Usage
Avg Tdb °F


Avg Profile B kW Usage
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Avg Tdb °F
Tue, 1/1/2013
Wed, 2/20/2013
Thu, 4/11/2013
Fri, 5/31/2013
Sat, 7/20/2013
Sun, 9/8/2013
Mon, 10/28/2013
Tue, 12/17/2013
Avg Profile B kW Usage
Avg Tdb °F

Appendix B: IPLC Example Data Print Outs



Serial Number	Stall Name	Power On Time (days)	'Plug-in'(A) Time (hrs)	Without (B) IPLC (Kwh)	With (C) IPLC (Kwh)	'Plug-in'(D) Count	Park Time (h)	Load Size (W)	Stall Save (%)	Overload Count	Requalify Count	Short Cou
119204A	119204A	47.93	0.00	0.00	0.00	0	----!----	----!----	----!----	0	0	
119204B	119204B	47.93	368.94	386.71	1.45	21	17.57	1048.16	99.63	0	0	
	Totals:		368.94	386.71	1.45	21				0	0	



Serial Number	Stall Name	Power On Time (days)	'Plug-in'(A) Time (hrs)	Without (B) IPLC (Kwh)	With (C) IPLC (Kwh)	'Plug-in'(D) Count	Park Time (h)	Load Size (W)	Stall Save (%)	Overload Count	Requalify Count	Short Cou
119207A	119207A	47.98	0.00	0.00	0.00	0	----!----	----!----	----!----	0	0	
119207B	119207B	47.98	698.14	793.44	627.03	12	58.18	1136.51	20.97	0	0	
	Totals:		698.14	793.44	627.03	12				0	0	