C20: Connecticut Energy Conscious Blueprint (ECB) Impact Evaluation Program Year 2012-2013

IMPACT FINDINGS

November 30, 2015

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AGENDA

- Big Picture Context
- Objectives
- Methods
- Findings
- Recommendations

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IMPACT EVALUATION

Program Period Evaluated

January 1, 2012 through October 31, 2013

Impact Evaluation Team

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IMPACT RESEARCH QUESTIONS & APPROACH

Questions	On-Sites	Project File Review	Secondary Data
A. What are the **electric energy and demand savings impacts and realization rates** of the program?			
B. What are the **natural gas energy savings impacts and realization rates** of the program?			
C. What are the estimated **non-energy impacts** as reported by participants?			
D. Are any **changes recommended to the PSD**?			
E. What are the **forward-looking realization rates** using the 2015 PSD?			

Approach meets requirements for NE-ISO Forward Capacity Market

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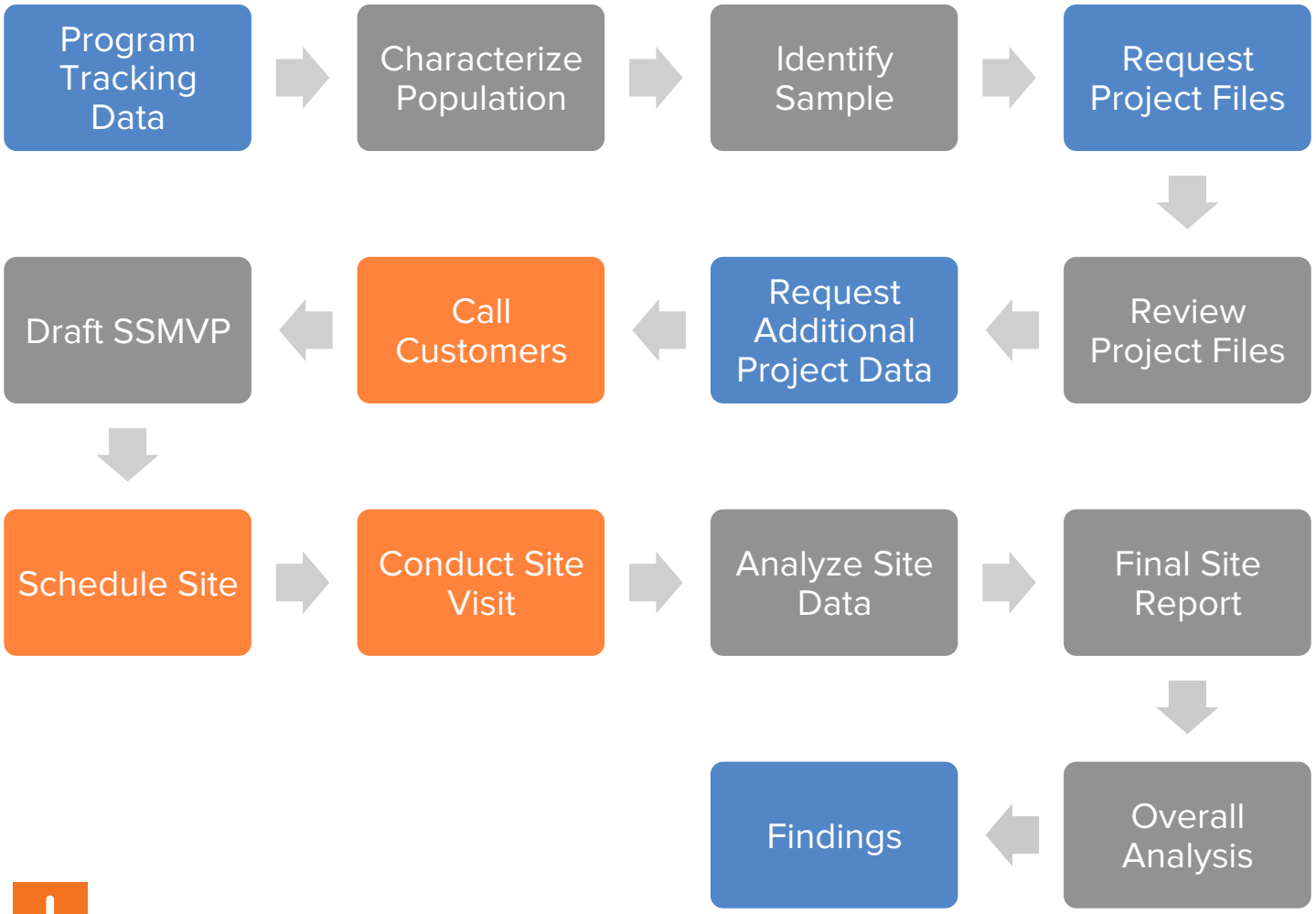
IMPACT METHODS BIG PICTURE



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IMPACT METHODS BIG PICTURE

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SAMPLE

Measure Group	Measures in Population	Population Energy Savings	Sampled Measures	Portion of Savings Sampled
Compressed Air	275	23,217 MWh	26	51%
HVAC	872	14,179 MWh	57	25%
Lighting	318	19,554 MWh	32	33%
Process	218	14,367 MWh	21	31%
HPBD/Other	50	4,569 MWh	10	77%
Overall Electric Savings	**1,733**	**75,885 MWh**	**146**	**39%**
Gas-Boiler	131	346,682 therms	17	31%
Gas-Other	158	631,733 therms	26	67%
Overall Gas Savings	**289**	**978,415 therms**	**43**	**54%**

Sample size based on savings and an assumed error ratio of 0.5

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IMPACT METHODS BIG PICTURE

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OVERALL RESULTS

Category	Realization Rate	Evaluated Savings	Relative Precision	Confidence Interval
Electric Energy Savings (MWh)	84%	63,978	+/-21%	90%
Electric Summer Demand Savings (MW)	85%	11.98	+/-20%	80%
Electric Winter Demand Savings (MW)	90%	8.82	+/-25%	80%
Natural Gas Savings (therms)	78%	762,393	+/-15%	90%

Summer demand savings meet a one tailed relative precision of +10% at 80% confidence.
Winter demand savings meet a one tailed relative precision of +9% at 80% confidence.

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ENERGY RESULTS

Measure Group	Units	Reported	Evaluated	Weighted Realization Rate	Rel. Prec. (90% Confidence)	Forward Looking Realization Rate
Compressed Air	MWh	23,217	11,376	49%	± 18%	49%
HVAC	MWh	14,179	12,052	85%	± 22%	85%
Lighting	MWh	19,554	21,510	110%	± 20%	116%
Process	MWh	14,367	14,654	102%	± 25%	102%
HPBD/Other	MWh	4,569	4,386	96%	± 18%	96%
Electric Overall	**MWh**	**75,885**	**63,978**	**84%**	**± 21%**	**86%**
Gas-Boiler	therms	346,682	332,815	96%	± 14%	96%
Gas-Other	therms	631,733	429,578	68%	± 15%	68%
Gas Overall	**therms**	**978,415**	**762,393**	**78%**	**± 15%**	**78%**

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SAMPLE REALIZATION RATE SUMMARY

Measure Group	Total Sample Reported kWh	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 90% Confidence
Compressed Air	11,921,803	49%	0%	1577%	0.11	18%
HVAC	4,070,802	85%	-29%*	871%	0.13	22%
Lighting	6,581,511	102%	0%	277%	0.12	20%
Process	3,742,329	102%	0%	220%	0.15	25%
HPBD/Other	3,394,326	96%	0%	199%	0.11	18%

* Negative savings on project where savings were claimed for multiple, overlapping measures (double-counting savings).

Measure Group	Total Sample Reported Therms	Weighted Avg Realization Rate	Min Realization Rate	Max Realization Rate	Std Error	Relative Precision @ 80% Confidence
Boiler	108,141	96%	24%	242%	0.09	14%
Other	422,714	68%	0%	263%	0.09	15%

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SUMMER DEMAND RESULTS

Measure Group	Reported (MW)	Evaluated (MW)	Weighted Realization Rate	Rel. Prec. (80% Confidence)	Forward Looking Realization Rate
Compressed Air	2.997	1.648	55%	± 11%	55%
HVAC	4.069	2.685	66%	± 20%	66%
Light	3.708	4.227	114%	± 16%	121%
Process	2.707	2.842	105%	± 35%	105%
HPBD/Other	0.584	0.572	98%	± 22%	98%
Electric Overall	**14.064**	**11.975**	**85%**	**± 20%**	**87%**

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WINTER DEMAND RESULTS

Measure Group	Reported (MW)	Evaluated (MW)	Weighted Realization Rate	Rel. Prec. (80% Confidence)	Forward Looking Realization Rate
Compressed Air	2.789	1.618	58%	± 11%	58%
HVAC	1.229	1.327	108%	± 36%	108%
Light	2.661	2.980	112%	± 20%	113%
Process	2.283	2.534	111%	± 41%	111%
HPBD/Other	0.805	0.362	45%	± 29%	45%
Electric Overall	**9.768**	**8.822**	**90%**	**± 25%**	**91%**

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ADJUSTMENTS

Documentation
E -19.4%
G -14.0%

Technology
E -0.9%
G 0.0%

Quantity
E -0.1%
G +3.0%

Operational
E +6.3%
G -14.0%

Heating & Cooling
E -1.5%
G 0.0%

Overall adjustments shown for electric (E) and gas (G) energy savings. Adjustments varied by measure and detailed tables are in section 4.3 and 4.4 of the report.

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COMPRESSED AIR

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -52% S -57% W -58%	E -2% S -3% W -3%	E 0% S 0% W 0%	E +3% S +15% W +19%	NA

- Documentation:
  - Biggest driver of downward change a **single very large project with error in compressor sequencing control which affected assumed full load hours**
  - Most common errors were ex ante assumptions not in line with manufacturer specifications and errors in **performance curves**
- Operational:
  - **Differences in evaluated operating hours** based on power metering and participant interviews compared to reported (ex-ante) assumptions; both greater and fewer operating hours.
  - **Measured operating characteristics of the equipment that were different** from what was assumed in the reported (ex-ante) calculations (*e.g.* compressor air flow, etc.)
  - **Installed equipment was found to replace backup equipment**.
  - Installed equipment was found to **not be operating as designed**.

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Overall adjustments shown for energy (E), summer demand (S), and winter demand (W) savings.

HVAC

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -12% S -6% W -9%	E 0% S 0% W 0%	E 0% S -2% W 0%	E -3% S -26% W +17%	NA

- Documentation:
  - Erroneous **facility types** used for assumptions
  - One very large cooling project with no ex ante calculations; one very large VFD project which was for backup equipment
  - Incorrect and rounded **cooling capacities** used in economizer estimates
  - Incorrect chiller **performance curves**
- Operational:
  - Differences between assumed and actual load hours
  - Beyond code operations for economizers limited

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LIGHTING

Documentation	Technology	Quantity	Operational	Heating & Cooling
E +4%	E -1%	E 1%	E +13%	E -7%
S +12%	S -2%	S 0%	S +16%	S -12%
W +6%	W 0%	W -1%	W +7%	W 0%

- Documentation:
  - **Incorrect PSD factors** used in analysis
  - **Calculation errors**
  - Erroneous **facility types** used for assumptions
- Quantity:
  - Analysis not based on **final lighting design**
- Operational:
  - **Differences between assumed and actual hours**
- Heating and Cooling:
  - Savings claimed for spaces with **no or more efficient cooling than assumed**

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PROCESS MEASURES

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -8% S -7% W +15%	E 0% S 0% W 0%	E -1% S -7% W -8%	E +11% S +19% W +4%	NA

- Documentation:
  - **Calculation errors**
- Operational:
  - Differences between assumed and actual **hours of operation**
  - Differences between assumed and actual **equipment loads**

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HBPD AND OTHER

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -13% S 0% W 0%	E 0% S 0% W 0%	E 0% S 0% W 0%	E +9% S -2% W -55%	NA

- Documentation:
  - One project: Calculation error due to **incorrect cell reference** in a work book
- Operational:
  - **Differences between the ex ante and evaluation-team created models**

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GAS - BOILER

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -3%	E 0%	E 0%	E -1%	NA

- Documentation:
  - **Calculation errors**
  - **Baseline assumptions** not in line with PSD
- Operational:
  - **Boiler system performance** found to be less than de-rated nominal efficiency
  - Difference in **annual loading hours**

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GAS - OTHER

Documentation	Technology	Quantity	Operational	Heating and Cooling
E -20%	E 0%	E 5%	E -17%	NA

- Documentation:
  - **Calculation errors**
  - Erroneous **facility types** used for assumptions
- Operational:
  - Differences between assumed and evaluated **equipment loading**
  - Differences between assumed and evaluated **hours of operation**

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NON-ENERGY BENEFITS

- One lighting measure resulted in a decrease in maintenance hours
- Nearly 20% of non-lighting measures resulted in a decrease in maintenance hours
- Five measures resulted in increased throughput; 4 of those increased revenue

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PROGRAM RECOMMENDATIONS

Reduce Errors in Calculations

- Modify the review process
- Provide guidance on PSD and assumptions
- Disallow defaults for cooling equipment calculations
- Correct vendor use of lighting peak estimates
- Require CAGI performance curves for air compressors
- Require ASHRAE 90.1-2007 basis for condensing boilers
- Collect condensing boiler water supply and return estimates in application

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PROGRAM RECOMMENDATIONS

Improve Documentation for Review and Evaluation

- Require sufficient documentation to justify savings
- Require final building simulation files for HPBD measures

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PROGRAM RECOMMENDATIONS

Improve Savings Estimates

- Consider a study to update effective full load hours (EFLH) for boiler replacements

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PROGRAM RECOMMENDATIONS

Reconsider Cost-Effectiveness

- Reconsider the cost-effectiveness of incentivizing enthalpy economizers

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PSD RECOMMENDATIONS

Revise condensing boiler adjustment factor in PSD from 0.97 to 0.93 – 0.95

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EVALUATION RECOMMENDATIONS

Use the error ratios from this study for developing next evaluation sample

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ERROR RATIOS

Group	Energy			Summer Demand			Winter Demand		
	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision	c.v.	e.r.	Confidence/ Precision
Electric - Compressed Air (kWh)	2.18	1.72	90%/18%	1.36	1.7	80%/11%	1.28	1.75	80%/11%
Electric - HVAC (kWh)	1.41	1.15	90%/22%	1.82	1.82	80%/20%	1.62	2.02	80%/36%
Electric – Lighting (kWh)	0.62	0.55	90/20%	0.72	0.62	80%/16%	0.84	0.75	80%/20%
Electric – Process (kWh)	0.69	0.66	90%/25%	2.54	2.21	80%/35%	2.19	2.74	80%/41%
Electric - HPBD/Other (kWh)	0.76	0.67	90%/18%	1.7	0.87	80%/22%	1.7	5.39	80%/29%
Electric Overall	**0.99**	**0.95**	**90%/21%**	**1.62**	**1.4**	**80%/20%**	**1.53**	**1.95**	**80%/25%**
Gas – Boiler (therms)	0.46	0.39	90%/14%	-	-	-	-	-	-
Gas – Other (therms)	0.97	1.03	90%/15%	-	-	-	-	-	-
Gas Overall	**0.71**	**0.82**	**90%15%**	**-**	**-**	-	**-**	**-**	-

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THANK YOU

Questions?

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EXTRA MATERIAL

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DOCUMENTATION ADJUSTMENTS

- Direction
  - Downward (negative) for almost all measures
  - Upward (positive) for lighting
- Causes
  - **Calculation errors**
  - Errors in assumptions
    - Operating hours
    - Facility type
    - EFLH
    - Space size
  - Measures installed on backup equipment

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TECHNOLOGY ADJUSTMENTS

- Direction
  - Small downward (negative) overall
  - Downward (negative) for compressed air and lighting
  - Zero for others
- Causes
  - Difference in equipment
  - Difference in assumptions

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QUANTITY ADJUSTMENTS

- Direction
  - Small upward (positive) for energy overall (electric and gas)
  - Small downward (negative) for demand
  - Zero for most measures
- Causes
  - Errors in capacities used
  - Errors in quantity of installed chillers
  - Equipment not installed
  - For lighting, ex ante analysis apparently not based on final lighting design

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OPERATIONS ADJUSTMENTS

- Direction
  - Both upward (positive) and downward (negative) (measure specific)
- Causes
  - Differences in operating hours
  - Differences in operating characteristics
  - Differences in efficiency of operating equipment – mostly due to operating conditions (especially boilers and compressed air)
  - Controls not functioning

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HEATING AND COOLING ADJUSTMENTS

- Direction
  - Downward (negative) adjustment for lighting
- Causes
  - More efficient cooling than assumed
  - No cooling
  - Minor correction for ‘F’ Factor

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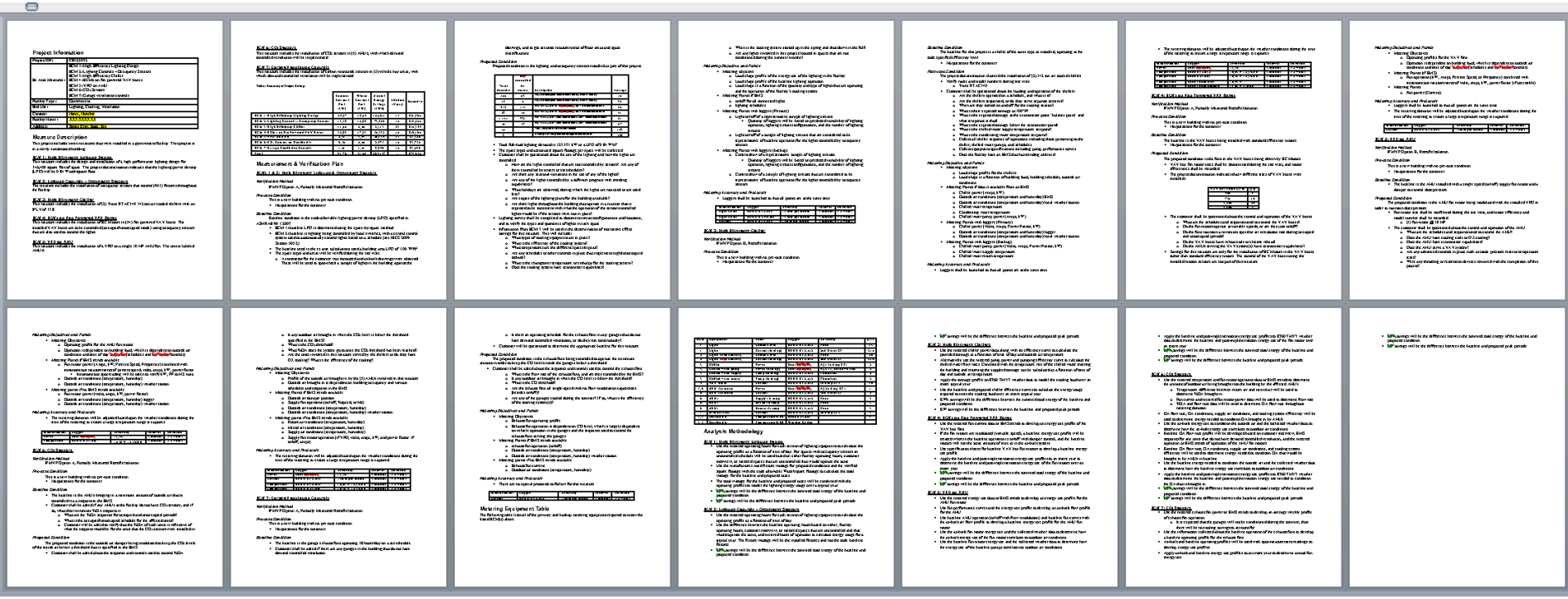
SSMVP



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SSMVP

- Description of the Project
- Measure Description
- Measurement and Verification Plan by Measure
  - Verification method
  - Pre-case condition
  - Baseline condition
  - Proposed condition
  - Metering objectives and points
  - Metering accuracy and protocols
- Metering Equipment
- Analysis Methodology by Measure

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SSMVP - IPMVP

IPMVP Option	Used For	Examples
A. Retrofit Isolation with Key Parameter Measurement	Calibrating energy models where metering all points is cost-prohibitive for the amount of savings, or not possible.	Spot check on lighting power plus logging hours of usage; using an on/off logger to estimate packaged air conditioning unit load.
B. Retrofit Isolation with All Parameter Measurement	Determining loading and duty cycle for measures that have significant savings and where all significant parameters can be metered.	Determining the duty cycle of a variable frequency drive; Measuring the duty cycle and output of a large chiller.
C. Whole Facility	Projects that are expected to save at least 10% of facility / meter consumption.	Multiple measure / comprehensive facility projects such as retrocommissioning, new control systems, or major system replacements or upgrades.
D. Calibrated Simulation	New construction primarily, or major retrofit projects and complex projects that are expected to save less than 10% of the facility / meter consumption.	New construction and retrocommissioning projects where the quantity of affected equipment and systems results in prohibitively expensive alternative M&V methods.

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METERING EQUIPMENT

- Practice safe metering
- All loggers meet M/MVDR Equipment Requirements
  - **Dent Elite Energy Logger**
  - **Hobo U12-013 External Channel Status Loggers**
  - **Hobo U12-012 Lumen Level Loggers**
  - **Hobo UX90 Light On/Off Logger**

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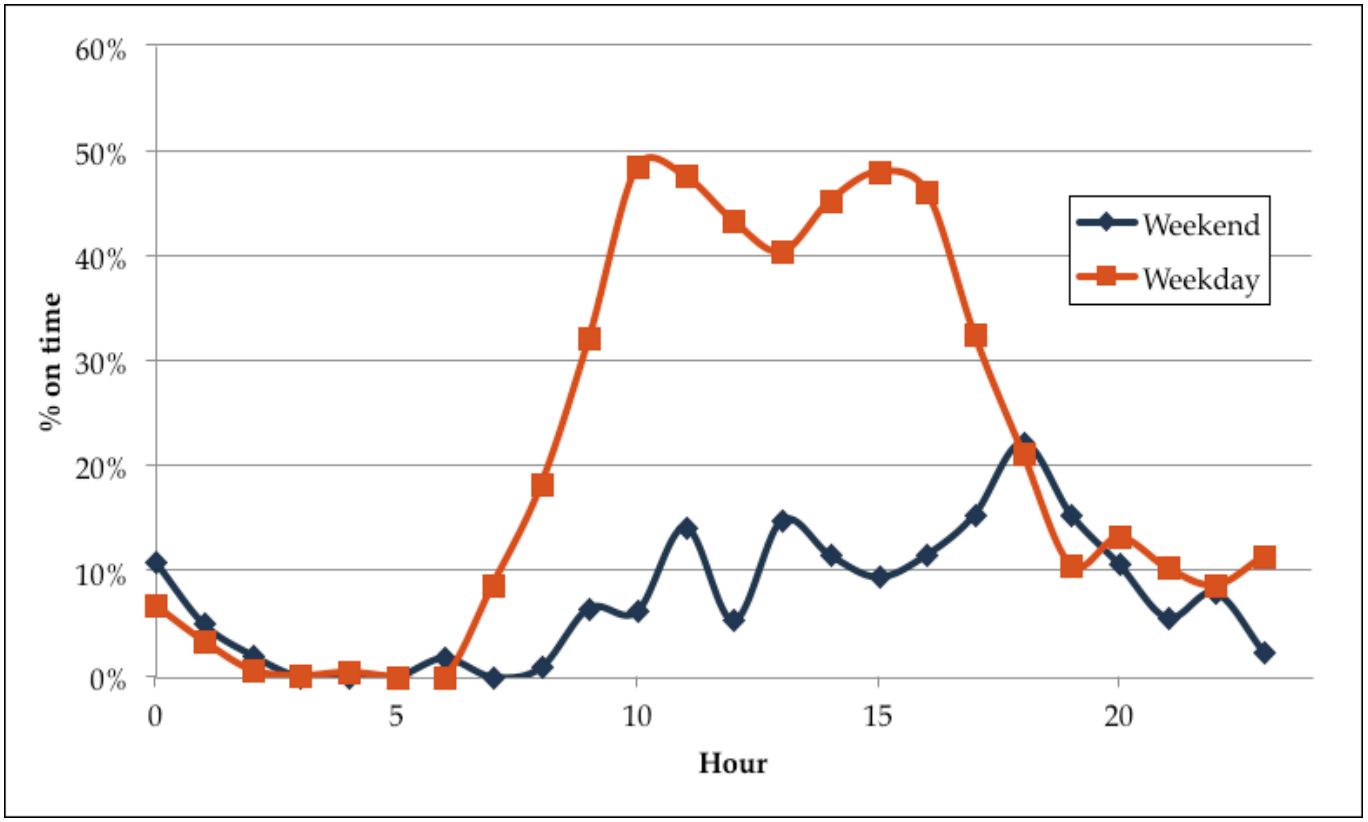
METERING – EXAMPLE INSIGHTS FROM LIGHTING



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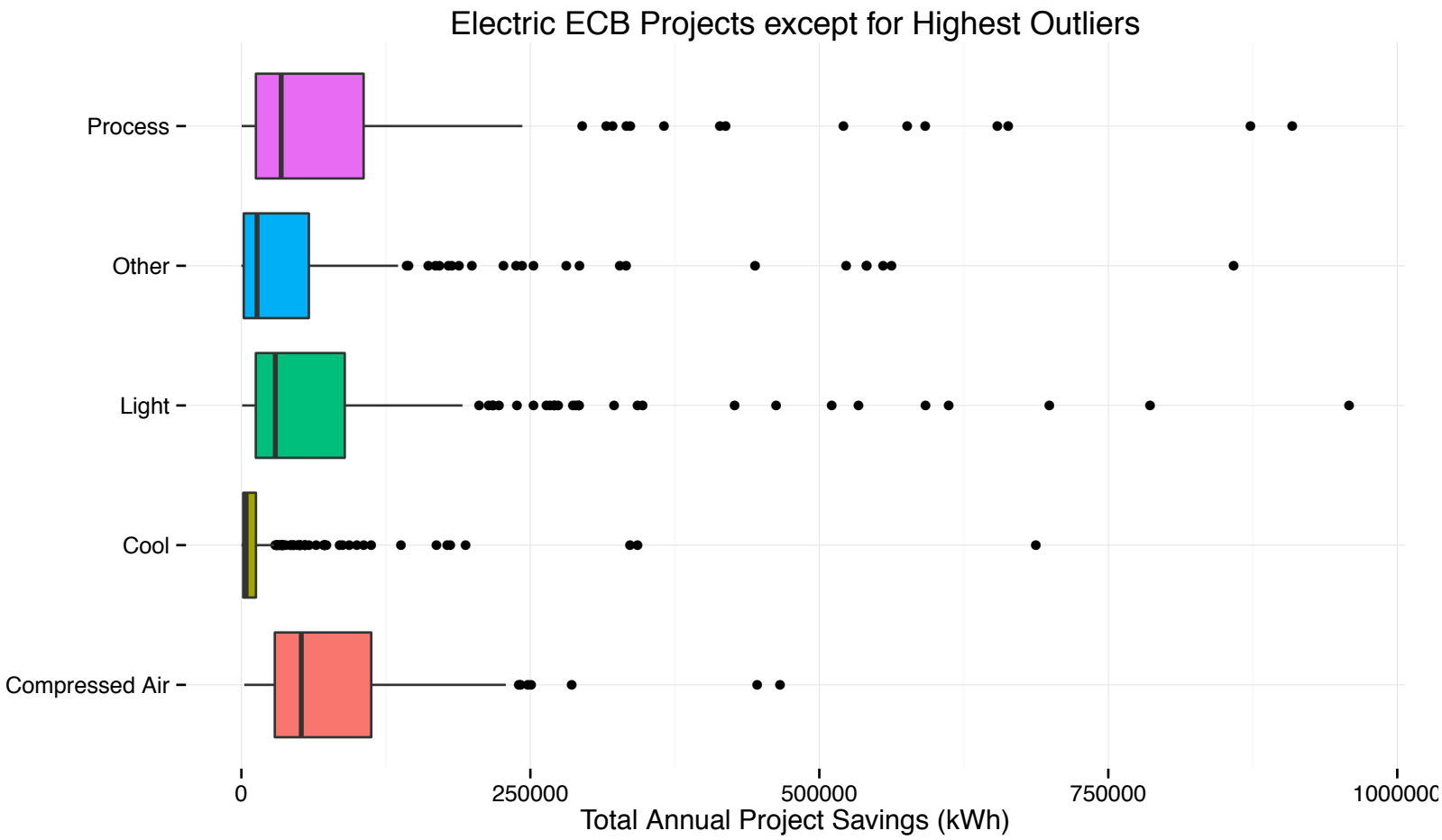
ELECTRIC PROJECT POPULATION



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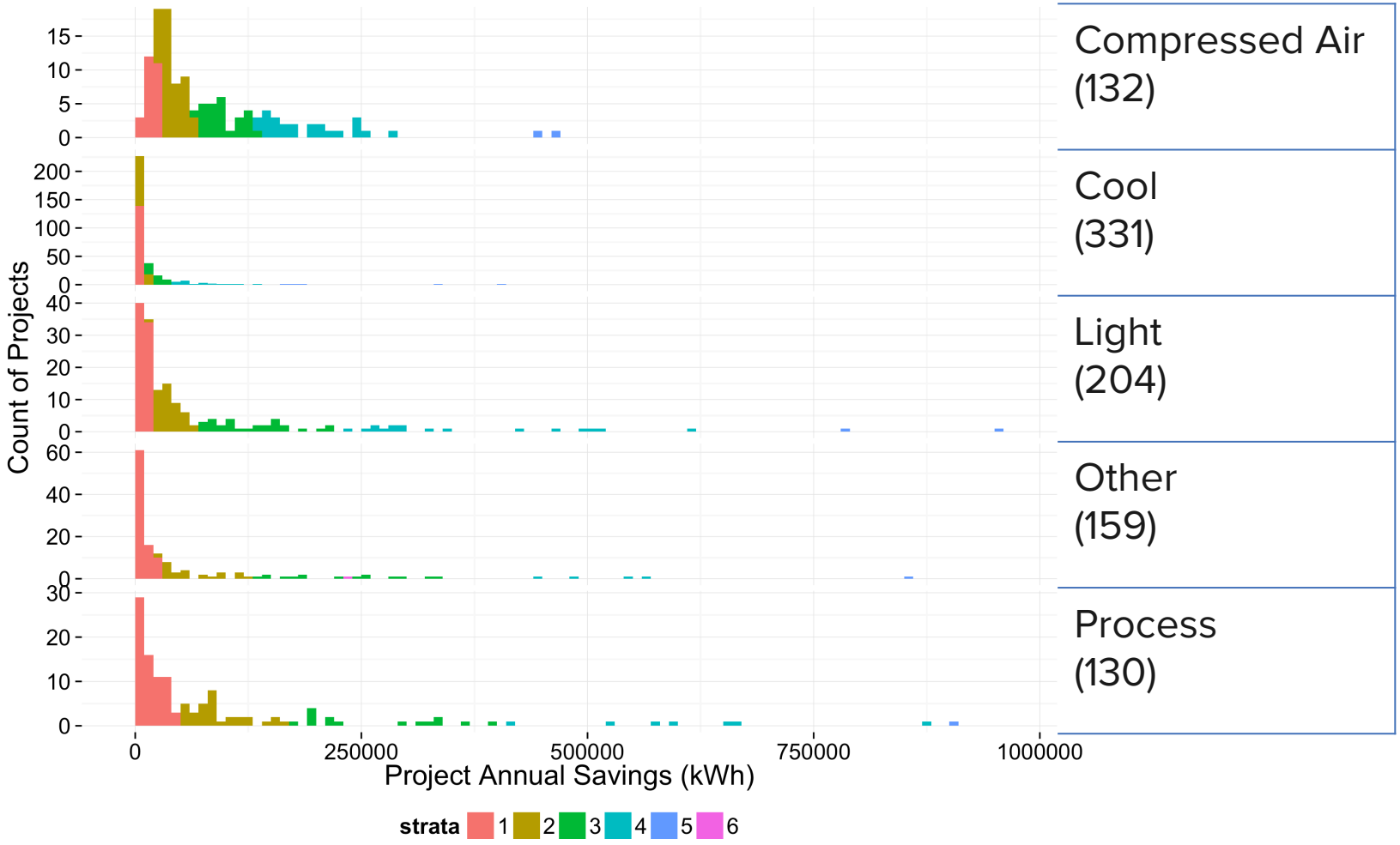
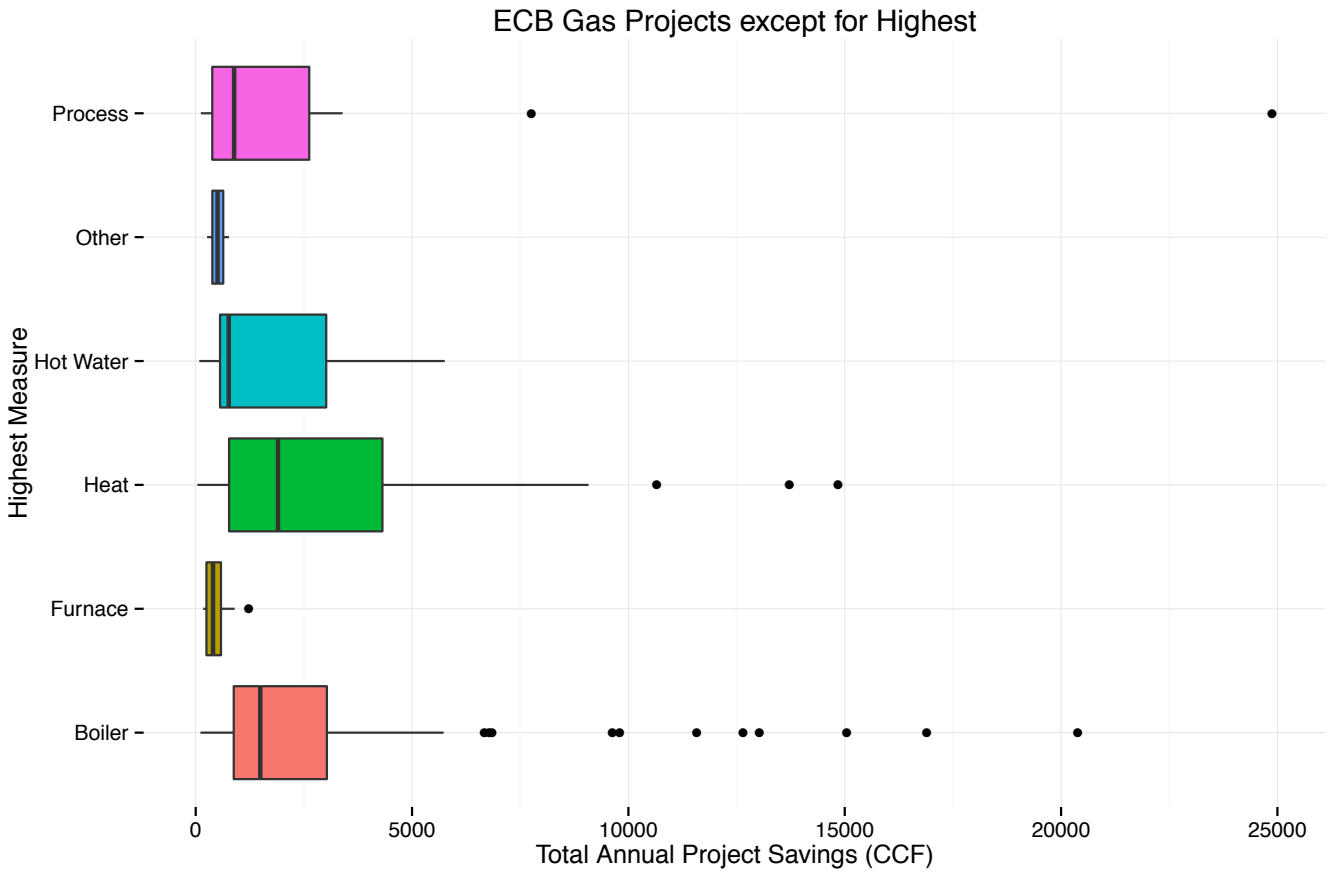
ELECTRIC PROJECT STRATA



GAS PROJECT POPULATION



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SAMPLE DETAIL

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Measure Group	Stratum	Sample Type	Population Projects	Portion of Annual Savings	Original Sample Target	Achieved Sample *
Compressed Air	1	None	27	0.63%	0	0
Compressed Air	2	Random	48	2.70%	3	3
Compressed Air	3	Random	29	3.83%	4	4
Compressed Air	4	Random	25	6.49%	4	**5**
Compressed Air	5	Census	3	2.66%	3	**2**
Cool	1	None	159	0.30%	0	0
Cool	2	Random	118	1.12%	2	**4**
Cool	3	Random	55	1.69%	3	**5**
Cool	4	Random	23	2.12%	3	**5**
Cool	5	Census	6	2.24%	6	**5**
Light	1	None	84	1.08%	0	0
Light	2	Random	62	3.18%	3	**4**
Light	3	Random	35	6.27%	3	3
Light	4	Random	19	9.61%	3	3
Light	5	Census	4	6.74%	4	4
Other	1	None	102	1.03%	0	0
Other	2	Random	29	2.51%	2	2
Other	3	Random	19	5.66%	2	**3**
Other	4	Random	6	4.30%	3	**4**
Other	5	Census	3	5.22%	3	3
Process	1	None	73	1.68%	0	0
Process	2	Random	32	4.04%	1	1
Process	3	Random	16	5.76%	2	2
Process	4	Random	7	5.94%	2	2
Process	5	Census	2	13.18%	2	2
Overall	-	-	**986**	**100.0%**	**58**	**66**

* Bold values indicate a change

SAMPLE: GAS

Measure Group	Stratum	Sample Type	Projects	Portion of Annual Savings	Original Sample Target	Achieved Sample *
Boiler	1	None	4	0.10%	0	**1**
Boiler	2	Random	71	9.50%	4	4
Boiler	3	Random	23	12.20%	4	4
Boiler	4	Census	4	6.10%	4	**2**
Other	1	None	14	0.20%	0	**3**
Other	2	Random	95	13.40%	5	5
Other	3	Random	17	17.80%	6	6
Other	4	Census	7	40.80%	7	**5**
Overall	**-**	**-**	**235**	**100.0%**	**30**	**30**

* Bold values indicate a change

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DETAILED RESULTS

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COMPRESSED AIR

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	23,216,920 kWh		2,997 kW		2,789 kW	
Documentation Adjustment	-12,072,798 kWh	-52%	-1,708 kW	-57%	-1,618 kW	-58%
Technology Adjustment	-464,338 kWh	-2%	-90 kW	-3%	-84 kW	-3%
Quantity Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Operation Adjustment	696,508 kWh	3%	450 kW	15%	530 kW	19%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	11,376,291 kWh	-51%	1,648 kW	-45%	1,618 kW	-42%
Realization Rate	49%		55%		58%	
Relative Precision	18%		11%		11%	
Confidence Interval	90%		80%		80%	

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HVAC

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	14,178,645 kWh		4,069 kW		1,229 kW	
Documentation Adjustment	-1,701,437 kWh	-12%	-244 kW	-6%	-111 kW	-9%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	0 kWh	0%	-81 kW	-2%	0 kW	0%
Operation Adjustment	-425,359 kWh	-3%	-1,058 kW	-26%	209 kW	17%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	12,051,848 kWh	-15%	2,685 kW	-34%	1,327 kW	8%
Realization Rate	85%		66%		108%	
Relative Precision	22%		20%		36%	
Confidence Interval	90%		80%		80%	

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LIGHTING

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	19,553,930 kWh		3,708 kW		2,661 kW	
Documentation Adjustment	782,157 kWh	4%	445 kW	12%	160 kW	6%
Technology Adjustment	-195,539 kWh	-1%	-74 kW	-2%	0 kW	0%
Quantity Adjustment	195,539kWh	1%	0 kW	0%	-27 kW	-1%
Operation Adjustment	2,542,011 kWh	13%	593 kW	16%	186 kW	7%
Heating and Cooling Adjustment	-1,368,775 kWh	-7%	-445 kW	-12%	0 kW	0%
Evaluated Savings	21,509,323 kWh	10%	4,227 kW	14%	2,980 kW	12%
Realization Rate	110%		114%		112%	
Relative Precision	20%		16%		20%	
Confidence Interval	90%		80%		80%	

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PROCESS

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	14,366,707 kWh		2,707 kW		2,283 kW	
Documentation Adjustment	-1,149,337 kWh	-8%	-189 kW	-7%	342 kW	15%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	-143,667 kWh	-1%	-189 kW	-7%	-183 kW	-8%
Operation Adjustment	1,580,338 kWh	11%	514 kW	19%	91 kW	4%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	14,654,041 kWh	2%	2,842 kW	5%	2,534 kW	11%
Realization Rate	102%		105%		111%	
Relative Precision	25%		35%		41%	
Confidence Interval	90%		80%		80%	

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HPBD

Savings Adjustment	Energy		Summer Seasonal Demand		Winter Seasonal Demand	
Reported Savings	4,568,983 kWh		584 kW		805 kW	
Documentation Adjustment	-593,968 kWh	-13%	0 kW	0%	0 kW	0%
Technology Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Quantity Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Operation Adjustment	411,208 kWh	9%	-12 kW	-2%	-443 kW	-55%
Heating and Cooling Adjustment	0 kWh	0%	0 kW	0%	0 kW	0%
Evaluated Savings	4,386,224 kWh	4%	572 kW	-2%	362kW	-55%
Realization Rate	96%		98%		45%	
Relative Precision	18%		22%		29%	
Confidence Interval	90%		80%		80%	

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GAS RESULTS: OVERALL

Savings Adjustment	Energy	
Reported Savings	978,415 therms	
Documentation Adjustment	-136,747 therms	-14%
Technology Adjustment	0 therms	0%
Quantity Adjustment	31,587 therms	3%
Operation Adjustment	-10,861 therms	-11%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	762,393	
Realization Rate	78%	
Relative Precision	15%	
Confidence Interval	90%	

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GAS RESULTS: SPLIT

BOILER: RR 96%

Savings Adjustment	Energy	
Reported Savings	346,682 therms	
Documentation Adjustment	-10,400 therms	-3%
Technology Adjustment	0 therms	0%
Quantity Adjustment	0 therms	0%
Operation Adjustment	-3,467 therms	-1%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	332,815 therms	
Realization Rate	96%	
Relative Precision	14%	
Confidence Interval	90%	

OTHER: RR 68%

Savings Adjustment	Energy	
Reported Savings	631,733 therms	
Documentation Adjustment	-126,347 therms	-20%
Technology Adjustment	0 therms	0%
Quantity Adjustment	31,587 therms	5%
Operation Adjustment	-107,395 therms	-17%
Heating and Cooling Adjustment	0 therms	0%
Evaluated Savings	429,578 therms	
Realization Rate	68%	
Relative Precision	15%	
Confidence Interval	90%	

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