METHODOLOGY FOR ANALYZING ENERGY AND DEMAND SAVINGS FROM ENERGY SERVICES PERFORMANCE CONTRACT USING SHORT-TERM DATA

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Outline

- Introduction
- Data Collection
- Methodology for Calculating Electricity Savings
- Methodology for Calculating Electric Demand Savings
- Case Studies
- Conclusions

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Energy Conservation Measures

- Energy reduction goals as mandated by Executive Order.
- Energy Services Performance Contract.
  - $3.8 million, 20 year.
  - 58 buildings.
  - Five primary types of Energy Conservation Measures:
    - Boiler insulation
    - Control system upgrades
    - Vending machine controls
    - Cooling tower variable frequency drives (VFDs)
    - Lighting retrofits

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Data Collection Methods

- Existing hourly metering equipment
  - Recalibrated.
- New equipment
  - Installed in III Corp HQ building and 87000 block thermal plant.
- Watt transducers with manual readouts
  - Selected 87000 block buildings and other buildings determined to be part of the ESPC project.
  - Manual readings taken weekly.
- Portable ACR loggers
  - Instantaneous signal recorded from the Watt-hour meters for short periods.

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Pre-Retrofit Data

PRE-RETROFIT DATA COLLECTION METHODS

ACR Logger

Synergistic Logger

Manual Readings

Utility Bills

Weather Data

PRE-RETROFIT PERIOD DEMAND MODELING

87000 Block Buildings

Miscellaneous Buildings

Thermal Plant and III Corps

PRE-RETROFIT PERIOD ELECTRICITY MODELING

Miscellaneous Buildings

Thermal Plant and III Corps

87000 Block Buildings

Miscellaneous -33001, 33003

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Post-Retrofit Data

Weather Data

POST-RETROFIT DATA COLLECTION METHODS

Miscellaneous Buildings

ACR Logger

87000 Block Buildings

Synergistic Logger

Thermal Plant and III Corps

Utility Bills

Miscellaneous -33001, 33003

POST-RETROFIT PERIOD ELECTRICITY DATA FOR SAVINGS CALCULATION

87000 Block Buildings

Miscellaneous Buildings

Thermal Plant and III Corps

POST-RETROFIT PERIOD DEMAND MODELING

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Summary of Retrofit Status

BUILDING #	LIGHTING	LIGHTING COMPLETED	VENDING MISER	VENDING MISER COMPLETED	HVAC CONTROLS	HVAC COMPLETION DATE	COOLING TOWER	COOLING TOWER COMPLETION DATE
87017 - DINING FACILITY	X	03-May-04			X	Dec-04		
87018 - PHYSICAL PLANT	X	20-Apr-04			X	Oct-04	X	14-Apr-05
87008 - BN HQ BLDG	X	27-Apr-04			X	Jan-05		
87010 - PHYSICAL FITNES	X	07-Apr-04			X	Dec-04		
87003 - BN HQ BLDG & OR	X	21-Apr-04			X	Jan-05		
87009 - BN HQ BLDG & OR	X	20-Apr-04			X	Jan-05		
87006 - HEALTH CLINIC (	X	15-Apr-04			X	Jan-05		
87005 - BDE HQ BLDG	X	20-Apr-04			X	Jan-05		
9212 - PATTON'S INN	X	06-May-04						
52019 - COMANCHIE ACTIV	X	21-May-04	X	27-Feb-04	X	Nov-04		
42000 - SPORTS USA	X	05-May-04			X	Mar-05		
6602 - BRONCO YOUTH CE	X	21-Jun-04	X	27-Feb-04	X	Mar-05		
5485 - PERSHING YOUTH	X	25-May-04	X	2-Mar-04	X	Mar-05		
85018 - WALKER YOUTH CE	X	26-May-04			X	Mar-05		
	▪ ▪ ▪	▪ ▪ ▪						

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Data Summary Table

Availability of Pre- and Post-retrofit data for each site

Gas Manual Reading Data Period | **Elec. Manual Reading Data Period** | **Elec. ACR Data Period**

			GAS				ELECTRICITY				ELECTRICAL DEMAND				
Bldg. #	Const. Start Date	Const. End Date	Baseline Model	Manual Reading Data Period	Pre-Retrofit Data	Post-Retrofit Data	Baseline Model	Manual Reading Data Period	Pre-Retrofit Data	Post-Retrofit Data	Baseline Model	ACR Data Period	Pre-Retrofit Data	Post-Retrofit Data	Manual Match ACR Data?
87017	May-04	Dec-04					3P	2/01-3/03	YES	NO	YES	3/03-8/03 6/26/05-7/09/05 7/31/05-8/13/05	YES	YES	YES
87018	Apr-04	Apr-05	3P	12/00-3/03	YES	YES	YES	5/01-3/03	Logger #938	Logger #938	YES	Logger #938		YES-Need more data	
87008	Apr-04	Jan-05					1P	12/00-3/03	YES	NO	YES	3/03-8/03 6/26/05-7/09/05 7/31/05-8/13/05	YES	YES	YES
87010	Apr-04	Dec-04					1P	2/01-3/03	YES	NO	YES	3/03-8/03	YES	NO	YES
87003	Apr-04	Jan-05					1P	12/00-3/03	YES	NO	YES	1/03-8/03 7/31/05-8/13/05	YES	YES	YES
87009	Apr-04	Jan-05					1P	12/00-3/03	YES	NO	YES	1/03-8/03 6/26/05-7/09/05 7/31/05-8/13/05	YES	YES	YES
87006	Apr-04	Jan-05					1P	12/00-3/03	YES	NO	YES	3/03-8/03 6/26/05-7/09/05 7/31/05-8/13/05	YES	YES	YES
87005	Apr-04	Jan-05					3P	12/00-3/03	YES	NO	YES	3/03-8/03 7/31/05-8/13/05	YES	YES	YES
9212	May-04	May-04	3P	6/02-4/03	YES	NO	3P	6/02-4/03	YES	NO	NO Model		NO	NO	
52019	Feb-04	Nov-04													
42000	May-04	Mar-05					NO Model		YES	NO	YES	11/02-3/03	YES	NO	YES
6602	Feb-04	Mar-05	3P	6/02-4/03	YES	NO	3P	6/02-4/03	YES	NO	YES	11/02-1/03, 8/03-5/04	YES	NO- Need data	
5485	Mar-04	Mar-05	3P	6/02-4/03	YES	NO	3P	6/02-4/03	YES	NO					
85018	May-04	Mar-05	3P	6/02-4/03	YES	NO	3P	6/02-4/03	YES	NO					
194	Feb-04	Feb-05	3P	6/02-4/03	YES	NO	2P	6/02-4/03	YES	NO	YES	11/02-1/03, 3/03-8/03	YES	NO	YES
5764	Mar-04	Jun-04	3P	6/02-4/03	YES	NO	1P,2P	6/02-4/03	YES	NO	YES	11/02-1/03	YES	NO	NO- SF 0.405
22020	Mar-04	Oct-04					NO Model				YES	12/02-3/03	YES	NO	NO

Type of Baseline Models for Each Site

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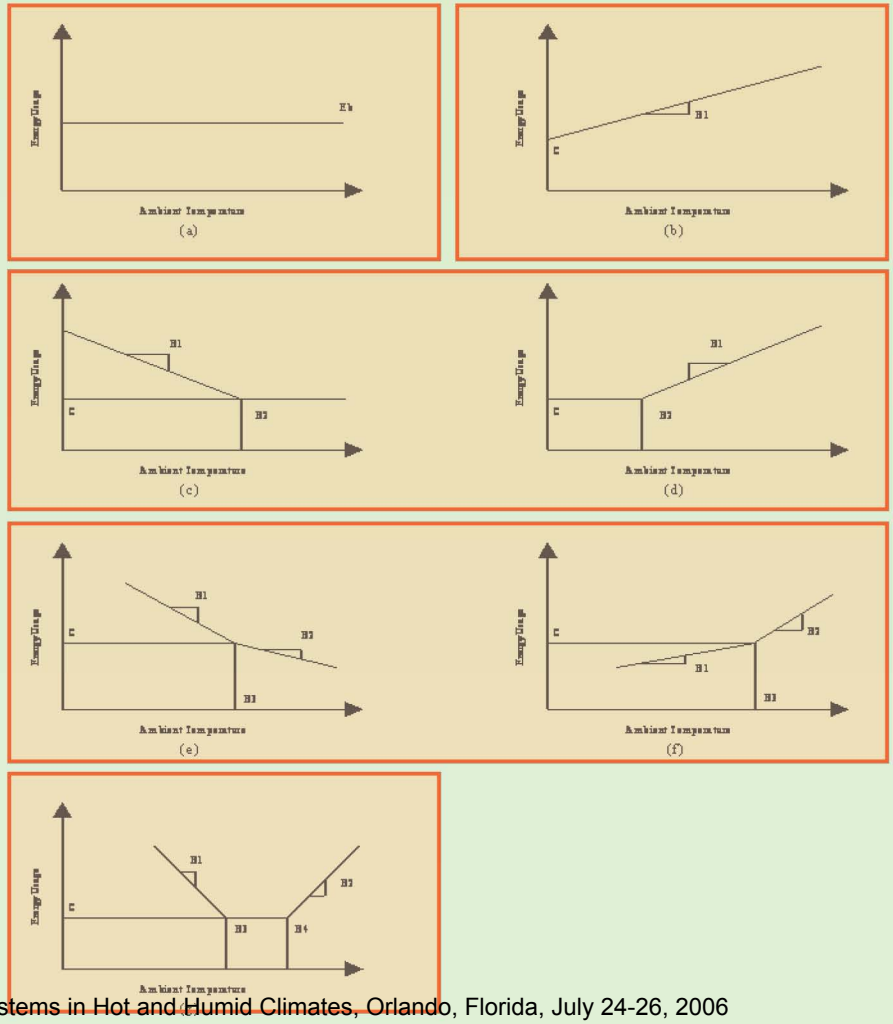
Regression Models of Whole-Building Electricity Use

- **Basic modeling approaches for electricity consumption:**
  - **Linear and change-point linear regression models.**
  - **Calculated with ASHRAE's IMT.**
- **Regression Models:**
  - **Mean model**
  - **Two Parameter Model**
  - **Three Parameter Model**
  - **Four Parameter Model**
  - **Five Parameter Model**



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Regression Models of Whole-Building Electricity Use

Name	Section	Independent Variable(s)	Form	Examples
No Adjustment /Constant Model	6.1.4.1	None	$E = E_b$	Non weather sensitive demand
Day Adjusted Model	6.1.4.2	None	$E = E_b \times \frac{day_b}{day_c}$	Non weather sensitive use (fuel in summer, electricity in summer)
Two Parameter Model	6.1.4.3	Temperature	$E = C + B_1(T)$	
Three Parameter Models	6.1.4.4	Degree days/Temperature	$E = C + B_1(DD_{BT})$ $E = C + B_1(B_2 - T)^+$ $E = C + B_1(T - B_2)^+$	Seasonal weather sensitive use (fuel in winter, electricity in summer for cooling) Seasonal weather sensitive demand
Four Parameter, Change Point Model	6.1.4.5	Temperature	$E = C + B_1(B_3 - T)^+ - B_2(T - B_3)^+$ $E = C - B_1(B_3 - T)^+ + B_2(T - B_3)^+$	
Five Parameter Models	6.1.4.6	Degree days/Temperature	$E = C - B_1(DD_{TH}) + B_2(DD_{TC})$ $E = C + B_1(B_3 - T)^+ + B_2(T - B_4)^+$	Heating and cooling supplied by same meter.
Multi-Variate Models	6.1.4.7	Degree days/Temperature, other independent variables	Combination form	Energy use dependent non-temperature based variables (occupancy, production, etc.).

ASHRAE Guideline 14 Regression Models

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Before-After Savings Calculation Method

Whole-building Electricity Savings

- Before-after savings methods.
  - Development of Baseline model.
  - Prediction for the post-retrofit period.
    - The building energy consumption would have been if the retrofit had not been performed.
    - Using post-retrofit weather and occupancy conditions.
  - Calculation of savings.
    - Subtracting the measured post-retrofit energy use from the baseline predictions of the building's pre-retrofit energy use.

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Diversity Factor Models for Electric Demand

Electric Demand Savings

- **ASHRAE's Diversity Factor Toolkit.**
  - **90th percentile values recommended for predicting peak cooling loads from light and receptacle loads.**
- **Diversity factor models for calculating demand saving.**
  - **24-hour profiles developed for each month of pre-retrofit period and post-retrofit period.**
  - **The maximum kW use (90th percentiles) of post-retrofit months compared against the same months of pre-retrofit period.**
- **If missing pre-retrofit period data.**
  - **ASHRAE's IMT change-point linear model applied.**

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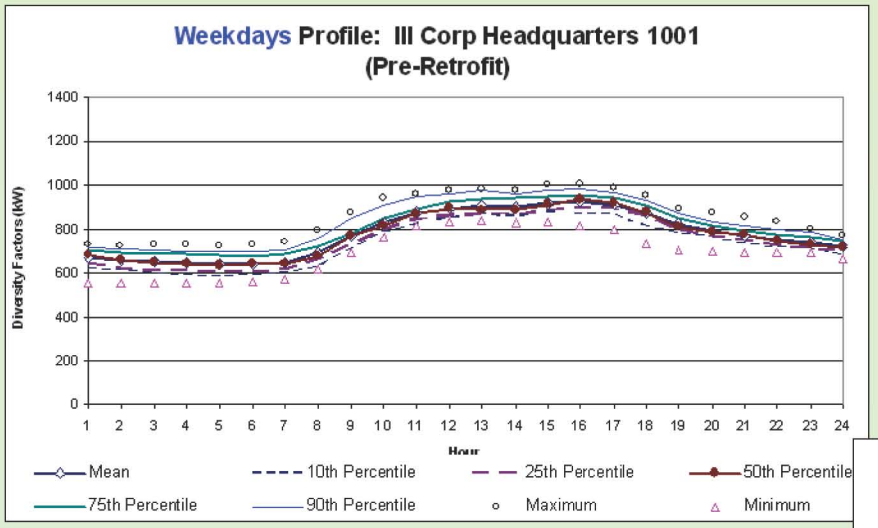
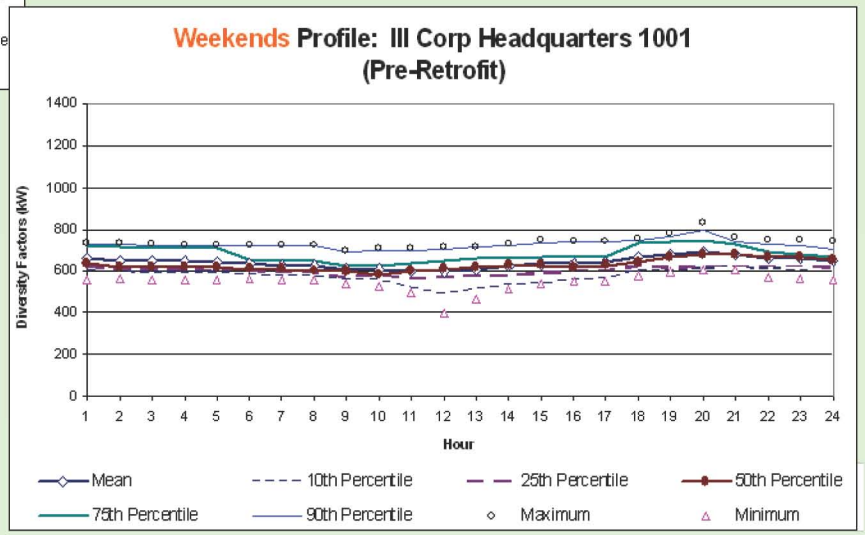
1093-RP Diversity Factor Analysis



Weekdays

Weekends



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Savings Summary Table

			Total Projected Annual Electricity Savings			Total Projected Annual Demand Savings			Electricity Savings For the Measured Period				Demand Savings For the Measured Period			
Bldg. #	Building Name	Building Size (ft2)	Audit-Estimated Electricity Savings (kWh/yr)	Projected Electricity Savings (kWh/yr)	% of Audit-Estimated Savings	Audit-Estimated Demand Savings (kW/yr)	Projected Demand Savings (kW/yr)	% of Audit-Estimated Savings	No. Of Days	Audit-Estimated Electricity Savings (kWh/period)	Measured Electricity Savings (kWh/period)	% of Audit-Estimated Savings	No. Of Months	Audit-Estimated Demand Savings (kW/period)	Measured Demand Savings (kW/period)	% of Audit-Estimated Savings
194	NCO CLUB (PHANT)	19,023	511,903	511,903	100.0%	47	47	100.0%								
410	HEADQUARTERS BU	102,391	931,344	346,705	37.2%	1,025	-402	-39.2%	202	515,428	191,875	37.2%	6	513	-201	-39.2%
1001	HEADQUARTERS BLDG.	312,800	821,700	787,465	95.8%	2,363	1,382	58.5%	365	821,700	787,465	95.8%	12	2,363	1,382	58.5%
4351	MOTOR POOL	16,317	25,314	25,314	100.0%	75	75	100.0%								
5485	PERSHING YOUTH	17,519	34,329	34,329	100.0%	68	68	100.0%								
5764	OFFICERS CLUB	36,649	319,596	319,596	100.0%	152	152	100.0%								
6602	BRONCO YOUTH CE	22,100	85,034	85,034	100.0%	125	125	100.0%								
9112	MOTOR POOL	20,832	106,906	106,906	100.0%	431	431	100.0%								
9122	MOTOR POOL	20,832	117,344	117,344	100.0%	477	477	100.0%								
9127	MOTOR POOL	20,240	58,304	58,304	100.0%	222	222	100.0%								
9212	PATTON'S INN	1,612	13,221	13,221	100.0%	53	53	100.0%								
9513	MOTOR POOL	20,832	90,926	90,926	100.0%	362	362	100.0%								
9535	MOTOR POOL	20,240	67,860	67,860	100.0%	260	260	100.0%								
9553	MOTOR POOL	24,560	40,097	40,097	100.0%	140	140	100.0%								
15060	MOTOR POOL	20,240	83,276	83,276	100.0%	329	329	100.0%								
18010*																
19012	MOTOR POOL	20,240	0	0		150	150	100.0%								
22020	ADMIN	21,096	195,943	195,943	100.0%	180	180	100.0%								
28000	1ST CAV	129,635	300,217	300,217	100.0%	0	0									
30015	MOTOR POOL	20,240	63,486	63,486	100.0%	218	218	100.0%								
30017	MOTOR POOL	20,240	58,581	58,581	100.0%	219	219	100.0%								
30033	MOTOR POOL	20,240	69,343	69,343	100.0%	256	256	100.0%								
33001	MEDAC		38,406	118,212	307.8%	138	138	100.0%	212	22,307	68,660	307.8%				
33003	MEDAC		37,754	-62,374	-165.2%	126	126	100.0%	212	21,928	-36,228	-165.2%				
35014	MOTOR POOL	20,480	52,109	52,109	100.0%	191	191	100.0%								
35023	MOTOR POOL	23,040	41,741	41,741	100.0%	135	135	100.0%								
36014			101,674	101,674	100.0%	303	303	100.0%								
38003	MOTOR POOL	20,240	64,908	64,908	100.0%	247	247	100.0%								
38014	MOTOR POOL	20,240	50,299	50,299	100.0%	183	183	100.0%								
42000	SPORTS USA	23,341	406,107	406,107	100.0%	92	92	100.0%								
50012	COMMUNITY EVENTS	4,203	13,713	13,713	100.0%	0	0									
52019	COMANCHIE ACTIV	13,450	196,510	196,510	100.0%	108	108	100.0%								
52024	COMANCHE CHILD	34,779	376,866	261,223	69.3%	217	288	132.8%	100	103,251	71,568	69.3%	4	72	96	132.8%
85018	WALKER YOUTH CE	15,652	50,954	50,954	100.0%	113	113	100.0%								
85020	COMMISARY	105,659	165,961	36,107	21.8%	470	156	33.2%	26	11,822	2,572	21.8%	1	39	13	33.2%
87003	BN HQ BLDG & OR	12,314	51,320	53,342	103.9%	146	146	100.0%	14	1,968	2,046	103.9%				
87004	CO HQ BUILDING	18,818	46,779	46,779	100.0%	126	126	100.0%								
87005	BDE HQ BLDG	9,840	26,450	31,833	120.4%	114	72	63.2%	14	1,015	1,221	120.4%	1	9	6	63.2%
87006	HEALTH CLINIC	4,073	11,047	9,646	87.3%	44	44	100.0%	28	847	740	87.3%				
87007	ENLISTED UPH	31,470	5,887	-6,763	-114.9%	0	0		17	274	-315	-114.9%				
87008	BN HQ BLDG	6,371	18,412	28,327	153.8%	70	70	100.0%	28	1,412	2,173	153.8%				
87009	BN HQ BLDG & OR	12,381	49,190	35,979	73.1%	162	162	100.0%	28	3,773	2,760	73.1%				
87010	PHYSICAL FITNES	23,631	98,108	98,108	100.0%	172	172	100.0%								
87011	CO HQ BUILDING	25,618	55,680	34,479	61.9%	157	157	100.0%	28	4,271	2,645	61.9%				
87012	ENLISTED UPH	42,306	9,719	29,329	301.8%	5	5	100.0%	17	453	1,366	301.8%				
87013	ENLISTED UPH	31,740	6,439	6,439	100.0%	0	0									
87014	CO HQ BUILDING	14,162	32,892	54,940	167.0%	96	44	45.8%	25	2,253	3,763	167.0%	3	24	11	45.8%
87015	ENLISTED UPH	42,306	6,502	-18,229	-280.3%	3	3	100.0%	17	303	-849	-280.3%				
87016	CO HQ BUILDING	25,168	50,197	84,341	168.0%	157	157	100.0%	14	1,925	3,235	168.0%				
87017	DINING FACILITY	15,695	41,390	61,985	149.8%	89	89	100.0%	28	3,175	4,755	149.8%				
87018	PHYSICAL PLANT **	3,327	522,971	522,971	100.0%	15	15	100.0%								
87019	CO HQ BUILDING	18,818	33,628	33,628	100.0%	126	126	100.0%								
87020	ENLISTED UPH	42,306	38,111	38,111	100.0%	79	79	100.0%								
87021	ENLISTED UPH	87,021	6,523	6,523	100.0%	1	1	100.0%								
87022	ENLISTED UPH	42,306	23,936	23,936	100.0%	54	54	100.0%								
91002	HEADQUARTERS	38,462	218,137	98,423	45.1%	121	96	79.5%	115	68,728	31,010	45.1%	4	40	32	79.5%
91012	ADMIN (STONE HA)	86,292	391,136	-189,531	-48.5%	388	18	4.6%	110	117,877	-57,119	-48.5%	4	129	6	4.6%
91014	ADMIN (HENSON H)	26,224	162,590	162,590	100.0%	184	184	100.0%								
Total for Measured Sites		**780,533**	**3,291,900**	**3,232,223**	**98.2%**	**1,484**	**1,484**	**100.0%**		**1,704,712**	**1,083,343**	**63.5%**		**3,190**	**1,345**	**42.2%**
Total for All Sites		**1,849,611**	**7,498,771**	**5,954,220**	**79.4%**	**11,782**	**8,642**	**73.4%**								

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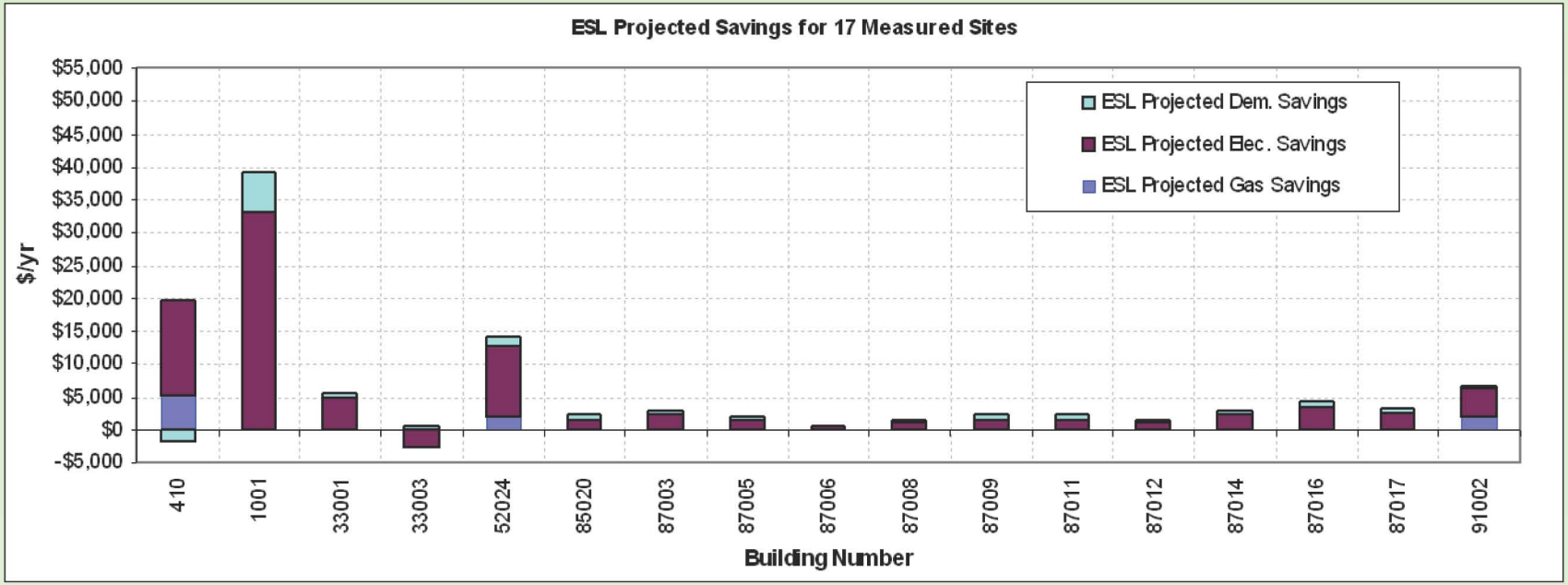
Savings Summary



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Description of Selected Buildings

Building Number	1001	91002	52024	87014
Building Name	III CORP	HEADQUAR-TERS	COMANCHE CHILD	CO HQ BUILDING
Floor Area (sq. ft.)	312,800	38,462	34,779	14,162
Baseline Period	Apr 03 to Mar 04	Sep 03 to Feb 04	Aug 03 to May 04	Dec 00 to Mar 03
Pre-retrofit Data Type	Hourly Data from Synergistic Logger	Hourly Data from Portable Logger (ACR)	Hourly Data from Portable Logger (ACR)	Weekly Manual Readings
Post-retrofit Data Type	Hourly Data from Synergistic Logger	Hourly Data from Portable ACR Logger	Hourly Data from Portable ACR Logger	Hourly Data from Portable ACR Logger
Retrofits	Lighting	Lighting, HVAC Controls	Lighting, HVAC Controls	Lighting, HVAC Controls

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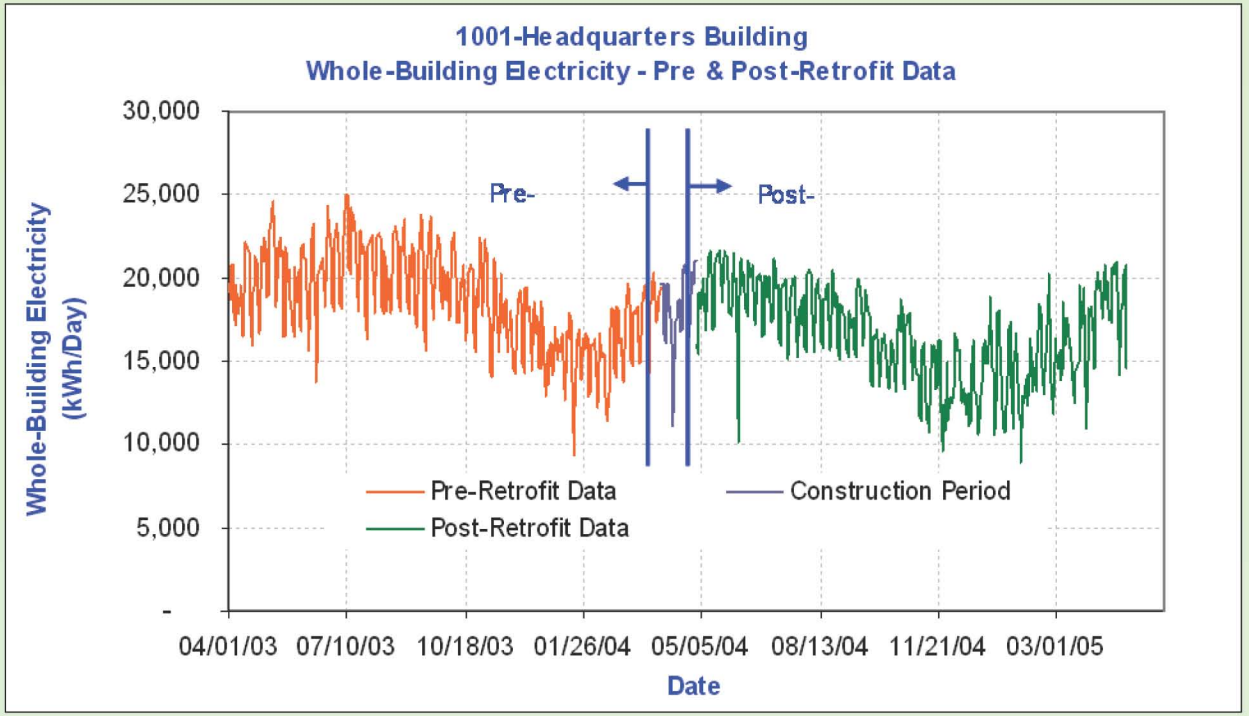
Savings Analysis for WBE – Building 1001

- Identify pre- and post-retrofit periods and construction period.
- Pre and post period: hourly data from Synergistic logger.
- Sum hourly data into daily totals.



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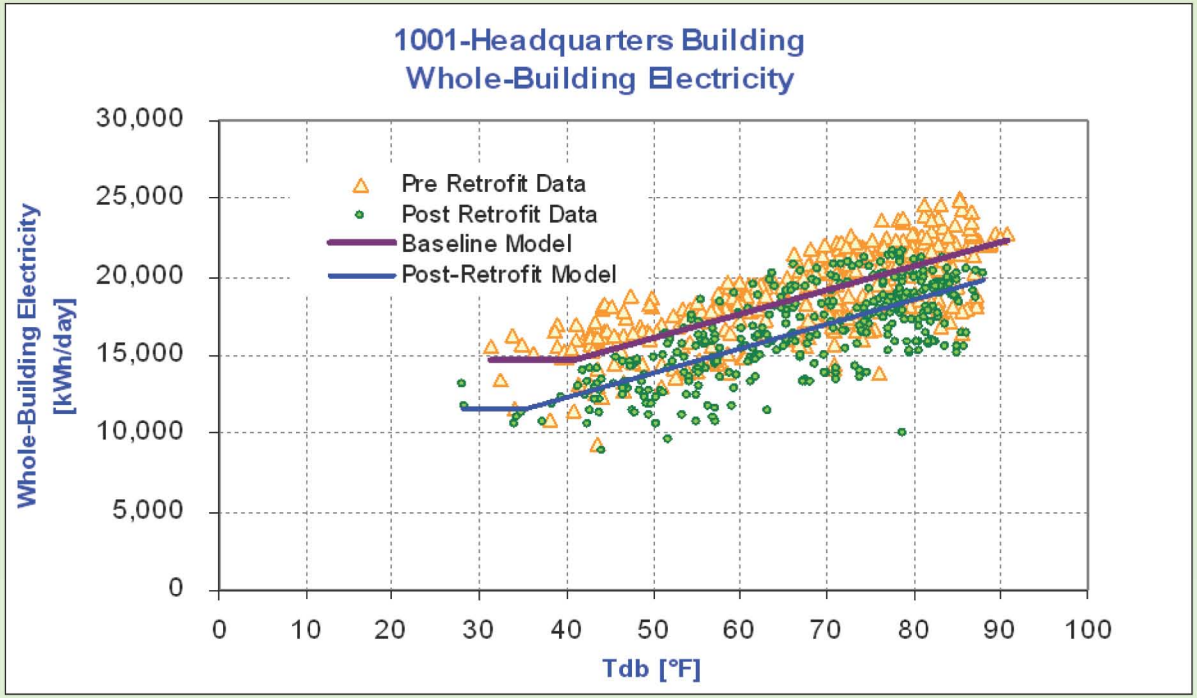
Savings Analysis for WBE – Building 1001

- **Measured daily kWh regressed against average daily temperature.**
- **Models of this type calculated for sites hourly data from Synergistic loggers were available for both pre- and post-retrofit periods.**
- **87000 block thermal plant and the III Corp building.**



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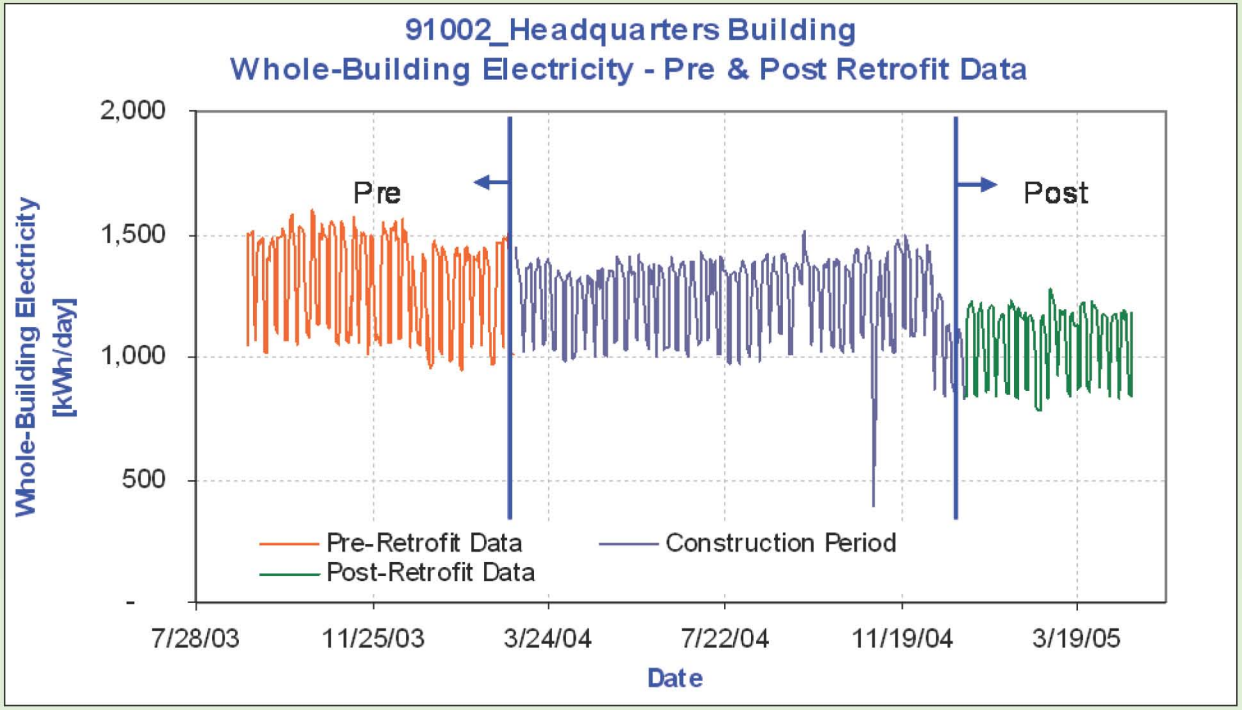
Savings Analysis for WBE – Building 91002

- Identify pre- and post-retrofit periods and construction period.
- Pre and post period: hourly data from portable data logger.
- Sum of hourly data into daily totals.



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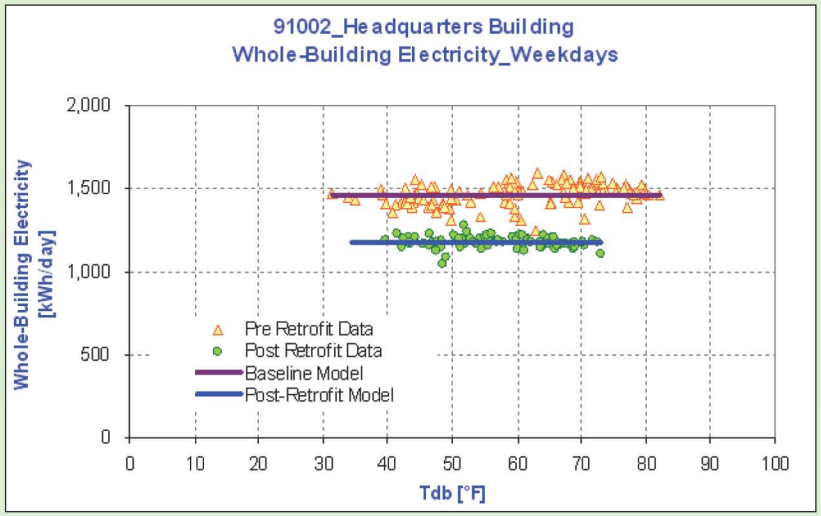
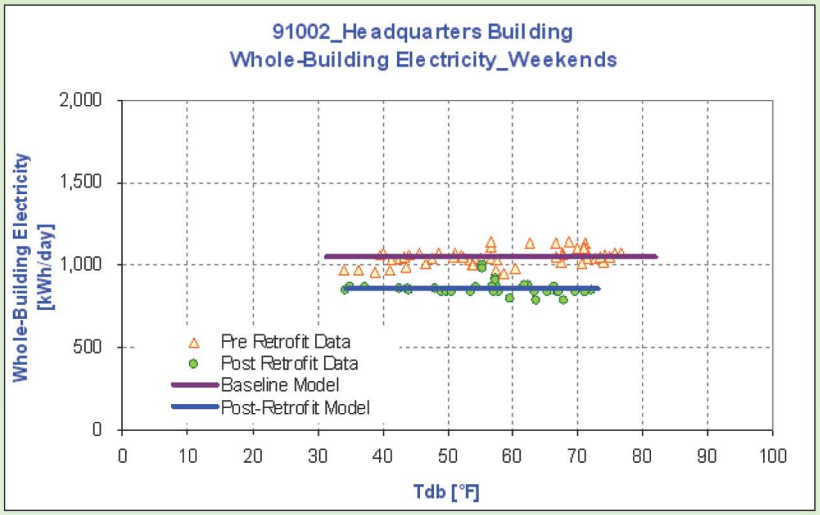
Savings Analysis for WBE – Building 91002

- Measured daily kWh regressed against average daily temperature.
- Weekdays and weekends models.
- Models of this type calculated for the measured miscellaneous sites.



Weekdays Model



Weekends Model

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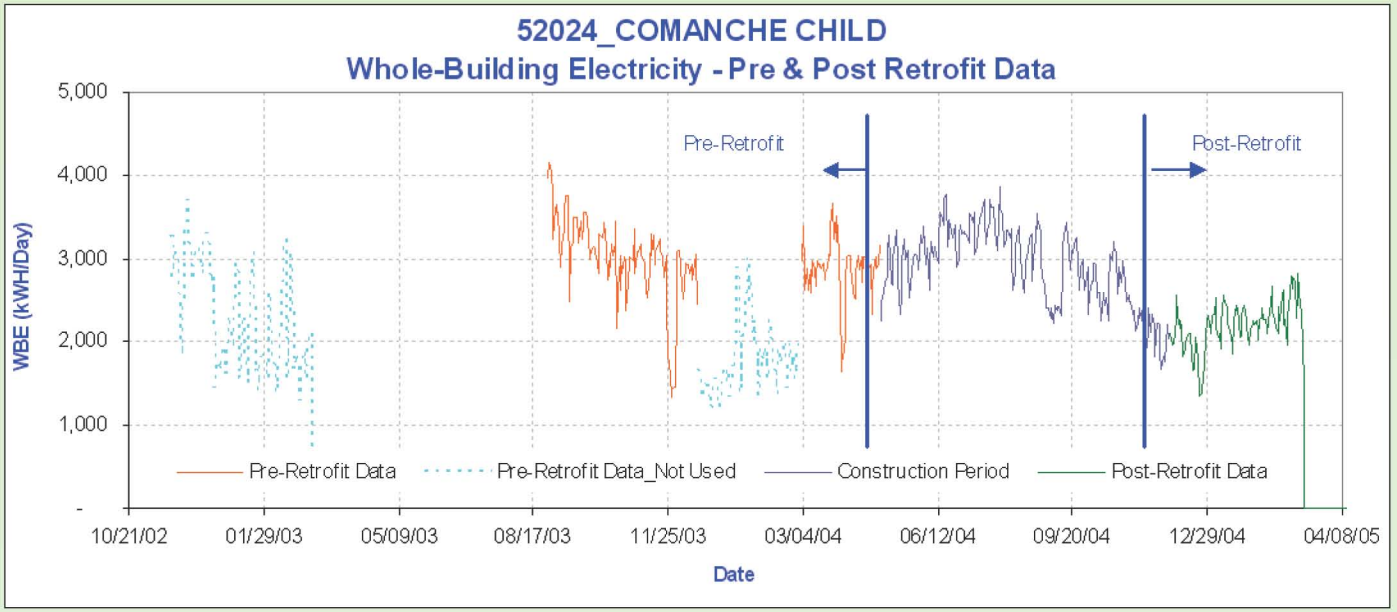
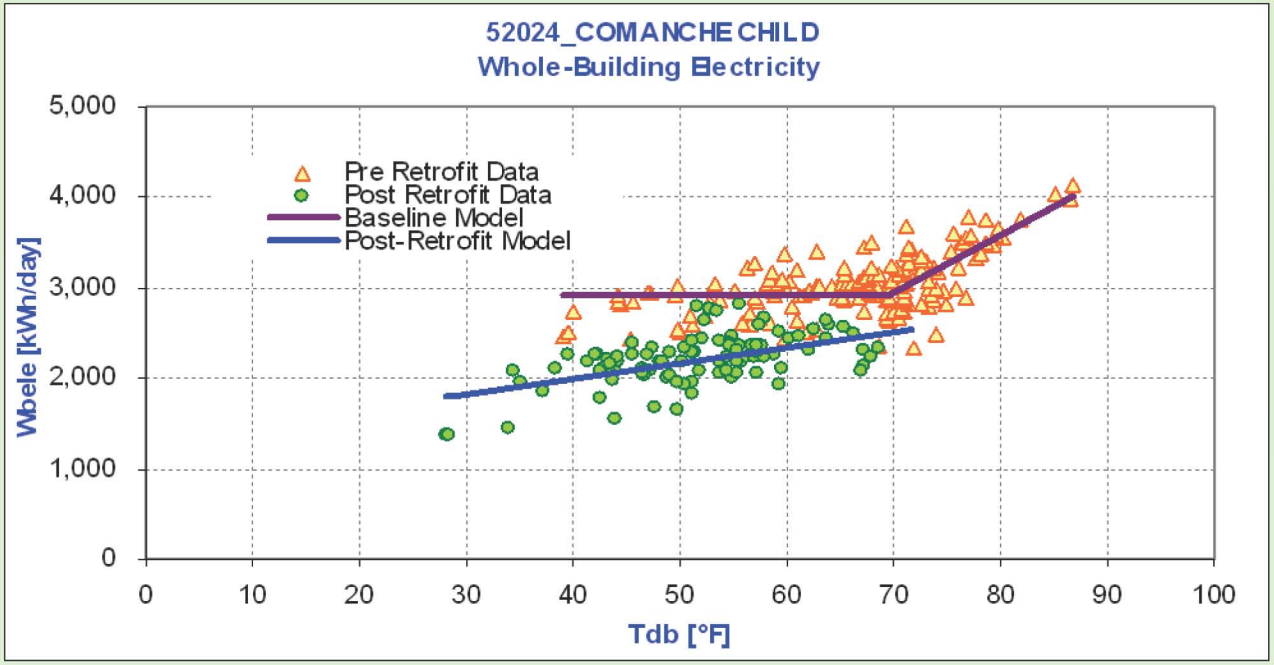
Savings Analysis for WBE – Building 52024

- Identify pre- and post-retrofit periods and construction period.
- Pre and post period: hourly data from portable data logger.
- Unusually low pre-retrofit kWh data excluded.
- Sum of hourly data into daily totals.



Savings Analysis for WBE – Building 52024

- Measured daily kWh regressed against average daily temperature.
- Models of this type applied for the measured miscellaneous sites.



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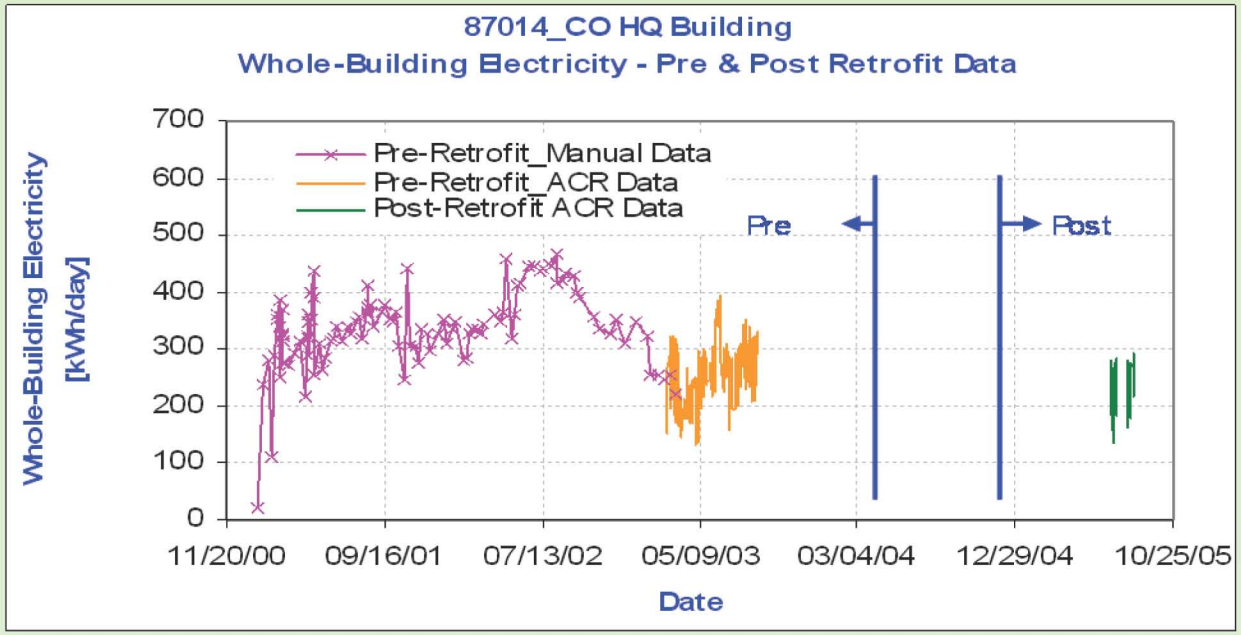
Savings Analysis for WBE – Building 87014

- Identify pre- and post-retrofit periods and construction period.
- Pre-retrofit period: weekly manual readings averaged to daily.
- Post-retrofit period: hourly data from portable loggers summed to daily.



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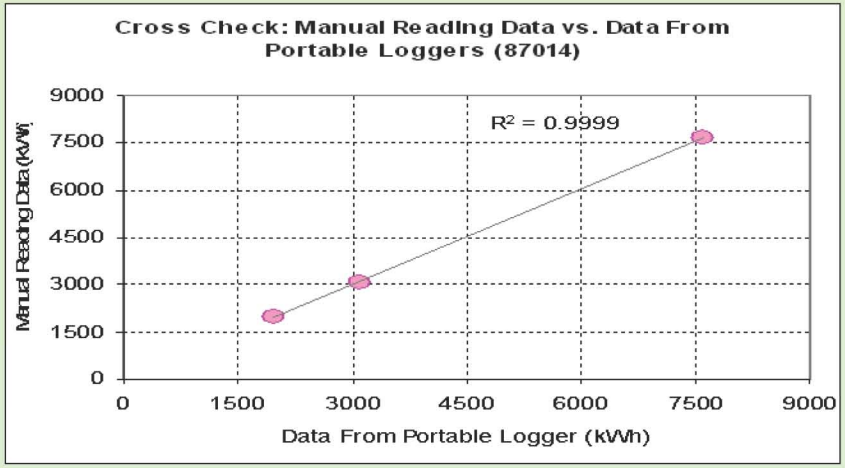
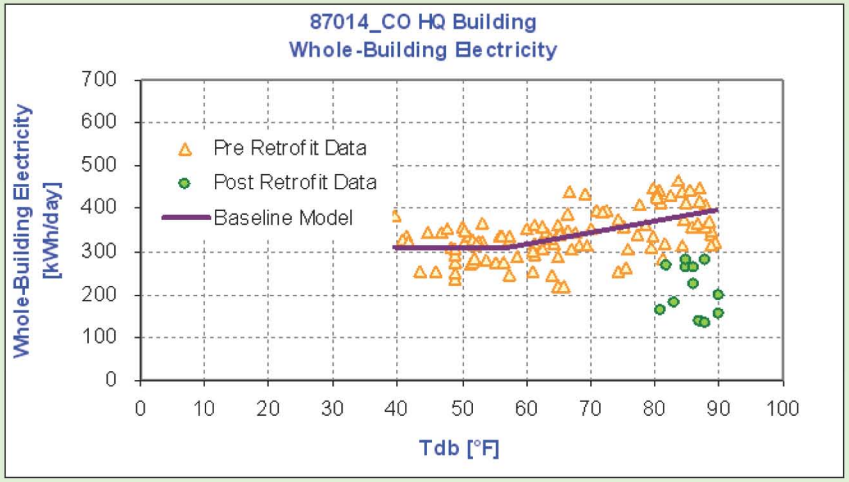
Savings Analysis for WBE – Building 87014

- Overlap period for the hourly data from portable ACR loggers and the manual readings.
- Comparison of the summed hourly data and weekly readings.
- Pre-retrofit period:
  - Manual weekly readings regressed against the average weekly temperature using three parameter model.
  - Pre-retrofit models acceptable in a large number of the buildings.
  - Helped to reduce the costs of installing loggers and developing the baseline models from hourly data.
- Post-retrofit period:
  - More data needed for post-model.





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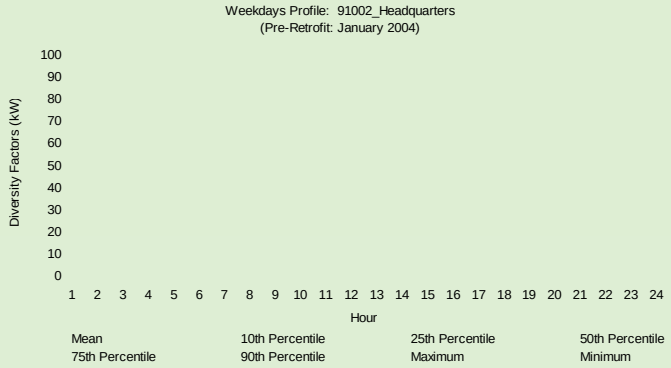
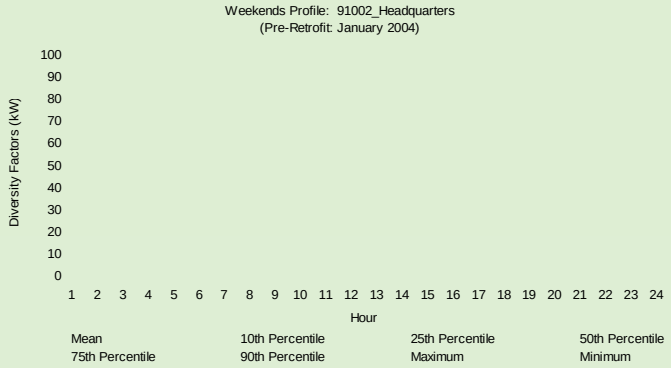
Savings Analysis for Demand – Building 91002

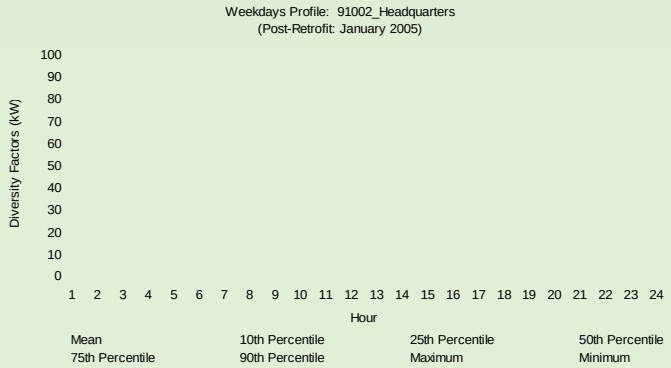
- Six months of hourly data for pre-retrofit period and four months of hourly data for post-retrofit period.
- 24-hour profiles developed using ASHRAE's Diversity Factor Toolkit.
- The max. kW (90th percentile) of the month used to calculate the demand savings.

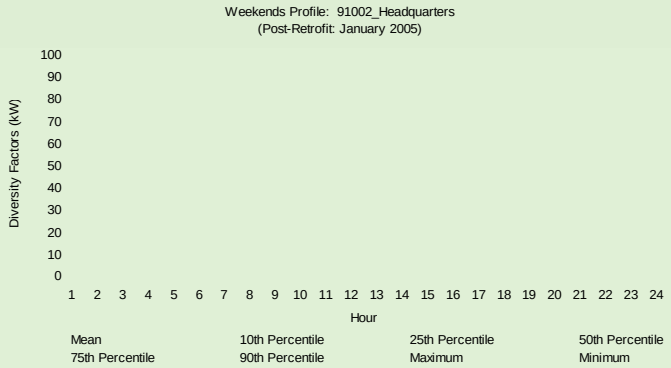
Jan 04: 88kW





Jan 05: 82kW





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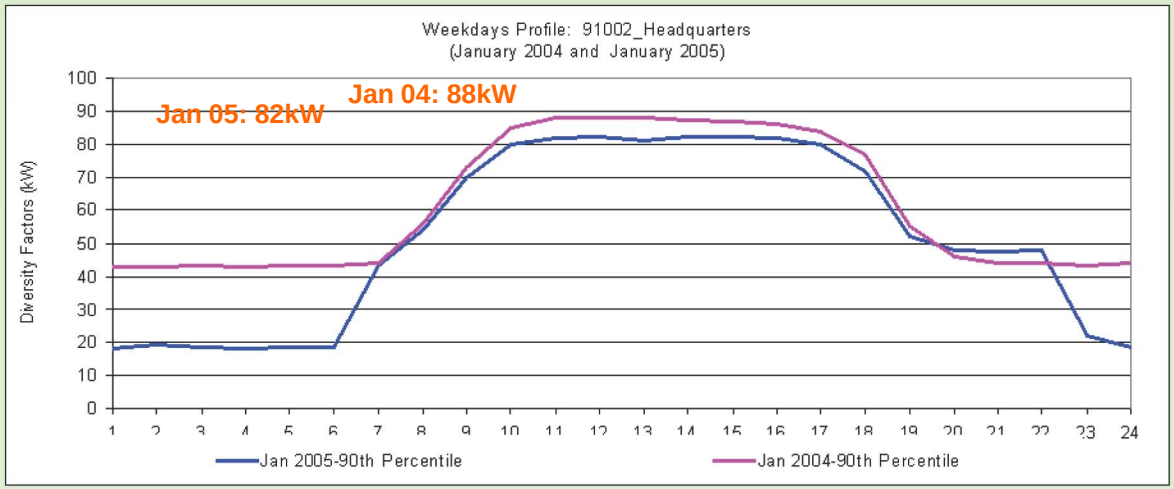
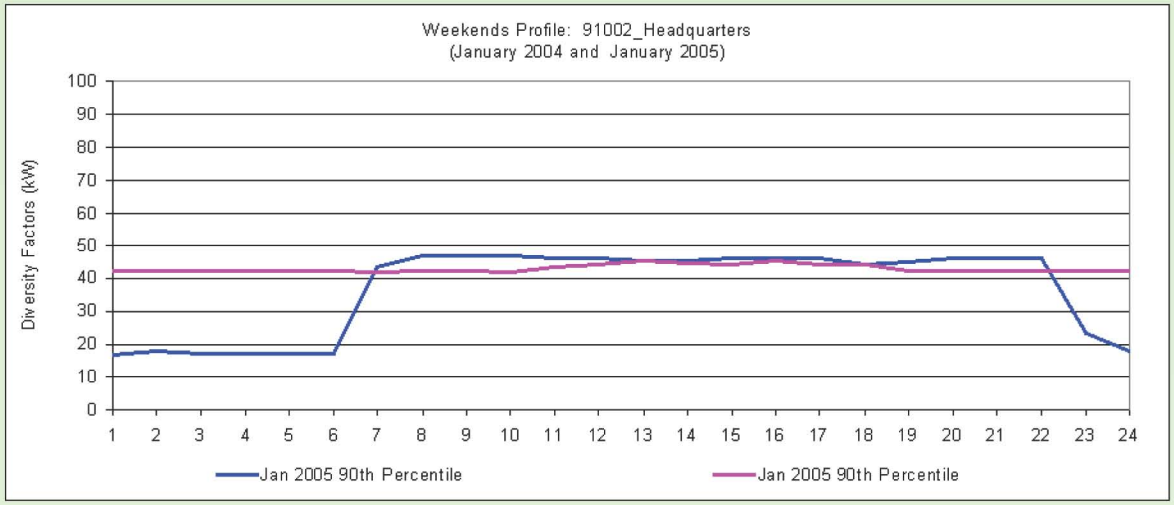
Savings Analysis for Demand – Building 91002

- 90 percentile curves for both pre-retrofit period (Jan 2004) and post retrofit period (Jan 2005)

Weekdays



Weekends



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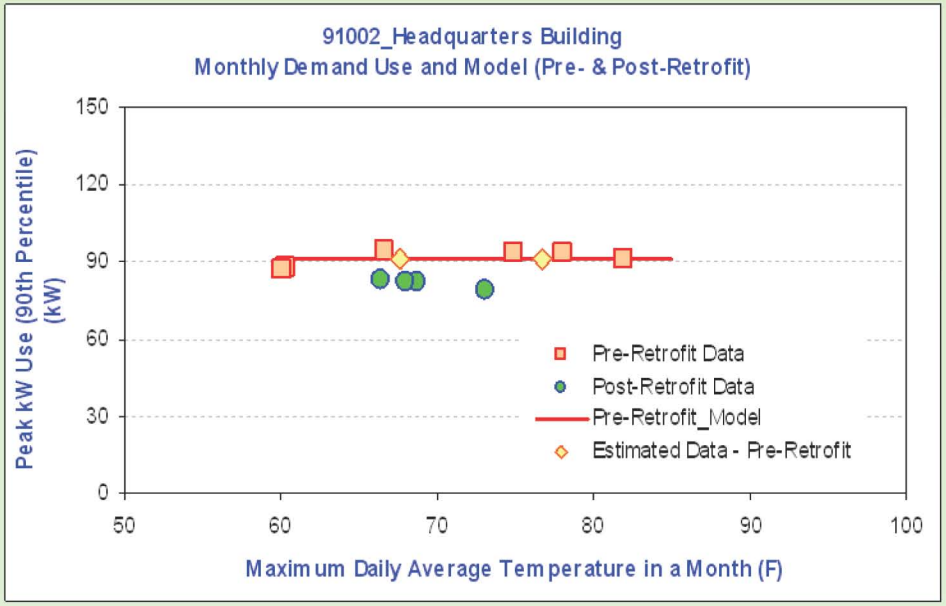
Savings Analysis for Demand – Building 91002

- Change-point linear models applied to extend the demand prediction from the 1093-RP demand savings analysis to months where no demand was available.
- The maximum monthly demand (90th percentile) plotted against the maximum average daily temperature of the month for the pre-retrofit period.
- The demand savings for March 2005 and April 2005:
  - The maximum demand-90th percentile from these two months.
  - The estimated demand from the 1P demand model for March 2003 and April 2003.



March 2003

April 2003

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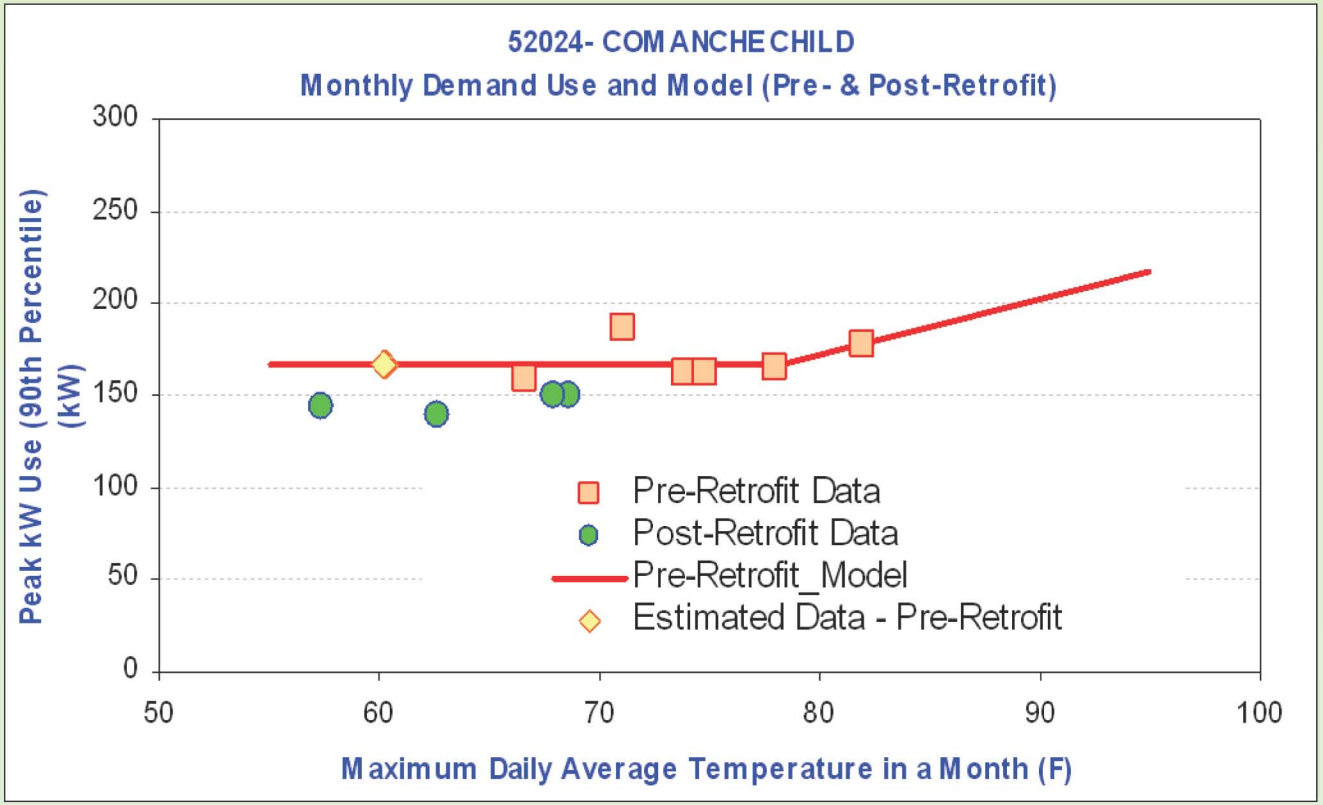
Savings Analysis for Demand – Building 52024



Estimated Demand

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Summary of Measured Savings

Bldg. #	Electricity Savings For the Measured Period				Demand Savings For the Measured Period			
	No. Of Days	Audit-Estimated Electricity Savings (kWh/period)	Measured Electricity Savings (kWh/period)	% of Audit-Estimated Savings	No. Of Months	Audit-Estimated Demand Savings (kW/period)	Measured Demand Savings (kW/period)	% of Audit-Estimated Savings
52024	100	103,251	71,568	69.3%	4	72	96	132.8%
1001	365	821,700	787,465	95.8%	12	2,363	1,382	58.5%
91002	115	68,728	31,010	45.1%	4	40	32	79.5%
87014	25	2,253	3,763	167.0%	3	24	11	45.8%

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Lessons Learned

- It could take five years for M&V for ESPC. Data from different sources may be blended for evaluating the results.
- Careful planning of data collection and inspection of the data and the resultant regressions needed for:
  - Applying regression models for the energy savings calculations.
  - 24-hour profiles from diversity factor models for the demand savings calculation.
- Reliable results can be obtained.
  - The data inspection performed in a consistent manner.

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Lessons Learned

- **Following guidelines found useful in determining when to use monthly data, or install a data logger to collect short-term or continuous data.**
  - **Getting started with ASHRAE's IMT and ASHRAE's Diversity Factor Toolkit.**
    - **Less work than developing one's own models**
    - **The results can be linked to peer-reviewed publications.**
  - **Use of hourly pre and post-retrofit data collection preferred**
    - **Budget**
    - **The expense of the installation, maintenance, data collection and data processing.**
  - **Use of short-term hourly data collection using portable loggers is very helpful.**
    - **Trouble-shooting manual meter readings or detecting utility billing errors.**
    - **Evaluate the demand savings using the methods discussed in this paper.**
  - **Use of weekly meter readings or monthly utility billing data for analysis is useful.**

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Questions?

THANKS!

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