ENERGY SAVINGS AND PERSISTENCE
FROM AN ENERGY SERVICES PERFORMANCE CONTRACT
AT AN ARMY BASE

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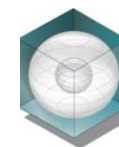
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Outline

Introduction

Methodology

Savings Analysis

Energy Savings Persistence

Recommendations

Summary

Introduction (1/2)

Energy reduction goals as mandated by Executive Order

ESPC (Energy Services Performance Contract):
- DO#1: 58 buildings in 2004-05
- DO#2: 47 buildings in 2006-08

- Energy Conservation Measures (ECMs)
    - HVAC control system upgrades
    - Lighting retrofits
    - Vending machine controls
    - Cooling tower variable frequency drivers (VFDs)

Introduction (2/2)

Laboratory's Measurement & Verification (M&V) efforts

- Hourly electricity data collection
  - 23 DO#1 buildings
  - 10 DO#2 buildings

- Energy and demand savings calculations
  - Liu et al. 2005; Cho et al. 2008; Kim et al. 2008
  - Short-term basis (just after the installation of ECMs)

Hence, this paper examined
the **persistence of energy savings from the application of M&V for the Fort Hood Energy Services Performance Contract (ESPC).**

Methodology (1/3)

Selection of Buildings

- **10 buildings (6 DO#1 and 4 DO#2)** based on the availability of suitable hourly data for the pre- and post-retrofit periods
- Post-retrofit periods: **2008-2010** data

ID No. for Ten Sites Analyzed in this Paper	Bldg. #	Building/ Thermal Plant Name	DO#1/ DO#2	Building Size (ft²)	Energy Conservation Measures (ECMs)				Annual Audit-Estimated Electricity Savings (kWh/year)
					HVAC Controls	Lighting	Vending Controls	Cooling Tower VFDs	
1	410	Headquarters Bldg.	DO#1	102,391	√	√	√		931,344
2	87007	Enlisted UPH Bldg.	DO#1	31,470	√	√			5,887
3	87012	Enlisted UPH Bldg.	DO#1	42,306	√	√			9,719
4	87017	Dining Facility	DO#1	15,695	√	√			41,390
5	87018	Physical Plant	DO#1	3,327	√	√		√	522,971
6	91012	Admin Bldg.	DO#1	86,292	√	√			391,136
Total for Six DO#1 Sites									**1,902,446**
7	13	Information Processing Ctr.	DO#2	22,000	√	√			71,392
8	113	Child Development Ctr.	DO#2	23,100	√	√			119,919
9	7051	Simulation Bldg.	DO#2	24,908	√		√		67,246
10	10041	Chapel Bldg.	DO#2	6,659	√	√			46,142
Total for Four DO#2 Sites									**304,700**

Methodology (2/3)

Hourly Data Collection

- Pre-retrofit data
  - DO#1 buildings: ACR loggers or manual readings
  - DO#2 buildings: ACR loggers

- Post-retrofit data
  - DO#1 buildings: Wattnode meter
  - DO#2 buildings: ACR loggers

- Weather data
 - NOAA NCDC data for WACO airport
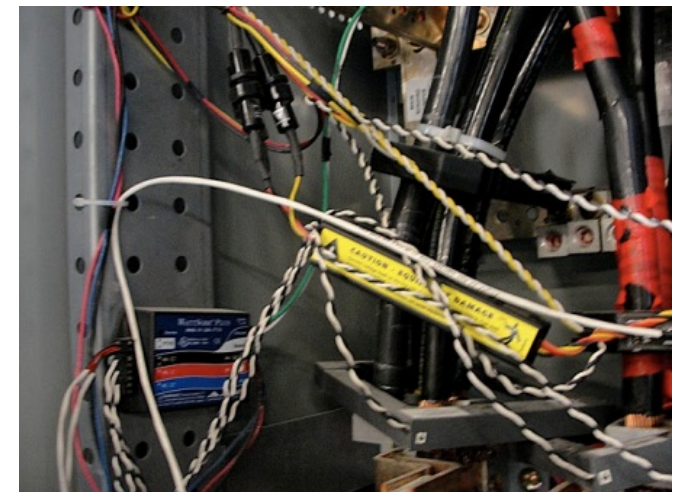
Methodology (3/3)

Savings Calculation Methods

- Development of baseline model using pre-ret
  - Calculate daily usage from hourly or 15-n
  - Model with the ASHRAE's IMT (Inverse M
  - Regression Models
    a. Mean model
    b. Two parameter model
    c. Three parameter model
    d. Four parameter model
    e. Five parameter model

- Prediction for the post-retrofit period using t
  - Using post-retrofit weather conditions
  - Electricity usage that would have been if the ret

- Calculation of savings: $E_{predicted} - E_{measured}$
  - $E_{predicted}$: predicted energy usage using the base
  - $E_{measrued}$: measured post-retrofit energy use
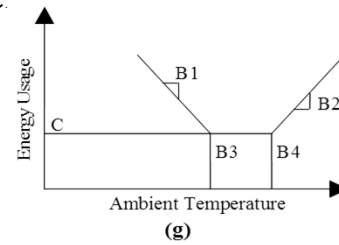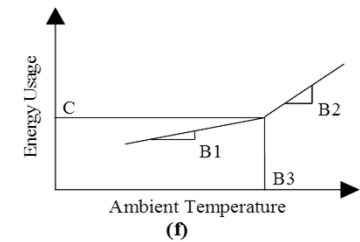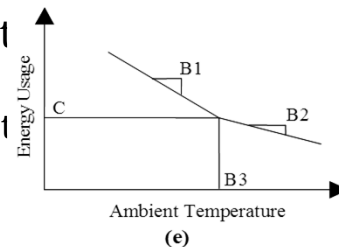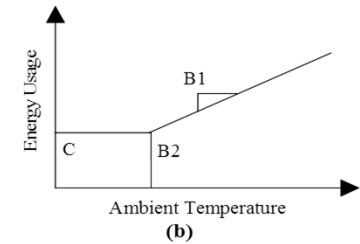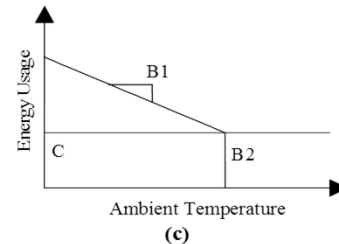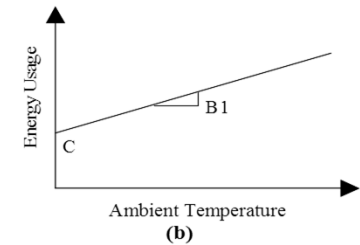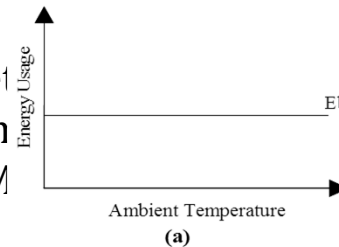
Savings Analysis: DO#1 410 (1/3)

410 Headquarters Building

- Sum hourly data into daily totals
- Retrofits: HVAC controls, lighting, and vending controls
- Pre-retrofit period used in this study: **Mar. 2003 to Feb. 2004**
- Post-retrofit period used in this study: **Jan. 2010 to Sep. 2010**
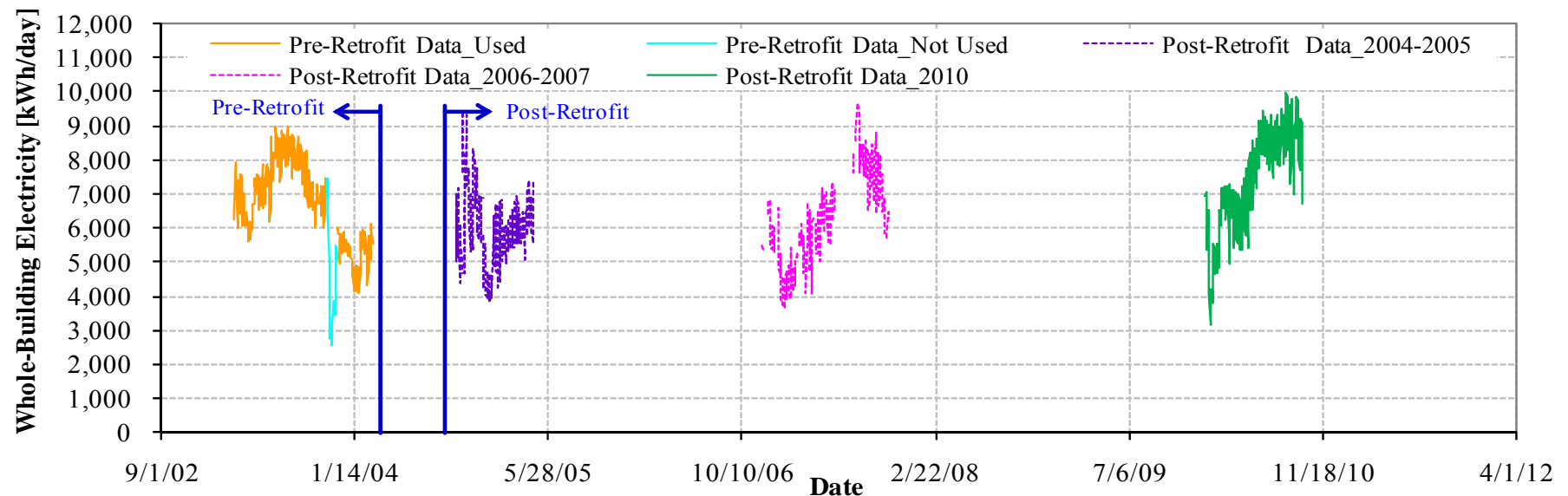
Savings Analysis: DO#1 410 (2/3)

410 Headquarters Building

- Three parameter baseline models for weekdays and weekends

Weekday

Weekend

Savings Analysis: DO#1 410 (3/3)

410 Headquarters Building

- Increased electricity usage of **−11.3%** of the audit-estimated savings
- Audit-estimated savings: 640,458 kWh
- Measured savings: −72,123 kWh
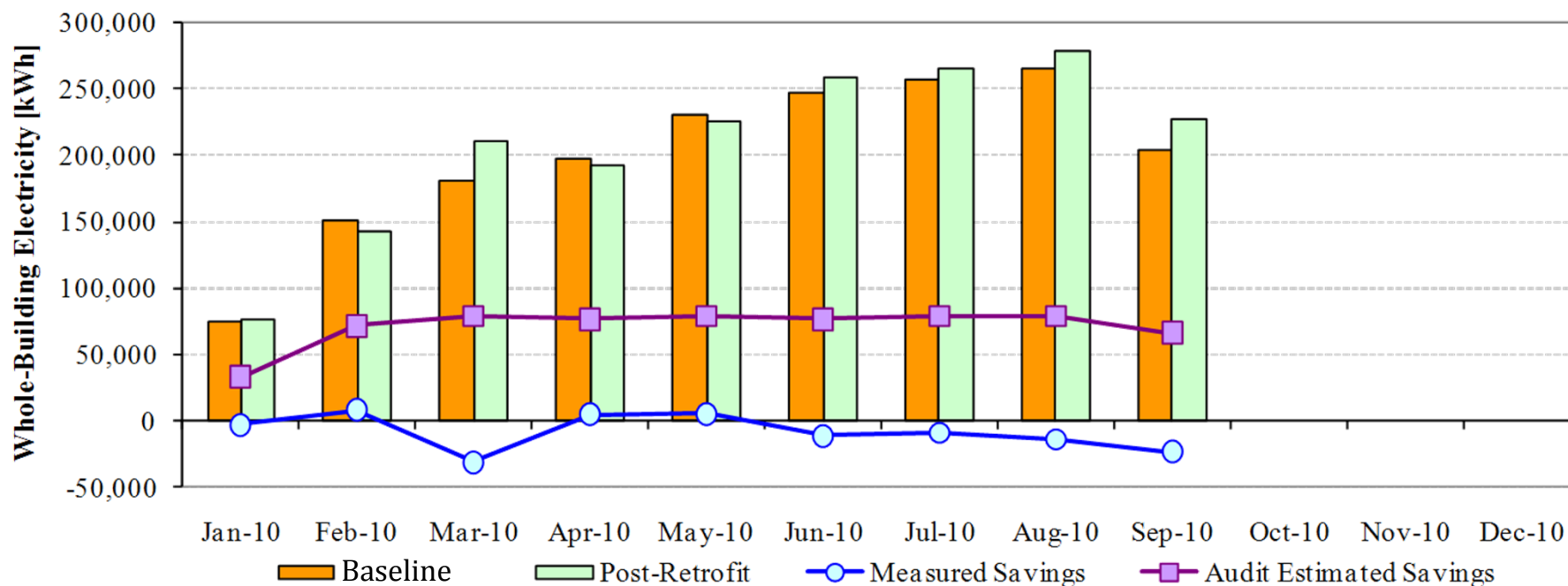
Savings Analysis: DO#2 113 (1/3)

113 Child Development Center

- Sum hourly data into daily totals
- Retrofits: HVAC controls and lighting
- Pre-retrofit period used in this study: **Oct. 2005 to Oct. 2006**
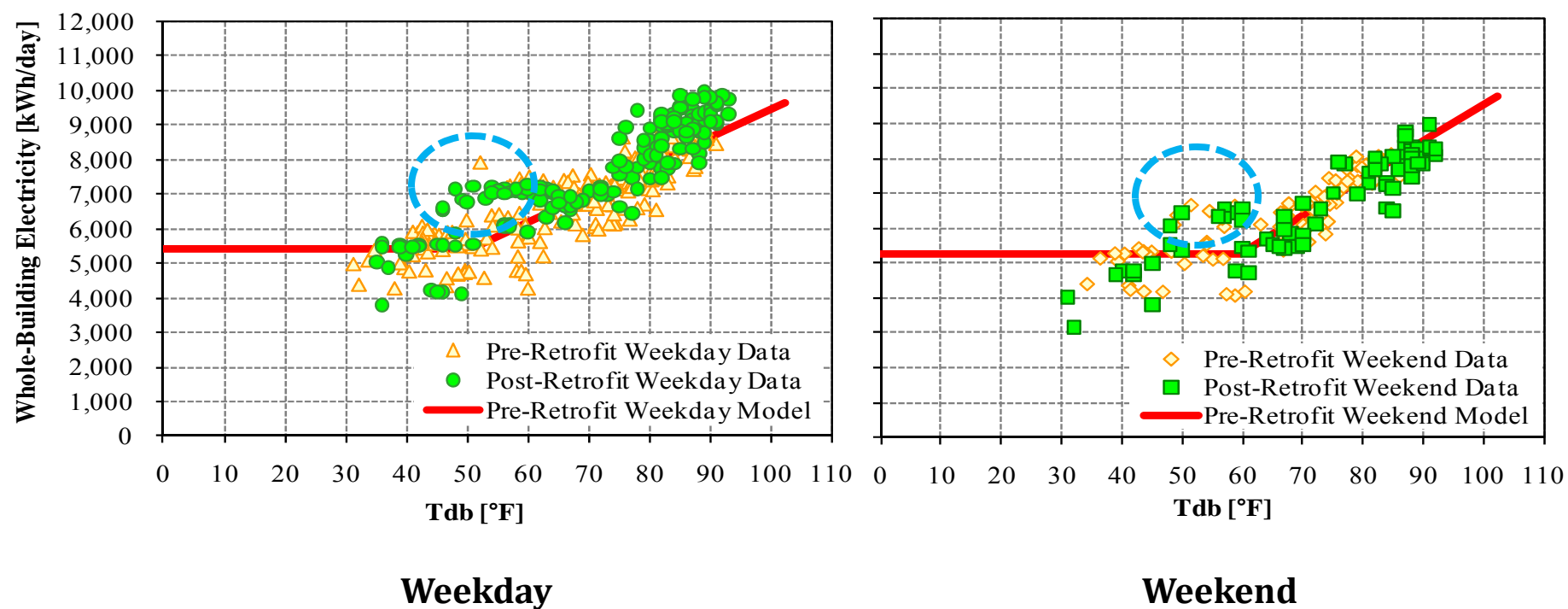- Post-retrofit period used in this study: **Sep. 2008 to Sep. 2010**
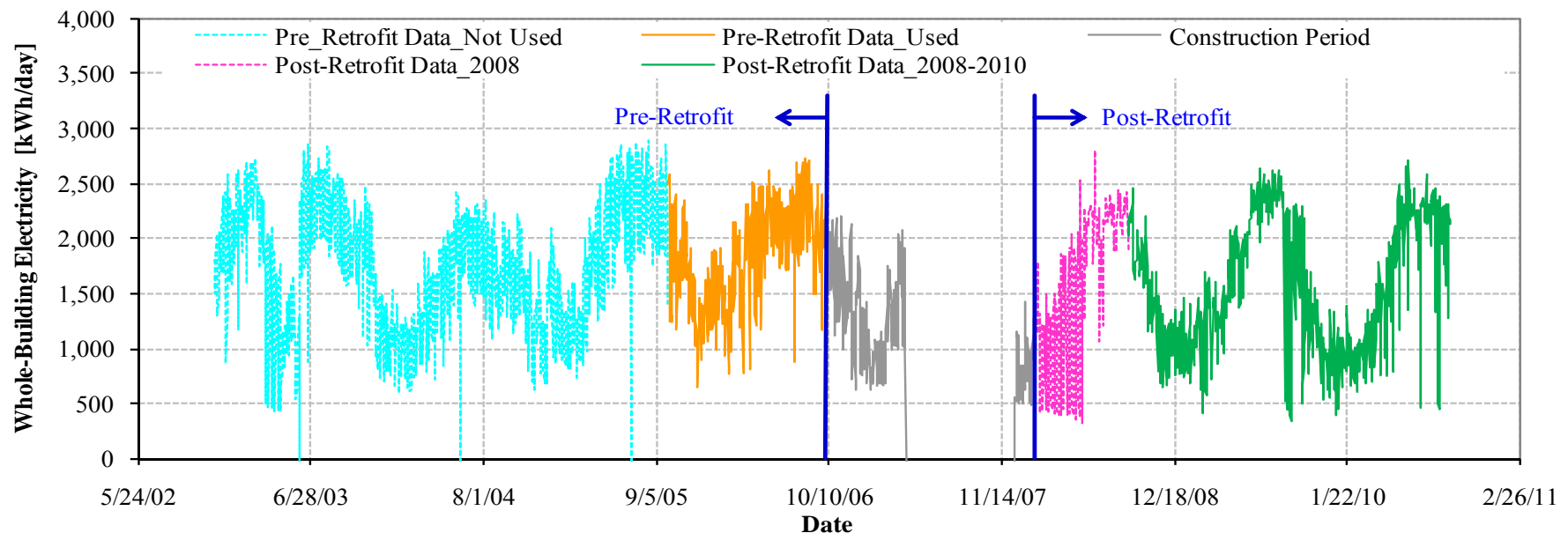
Savings Analysis: DO#2 113 (2/3)

113 Child Development Center

- Three parameter baseline models for weekdays and weekends

Weekday

Weekend

Savings Analysis: DO#2 113 (3/3)

113 Child Development Center

- **73.0%** of the audit-estimated savings
- Audit-estimated savings: 244,438 kWh
- Measured savings: 178,318 kWh

Savings Analysis: Summary
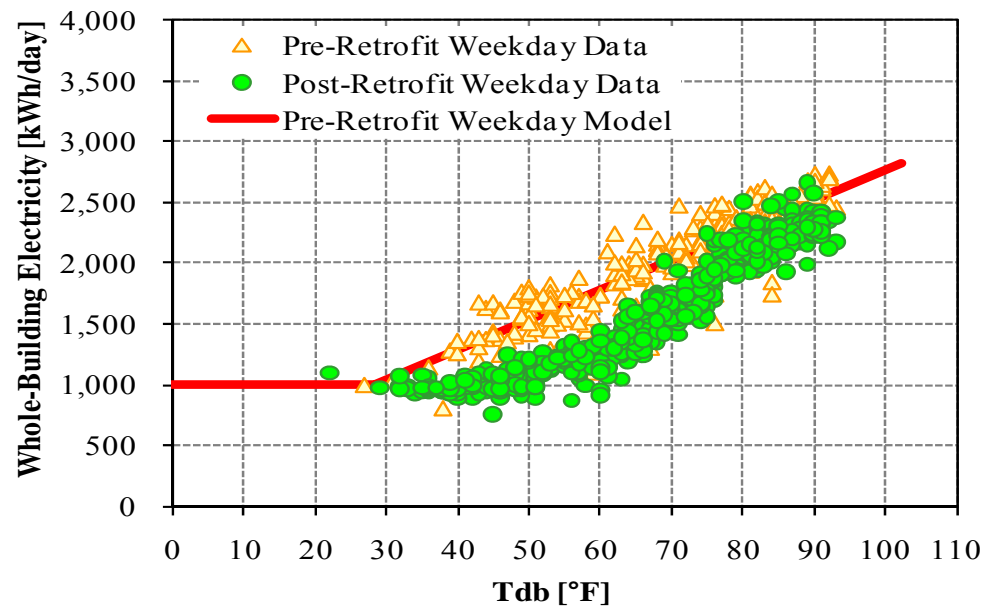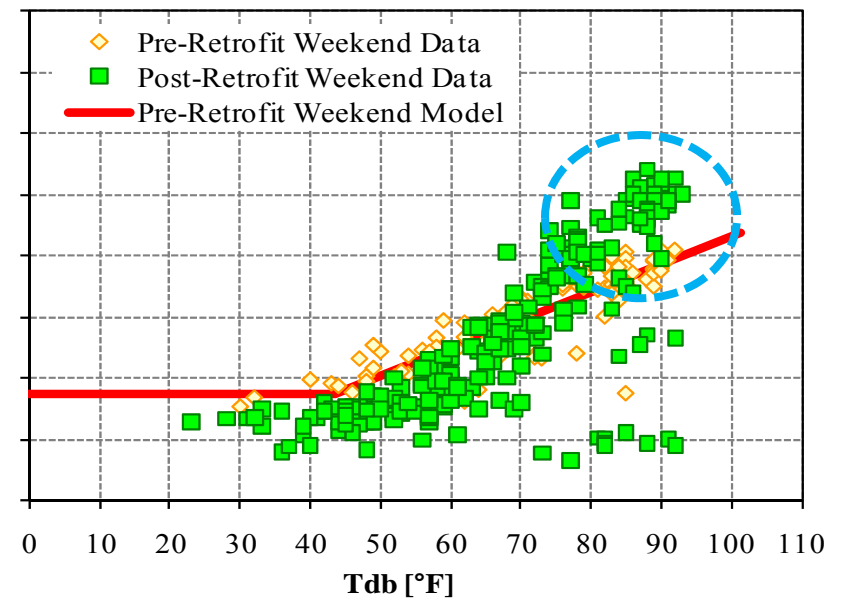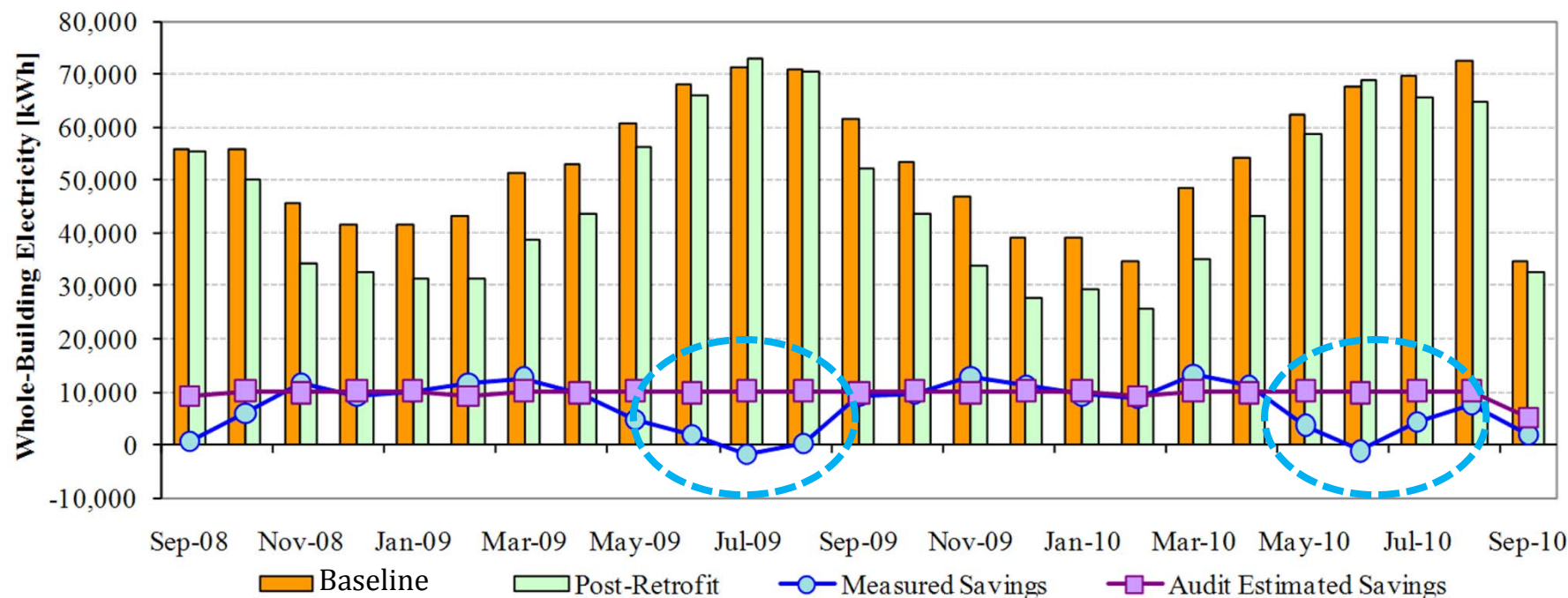
ID No. for Ten Sites Analyzed in this Paper	Bldg. #	Building/ Thermal Plant Name	DO#1/ DO#2	Baseline Period	Pre-Retrofit Data	Post-Retrofit Data	Pre-Retrofit Model	No. Of Days	Audit-Estimated Savings (kWh/period)	Measured Savings (kWh/period)	% of Audit-Estimated Savings
								Electricity Savings For the Measured Period (2010 for DO#1 and 2008-2010 for DO#2)			
1	410	Headquarters Bldg.	DO#1	Mar. 2003-Feb. 2004	Hourly data from ACR logger	15-min data from Wattnode	3P Weekday and Weekend Models	251	640,458	-72,123	-11%
2	87007	Enlisted UPH Bldg.	DO#1	Dec. 2000-Mar. 2003	Weekly manual readings	15-min data from Wattnode	4P All data model	234	3,774	24,905	660%
3	87012	Enlisted UPH Bldg.	DO#1	Dec. 2000-Mar. 2003	Weekly manual readings	15-min data from Wattnode	2P All data Model	251	6,683	-8,347	-125%
4	87017	Dining Facility	DO#1	Feb. 2001-Mar. 2003	Weekly manual readings	15-min data from Wattnode	3P All data Model	253	28,689	-36,290	-126%
5	87018	Physical Plant	DO#1	Mar.-Nov. 2001; May-Nov. 2002; and Apr.-Dec. 2003	Hourly data from ACR logger	15-min data from Wattnode	4P All data model	173	247,874	170,867	69%
6	91012	Admin Bldg.	DO#1	Dec. 2002-Feb. 2004	Hourly data from ACR logger	15-min data from Wattnode	3P Weekday and Weekend Models	251	268,973	-322,858	-120%
Total for Six DO#1 Sites									**1,196,451**	**-243,846**	**-20%**
7	13	Information Processing Ctr.	DO#2	Nov. 2005-Oct. 2006	Hourly data from ACR logger	Hourly data from ACR logger	3P All data Model	518	101,318	-357,110	-352%
8	113	Child Development Ctr.	DO#2	Oct. 2005-Oct. 2006	Hourly data from ACR logger	Hourly data from ACR logger	3P Weekday and Weekend Models	744	244,438	178,318	73%
9	7051	Simulation Bldg.	DO#2	Nov. 2005-Aug. 2006	Hourly data from ACR logger	Hourly data from ACR logger	3P Weekday and Weekend Models	754	138,914	939,767	677%
10	10041	Chapel Bldg.	DO#2	Dec. 2005-Dec. 2006	Hourly data from ACR logger	Hourly data from ACR logger	3P All data Model	571	72,184	175,858	244%
Total for Four DO#2 Sites									**556,854**	**936,833**	**168%**
Total for DO#1 and DO#2 Sites									**1,753,305**	**692,987**	**40%**

ID No. for Ten Sites Analyzed in this Paper	Bldg. #	Building/Thermal Plant Name	DO#1 / DO#2	Building Size (ft²)	Electricity Savings (kWh/period) for 2004-2005				Electricity Savings (kWh/period) for 2006-2007				Electricity Savings (kWh/period) for 2010 (DO#1) and 2008-2010 (DO#2)			
					No. Of Days	Audit-Estimated Savings	Measured Savings	% of Audit-Estimated Savings	No. Of Days	Audit-Estimated Savings	Measured Savings	% of Audit-Estimated Savings	No. Of Days	Audit-Estimated Savings	Measured Savings	% of Audit-Estimated Savings
	194	NCO Club	DO#1	19,023					335	469,829	53,620	11%				
1	410	Headquarters Bldg.	DO#1	102,391	202	515,429	-11,190	-2%	335	854,795	129,611	15%	251	640,458	-72,123	-11%
	1001	Headquarters Bldg.	DO#1	312,800	365	821,700	787,465	96%								
	5764	Officers Club	DO#1	36,649					335	293,328	113,722	39%				
	33001	MEDAC	DO#1	20,240	212	22,307	68,660	308%	699	73,550	135,350	184%				
	33003	MEDAC	DO#1	20,240	212	21,928	-36,228	-165%								
	52024	Comanche Child Bldg.	DO#1	34,779	100	103,251	71,568	69%	212	218,892	164,917	75%				
	87003	BN HQ Bldg.	DO#1	12,314					74	10,405	15,839	152%				
	87006	Health Clinic	DO#1	4,073	28	847	740	87%	46	1,392	2,460	177%				
2	87007	Enlisted UPH Bldg.	DO#1	31,470					365	5,887	25,138	427%	234	3,774	24,905	660%
	87008	BN HQ Bldg.	DO#1	6,371	28	1,412	2,173	154%	46	2,320	5,949	256%				
	87009	BN HQ Bldg.	DO#1	12,381	28	3,773	2,760	73%								
	87011	CO HQ Bldg.	DO#1	25,618	28	4,271	2,645	62%								
3	87012	Enlisted UPH Bldg.	DO#1	42,306					881	23,4__						-125%
	87014	CO HQ Bldg.	DO#1	14,162					335	30,18_						
	87015	Enlisted UPH Bldg.	DO#1	42,306					881	15,6__						
	87016	CO HQ Bldg.	DO#1	25,168					182	25,030	40,993	164%				
4	87017	Dining Facility	DO#1	15,695	28	3,175	4,755	150%								-126%
5	87018	Physical Plant	DO#1	3,327												69%
	91002	Headquarters Bldg.	DO#1	38,462	115	68,728	31,010	45%								
6	91012	Admin Bldg.	DO#1	86,292	110	117,877	-57,119	-48%					251	268,973	-322,858	-120%
		Total for DO#1 Sites				**1,684,700**	**867,239**	**51%**		**2,024,7__**						**-20%**
7	13	Information Processing Ctr.	DO#2	22,000					215	42,05_						-352%
8	113	Child Development Ctr.	DO#2	23,100					216	70,96_	60,295	85%	744	244,438	178,318	73%
	7012	AC Maintenance Hanger	DO#2	54,706					262	67,33_						
9	7051	Simulation Bldg.	DO#2	24,908					216	39,79_						677%
10	10041	Chapel Bldg.	DO#2	6,659					189	23,893	44,513	186%	571	72,184	175,858	244%
	23001	Physical Fitness Center	DO#2	58,841					216	76,696	-2,343	-3%				
	50004	Exchange Main Store	DO#2	307,336					468	363,595	-17,769	-5%				
	88030	Repair Bays	DO#2	171,957					217	171,767	76,232	44%				
		Total for DO#2 Sites								**856,097**	**137,670**	**16%**		**556,854**	**936,833**	**168%**
		Total for DO#1 and DO#2 Sites				**1,684,700**	**867,239**	**51%**		**2,880,864**	**958,912**	**33%**		**1,753,305**	**692,987**	**40%**

Callout annotations:

- **Site-by-site variation: –352% to 677% of the audit-estimated savings**
- **Higher savings than audit-estimated savings**
- **Less savings than audit-estimated savings**
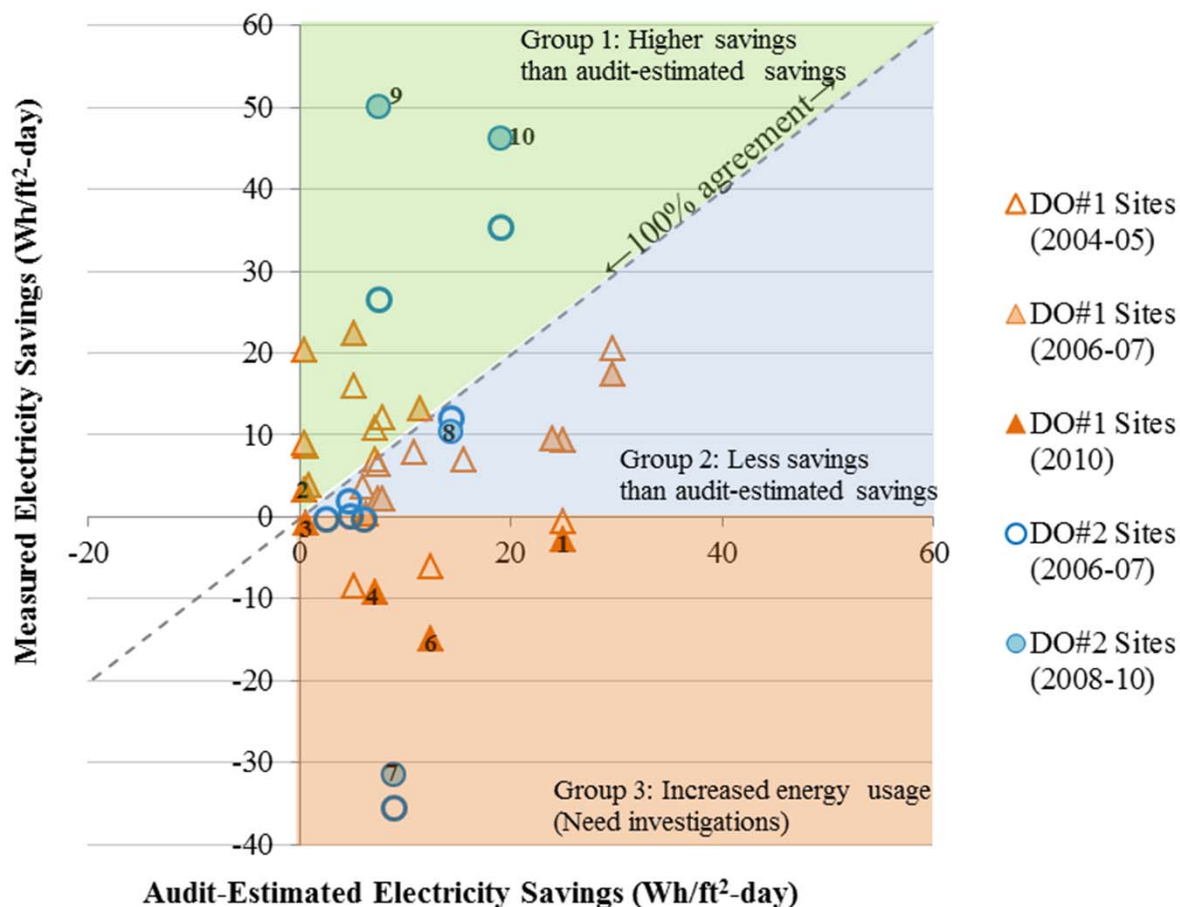- **Increased energy usage**

Energy Savings Persistence

Three groups

- Unmet savings for Group 2 and Group 3 buildings: unknown reasons

Note: The numbers in the figure are the building identification numbers in the first column of Table 3. ID No.5 (87018 Thermal Plant) was excluded in the figure due to its very large numbers of savings (431 Wh/ft^2-day of audit-estimated savings and 297 Wh/ft^2-day of measured savings: Group 2) compared to other sites.

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Recommendations

Three Recommendations

- Blink Test
  - Staged shut-down sequence for the systems of interests in the building
  - Quick way to identify the size of various loads

- Energy Sub metering
  - Sub metered energy data by major end-use
  - Helpful to identify the reasons of improved/deteriorated energy performance

- Lab Testing of Individual Measures
  - Testing in an independent lab before applying measures in the field
  - Helpful for a more accurate estimate of savings

Summary

Analysis of Long-Term Energy Savings from an ESPC at an Army Base

- 10 buildings at an army base

- Weather-dependent and weather-independent linear and change-point linear models calculated with the ASHRAE's IMT

- Results
    - For all 10 buildings: 40% of the audit-estimated savings
    - Site-by-site variation: −352% to 677% of the audit-estimated savings
    - 3 buildings: higher savings than the audit-estimated savings
    - 2 buildings: less savings that the audit-estimated savings
    - 5 buildings: negative savings (increased energy usage), overwhelming the total savings

Acknowledgement

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Thank You!