A Toolkit for Building Energy Consumption Data Quality Assurance/Quality Control

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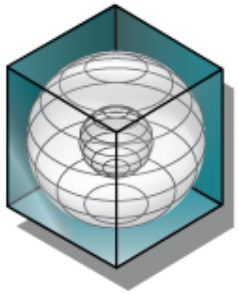

Energy Systems Laboratory
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Outline

- Motivation
- Building Energy Data Quality Assurance/Quality Control (QA/QC) Project
- Tool Development
  - Inputs
  - Modules
  - Outputs
- Examples
- Summary

Motivation

- Efficiently Manage Building Metering Data
- Reduce Manual Work Load in Preparation Data files, Plotting and Documentation
- Limit Errors due to Manual Operation
- Improve Compatibility when the Changes in Energy Data Metering Occurred

Building Energy Data QA/QC Project

- 150 Campus Buildings (~500 Meters), Total Area ~ 15 Million
- Hourly Consumption Data for Monthly Analysis
- Verify the Monthly Consumption for Billing Purpose
- Data Screening Methodology – “Energy Balance”
- Estimation of Missing/Unreliable Data by Developed Models
- Documentation of Analysis/Data/Plots

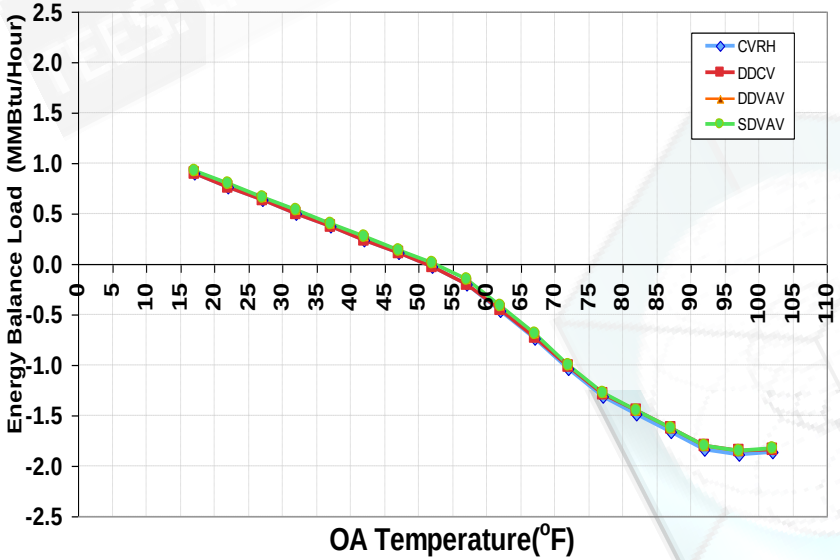
Data Screening: Energy Balance Methodology

- Assuming that there is not significant thermal energy storage in the building

$$\frac{d}{dt}\overline{E} = \overline{Q}vent + \overline{Q}solar + \overline{Q}cond + \overline{Q}occ + \overline{W}bheat - \overline{W}bcool + f\overline{W}bele = 0$$

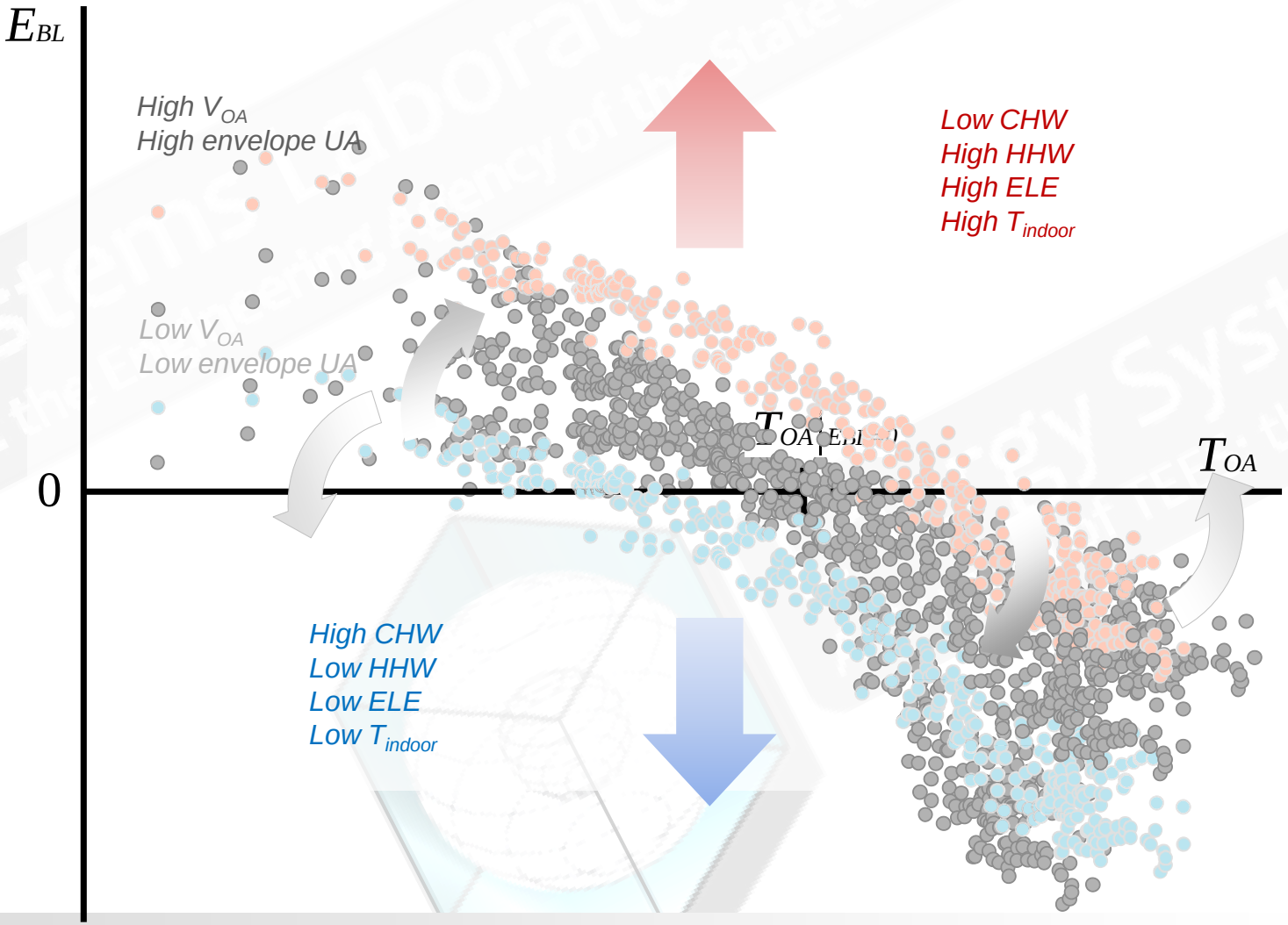
- Energy Balance equation :

$$EB_L = \overline{W}bheat - \overline{W}bcool + f\overline{W}bele = -(\overline{Q}vent + \overline{Q}solar + \overline{Q}cond + \overline{Q}occ)$$

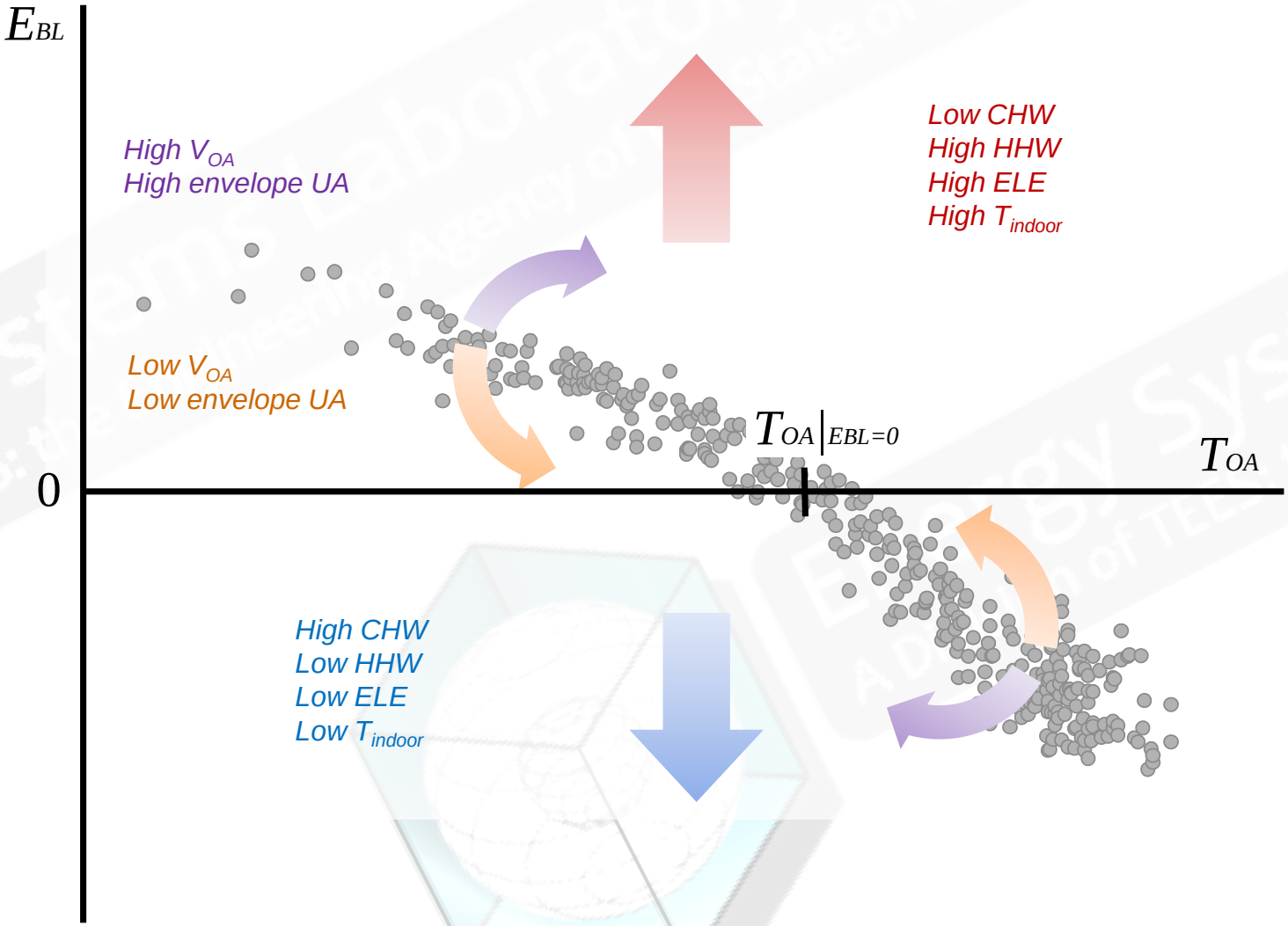


Independence of the energy balance load on secondary systems

Energy Balance Curve - Interpretation

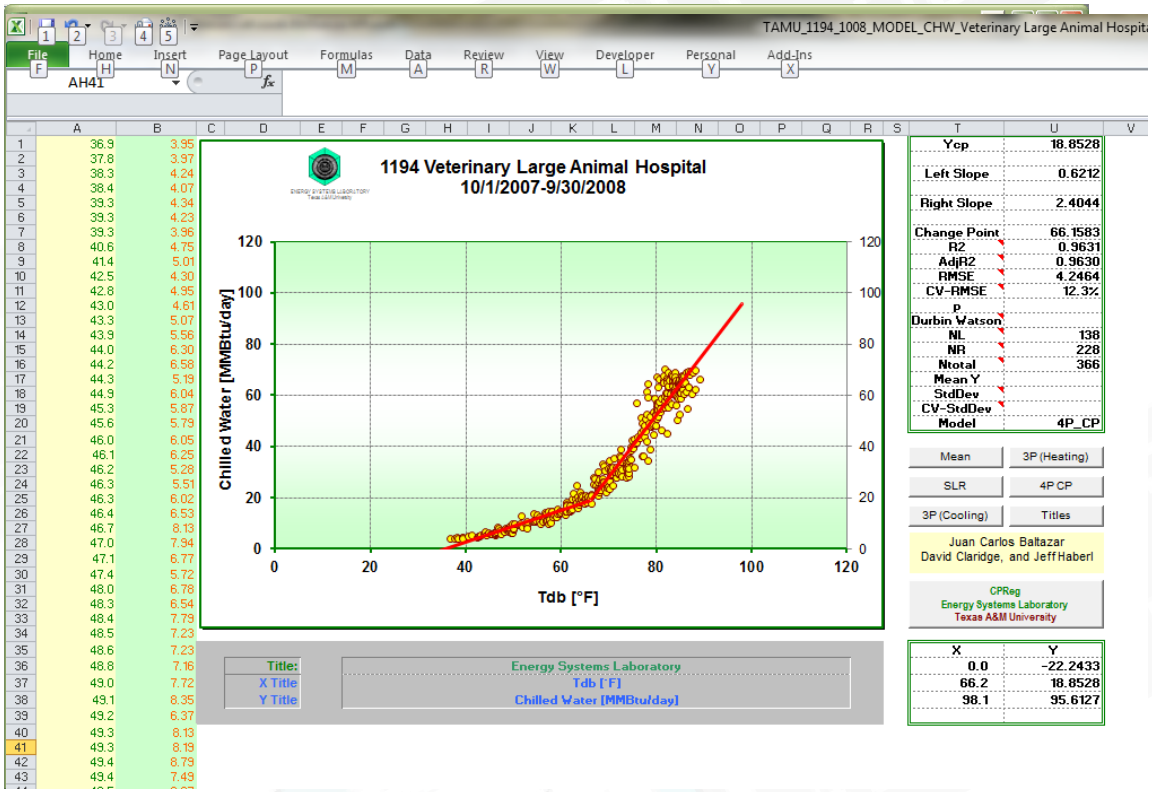


Energy Balance Curve - Interpretation



Model Development

CPReg

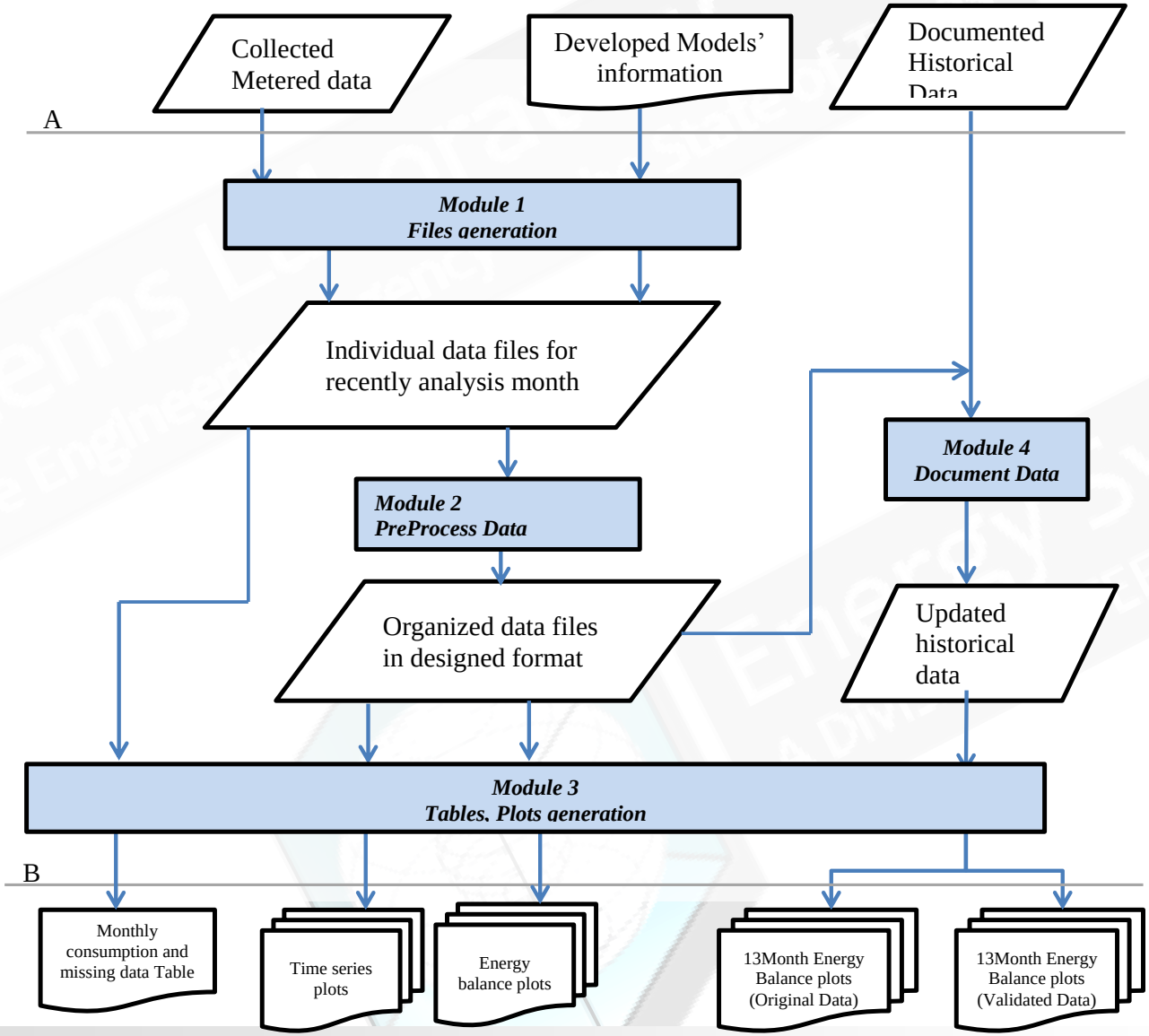


"Change Point Regression" tool (CPReg) is a tool for determining the statistical parameters of SLR, 3P-CP, 4P-CP, and Mean models.

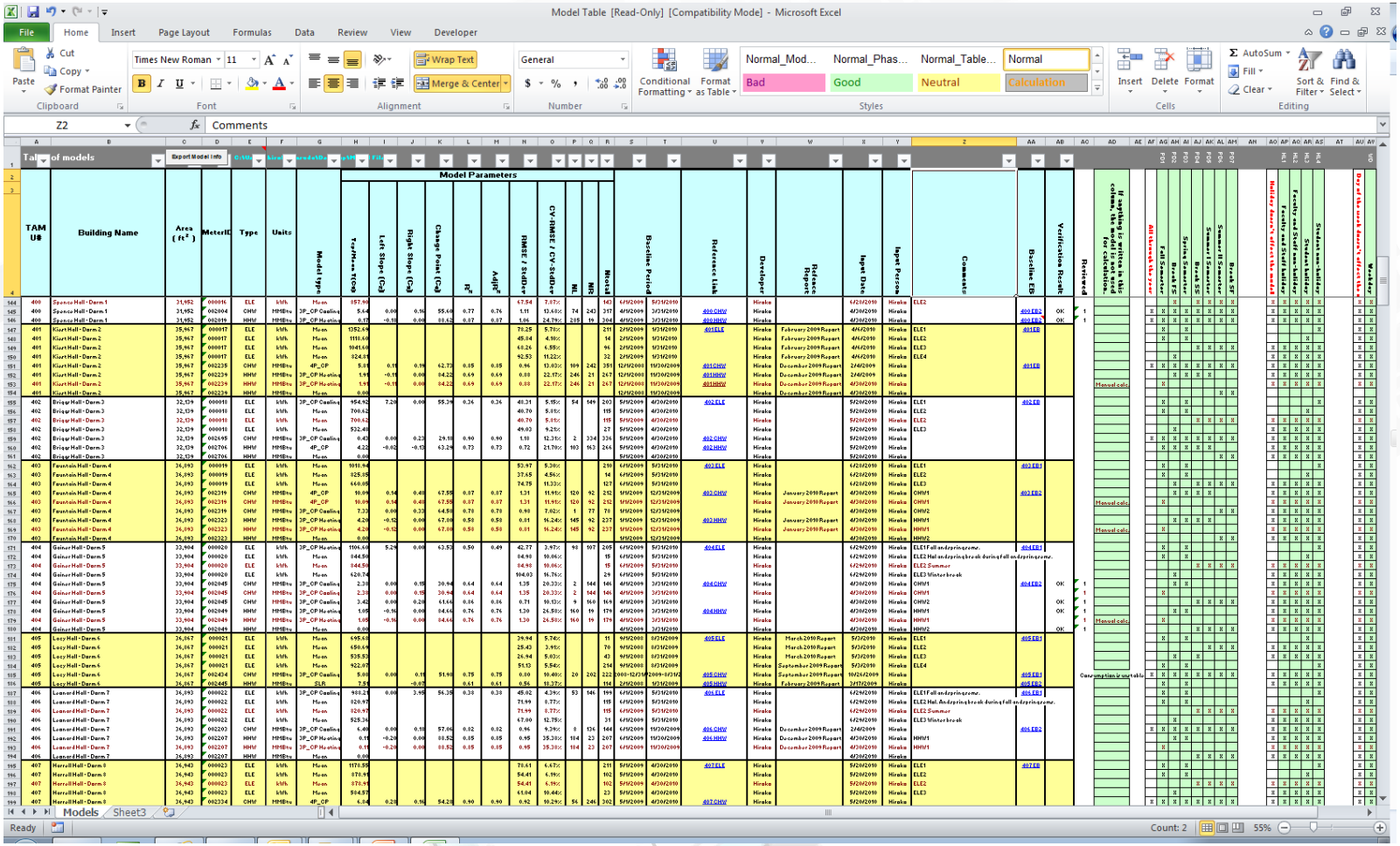
TAMU Data QC/QA- Tool

- Data Processing for TAMU Buildings
- Functions:
  - Separation and preparation of data files
  - Generation of plots
  - Detection and filling-in the missing data
  - Update and documentation of daily data files

Tool Developed for Data Process for Quality Control



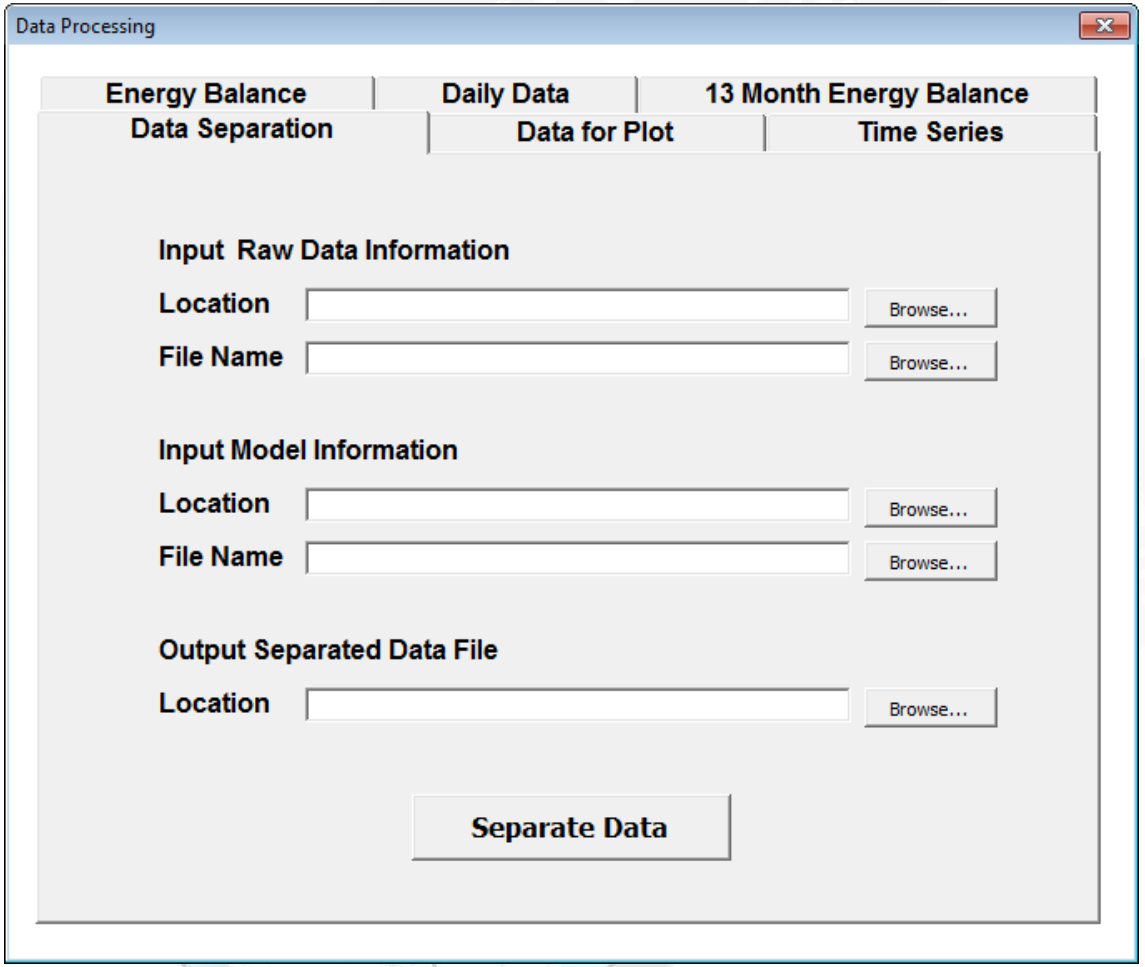
Input –Models Information



Data Processing Tool- Screen I

Module A
Module B
Module D

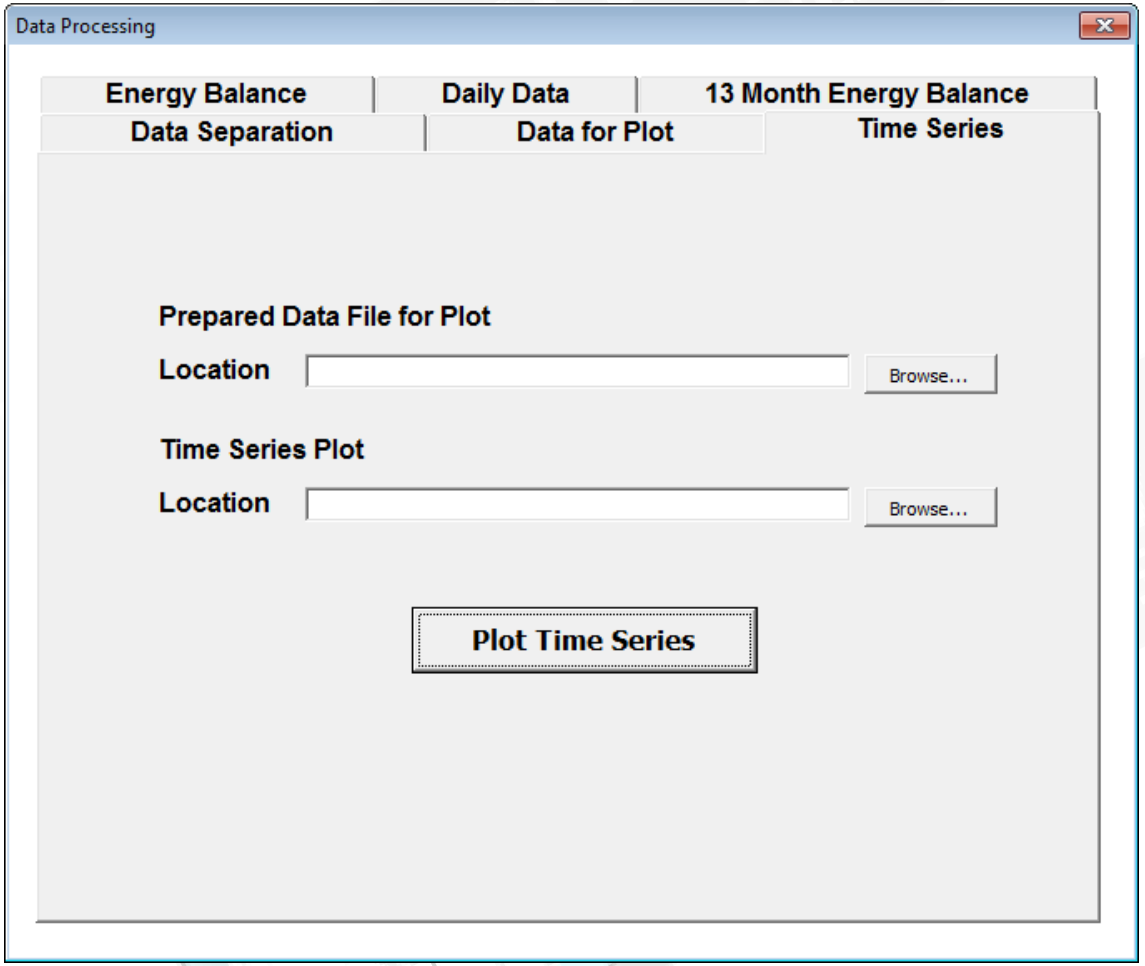
Separate data, detect missing data, generate summary table



Data Processing Tool- Screen II

Module E

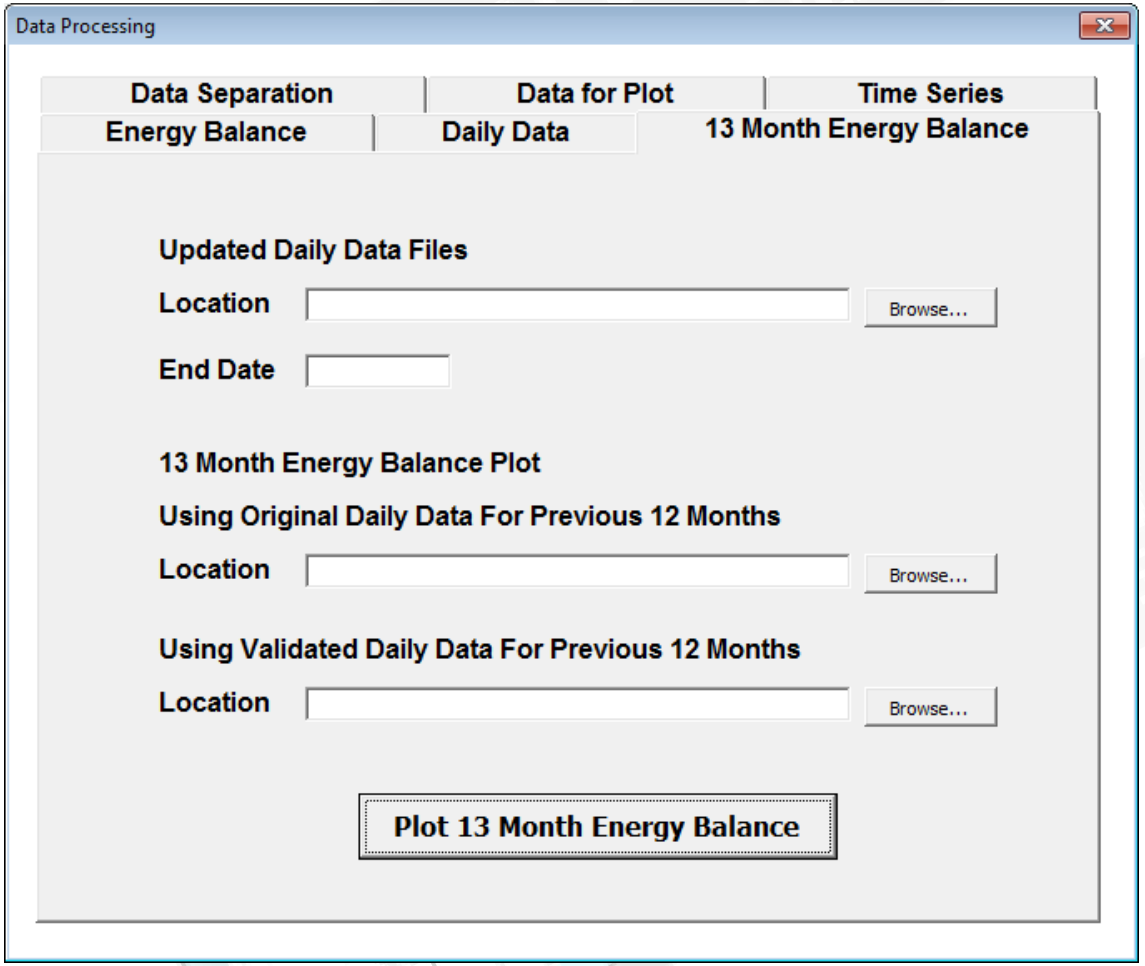
Plot current month time series plot



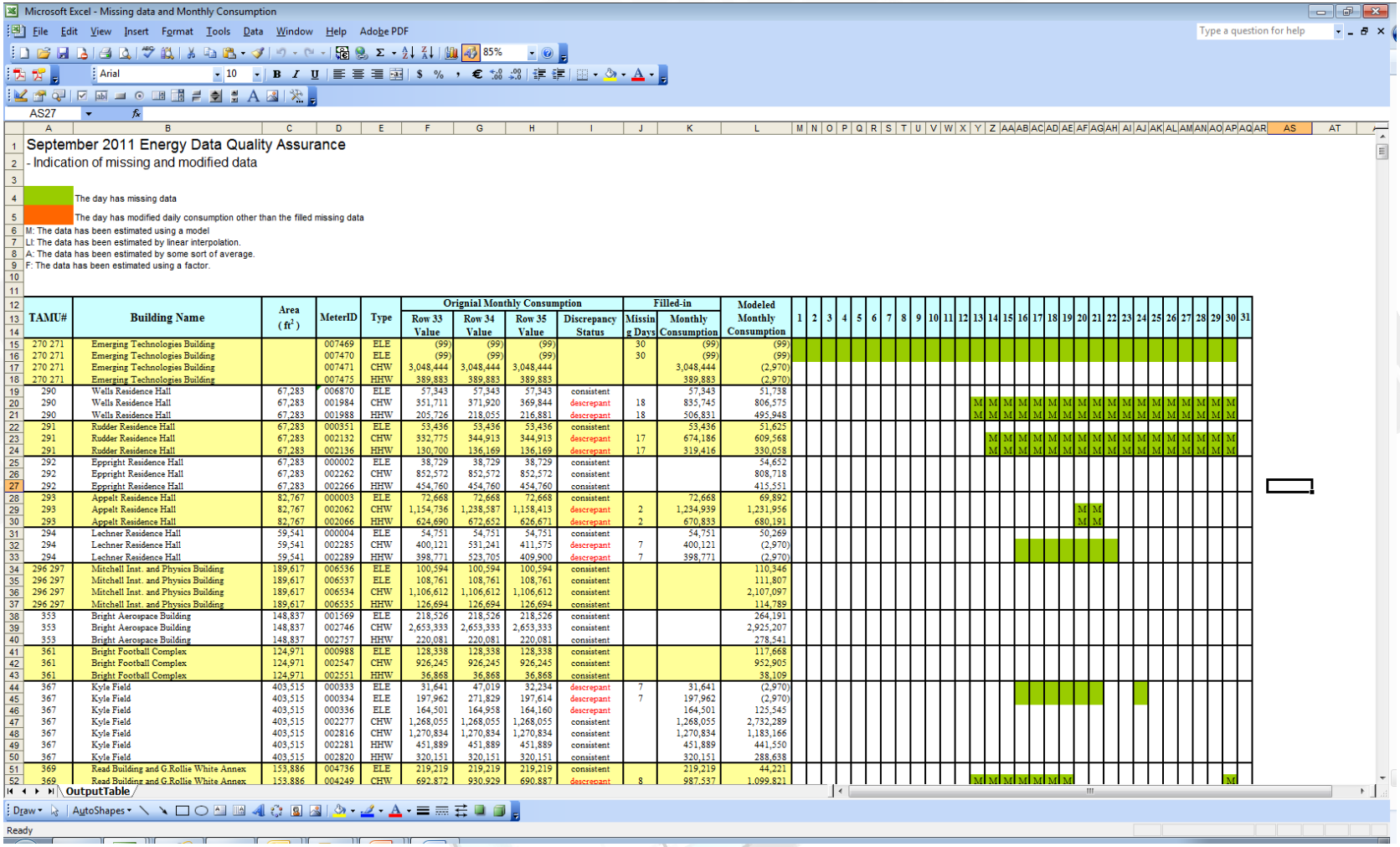
Data Processing Tool -Screen III

Module H

Plot energy balance plot in 13 month



Output I- Tables



Microsoft Excel - Missing data and Monthly Consumption

September 2011 Energy Data Quality Assurance
- Indication of missing and modified data

The day has missing data

The day has modified daily consumption other than the filled missing data

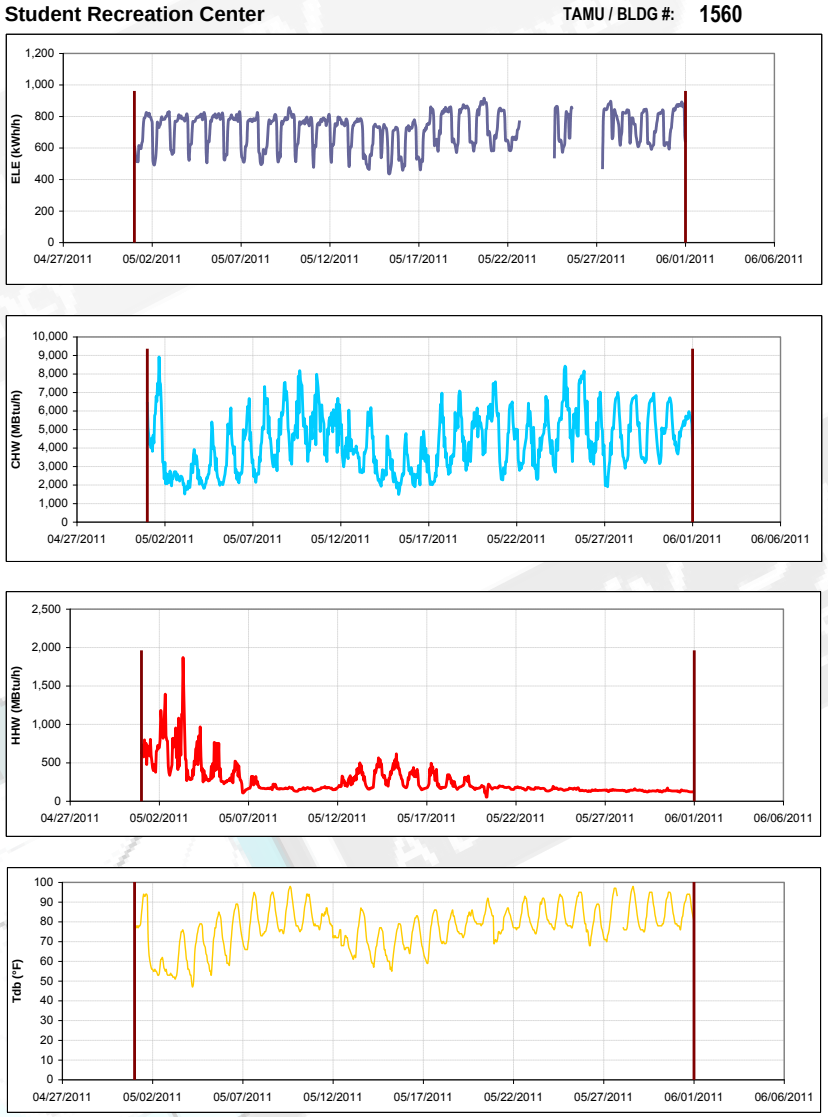
M: The data has been estimated using a model
LI: The data has been estimated by linear interpolation.
A: The data has been estimated by some sort of average.
F: The data has been estimated using a factor.

TAMU#	Building Name	Area (ft^2)	MeterID	Type	Orignial Monthly Consumption				Filled-in		Modeled Monthly Consumption	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
					Row 33 Value	Row 34 Value	Row 35 Value	Discrepancy Status	Missing Days	Monthly Consumption																																
270 271	Emerging Technologies Building		007469	ELE	(99)	(99)	(99)		30	(99)	(99)																														
270 271	Emerging Technologies Building		007470	ELE	(99)	(99)	(99)		30	(99)	(99)																														
270 271	Emerging Technologies Building		007471	CHW	3,048,444	3,048,444	3,048,444			3,048,444	(2,970)																														
270 271	Emerging Technologies Building		007475	HHW	389,883	389,883	389,883			389,883	(2,970)																														
290	Wells Residence Hall	67,283	006870	ELE	57,343	57,343	57,343	consistent		57,343	51,738												M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
290	Wells Residence Hall	67,283	001984	CHW	351,711	371,920	369,844	descrepant	18	835,745	806,575												M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
290	Wells Residence Hall	67,283	001988	HHW	205,726	218,055	216,881	descrepant	18	506,831	495,948												M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
291	Rudder Residence Hall	67,283	000351	ELE	53,436	53,436	53,436	consistent		53,436	51,625																														
291	Rudder Residence Hall	67,283	002132	CHW	332,775	344,913	344,913	descrepant	17	674,186	609,568														M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
291	Rudder Residence Hall	67,283	002136	HHW	130,700	136,169	136,169	descrepant	17	319,416	330,058														M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
292	Eppright Residence Hall	67,283	000002	ELE	38,729	38,729	38,729	consistent			54,652																														
292	Eppright Residence Hall	67,283	002262	CHW	852,572	852,572	852,572	consistent			808,718																														
292	Eppright Residence Hall	67,283	002266	HHW	454,760	454,760	454,760	consistent			415,551																														
293	Appelt Residence Hall	82,767	000003	ELE	72,668	72,668	72,668	consistent		72,668	69,892																														
293	Appelt Residence Hall	82,767	002062	CHW	1,154,736	1,238,587	1,158,413	descrepant	2	1,234,939	1,231,956																				M	M								
293	Appelt Residence Hall	82,767	002066	HHW	624,690	672,652	626,671	descrepant	2	670,833	680,191																				M	M								
294	Lechner Residence Hall	59,541	000004	ELE	54,751	54,751	54,751	consistent		54,751	50,269																														
294	Lechner Residence Hall	59,541	002285	CHW	400,121	531,241	411,575	descrepant	7	400,121	(2,970)																														
294	Lechner Residence Hall	59,541	002289	HHW	398,771	523,705	409,900	descrepant	7	398,771	(2,970)																														
296 297	Mitchell Inst. and Physics Building	189,617	006536	ELE	100,594	100,594	100,594	consistent			110,346																														
296 297	Mitchell Inst. and Physics Building	189,617	006537	ELE	108,761	108,761	108,761	consistent			111,807																														
296 297	Mitchell Inst. and Physics Building	189,617	006534	CHW	1,106,612	1,106,612	1,106,612	consistent			2,107,097																														
296 297	Mitchell Inst. and Physics Building	189,617	006535	HHW	126,694	126,694	126,694	consistent			114,789																														
353	Bright Aerospace Building	148,837	001569	ELE	218,526	218,526	218,526	consistent			264,191																														
353	Bright Aerospace Building	148,837	002746	CHW	2,653,333	2,653,333	2,653,333	consistent			2,925,207																														
353	Bright Aerospace Building	148,837	002757	HHW	220,081	220,081	220,081	consistent			278,541																														
361	Bright Football Complex	124,971	000988	ELE	128,338	128,338	128,338	consistent			117,668																														
361	Bright Football Complex	124,971	002547	CHW	926,245	926,245	926,245	consistent			952,905																														
361	Bright Football Complex	124,971	002551	HHW	36,868	36,868	36,868	consistent			38,109																														
367	Kyle Field	403,515	000333	ELE	31,641	47,019	32,234	descrepant	7	31,641	(2,970)																														
367	Kyle Field	403,515	000334	ELE	197,962	271,829	197,614	descrepant	7	197,962	(2,970)																														
367	Kyle Field	403,515	000336	ELE	164,501	164,958	164,160	descrepant		164,501	125,545																														
367	Kyle Field	403,515	002277	CHW	1,268,055	1,268,055	1,268,055	consistent		1,268,055	2,732,289																														
367	Kyle Field	403,515	002816	CHW	1,270,834	1,270,834	1,270,834	consistent		1,270,834	1,183,166																														
367	Kyle Field	403,515	002281	HHW	451,889	451,889	451,889	consistent		451,889	441,550																														
367	Kyle Field	403,515	002820	HHW	320,151	320,151	320,151	consistent		320,151	288,638																														
369	Read Building and G.Rollie White Annex	153,886	004736	ELE	219,219	219,219	219,219	consistent		219,219	44,221																														
369	Read Building and G.Rollie White Annex	153,886	004249	CHW	692,872	930,929	690,887	descrepant	8	987,537	1,099,821												M	M	M	M	M	M	M											M	

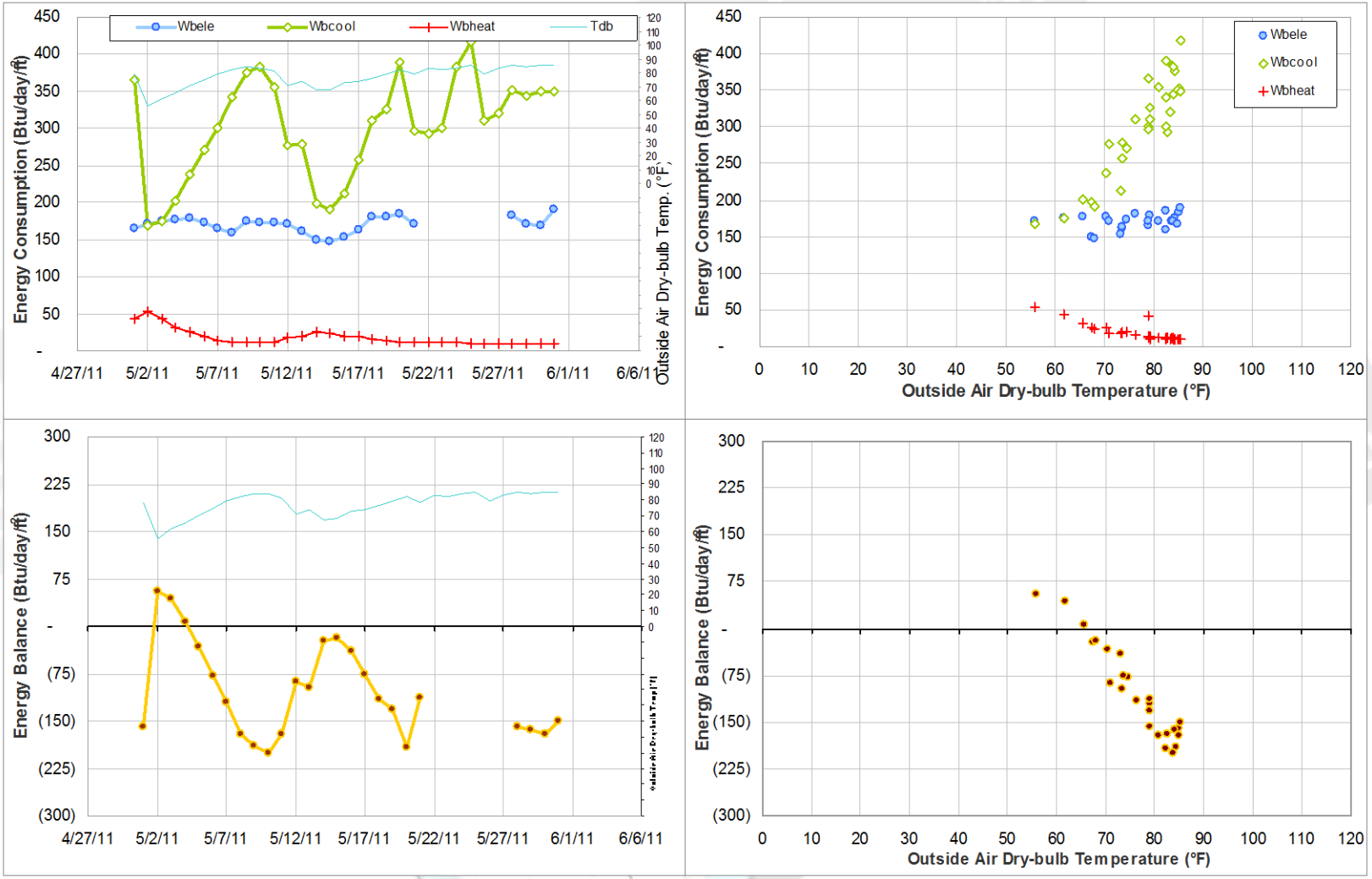
OutputTable

Ready

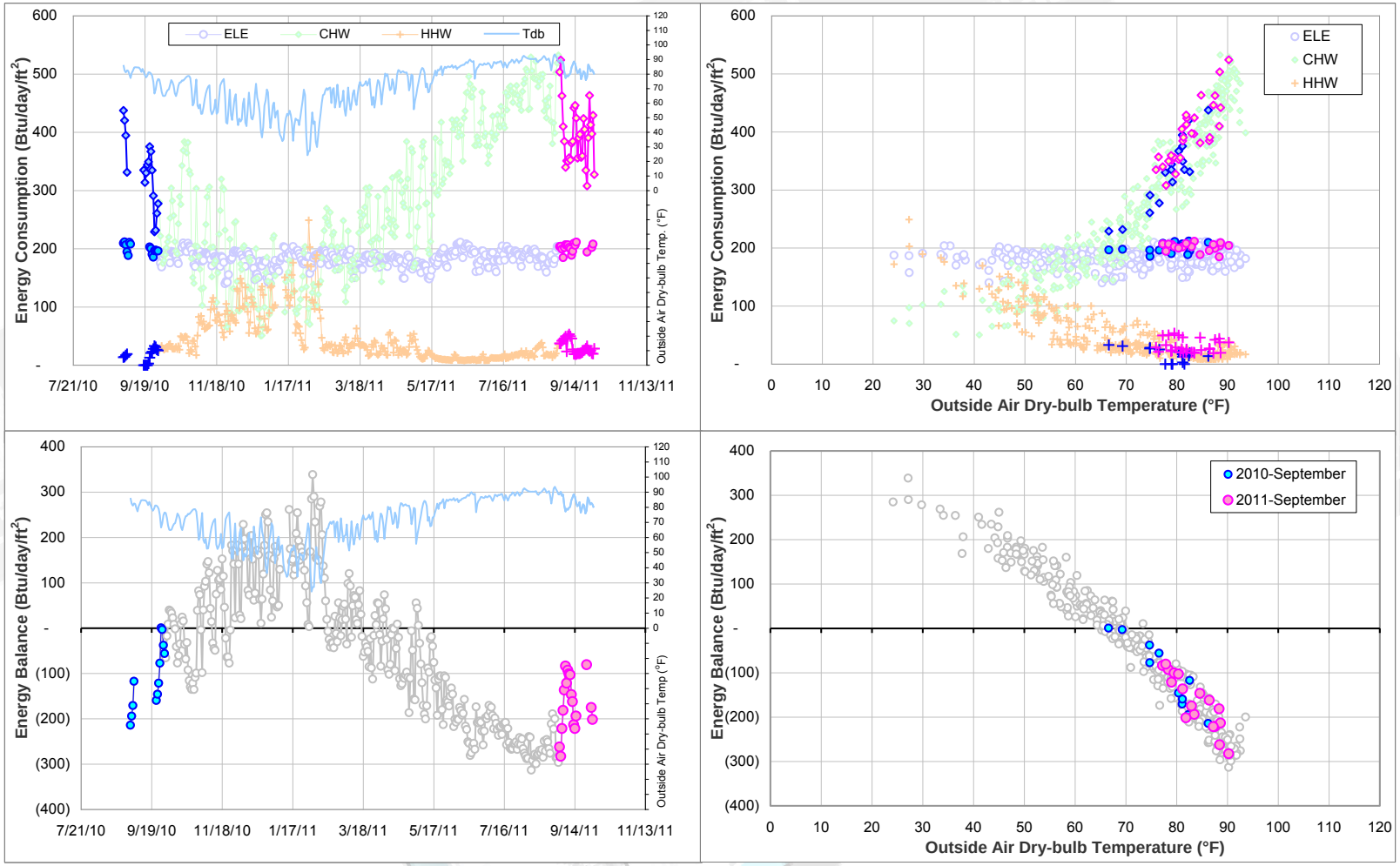
Output II-Time Series Plot



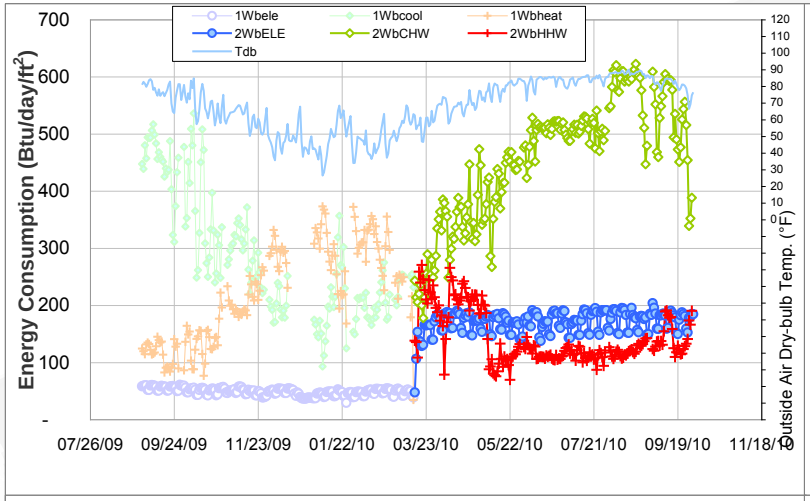
Output III-
Monthly Energy Balance Plot

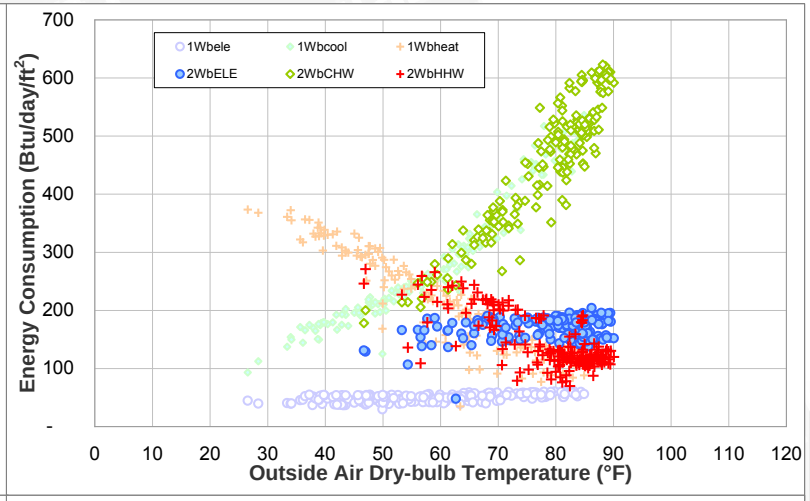


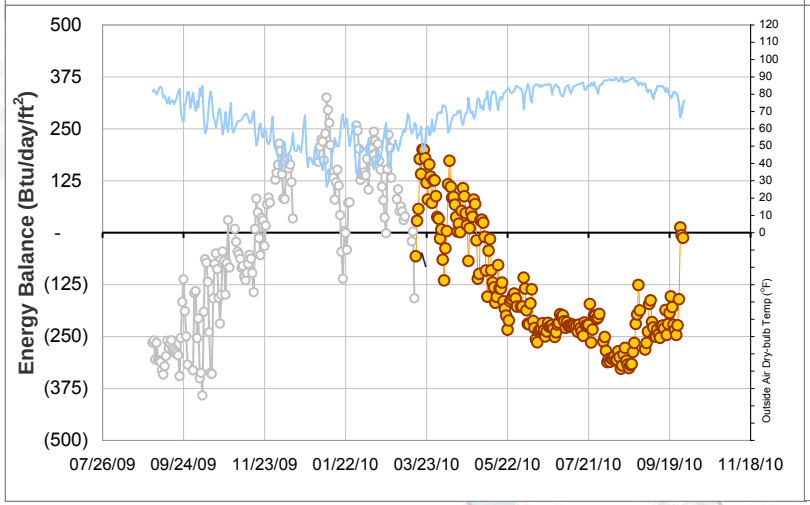
Output-IV
13 Month Energy Balance Plot

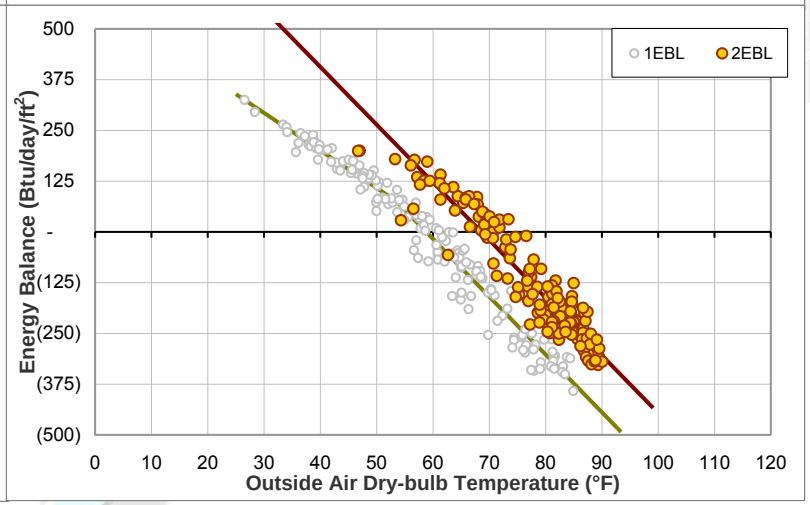


Electricity Problems (WERC)

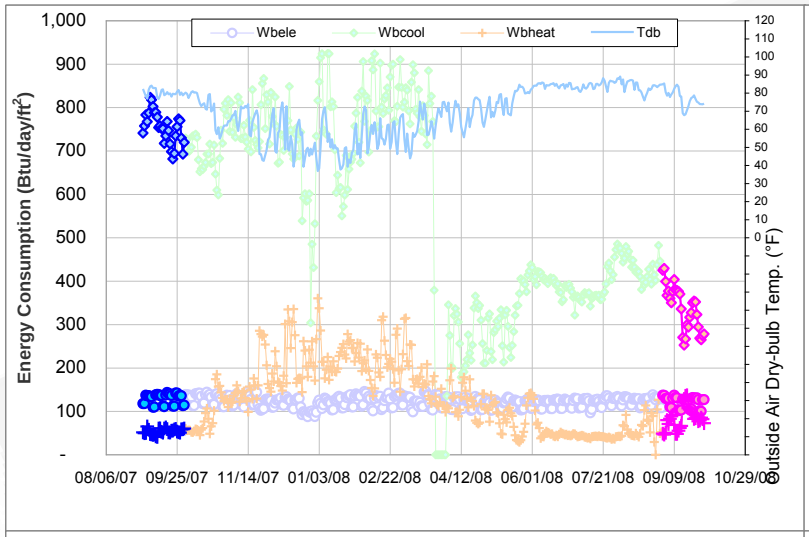


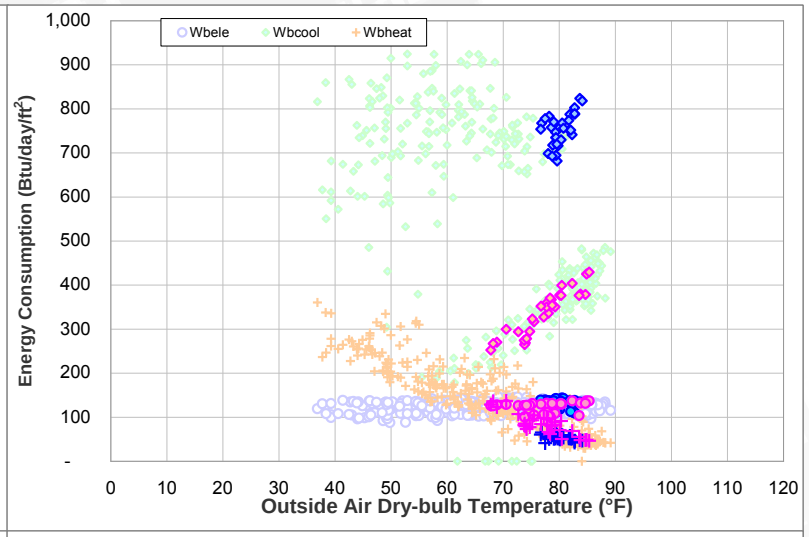


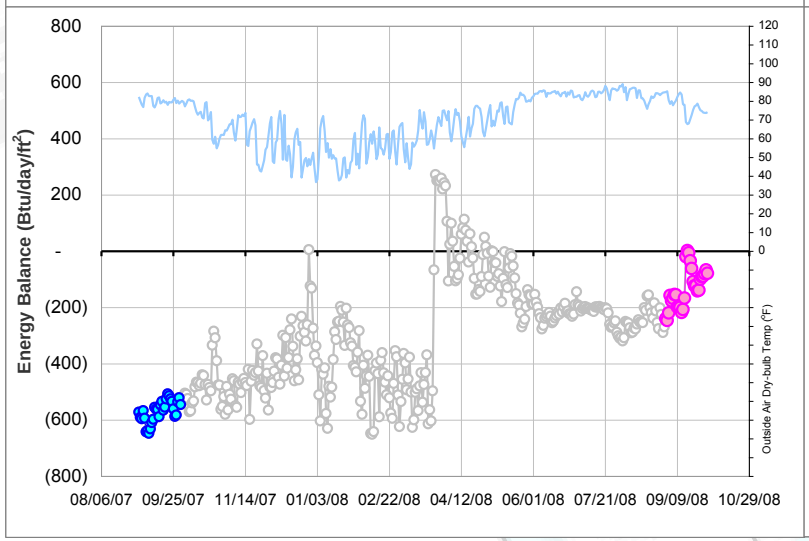


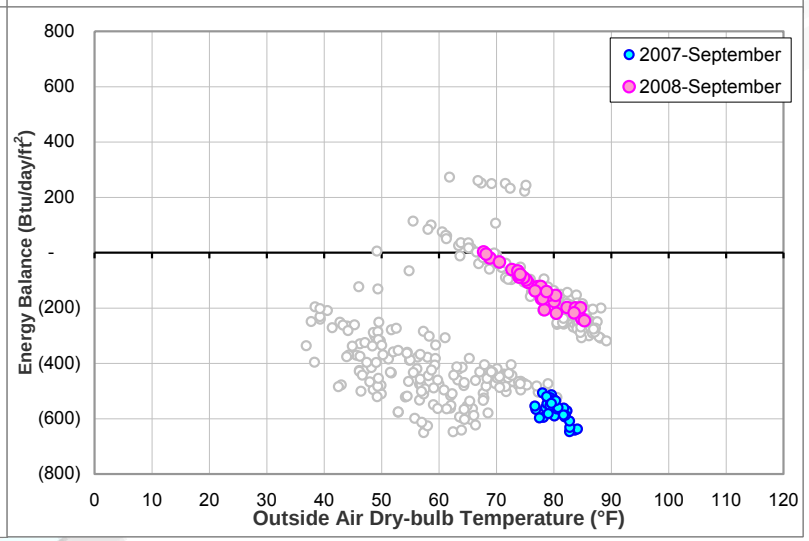


Flow Meter Problem (Butler Hall)









Summary

- Apply the Energy Balance methodology in building consumption data quality control

- Develop tool for analysis of consumption data
  - Generate individual data file (Hourly, daily monthly) for analysis from a file including hourly metering data
  - Automatic fill-in missing daily data based on the developed models
  - Generate times series and energy balance plots for analysis
  - Document the historical daily data

Thanks!