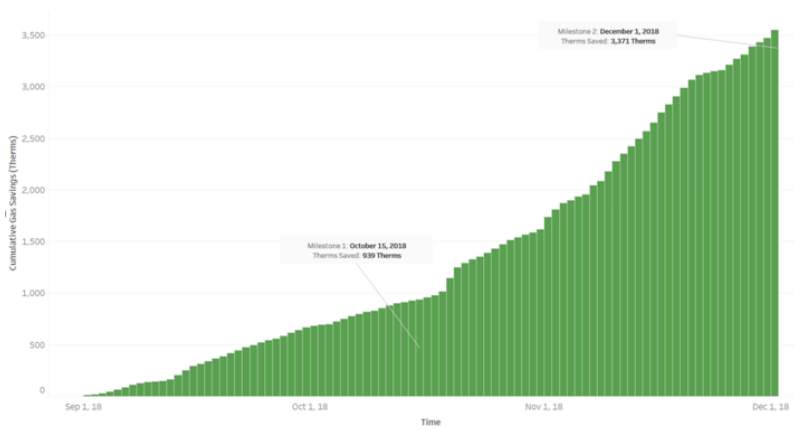
NMEC Verification for Laboratory Energy Projects

Presented By:

Jordan Sager, P.E. - Energy Manager, UC Santa Barbara

David Gilliland, P.E. - Director, kW Engineering



UCSB Case Study

- Chemistry + Physical Sciences – North (Chem + PSBN) Building
- 4 floors, 2 wings, 3 energy sources each (electric, gas, chilled water)
- Chem wing has chiller that serves campus loop
- During implementation phase, new chiller installed in PSB-N wing

Major Mechanical Systems

Wing	Ventilation	Heating	Cooling	Zone Controls
Physical Sciences - North	CAV	Dedicated Boiler Plant	Campus Loop	Pneumatic
Chemistry	VAV	Dedicated Boiler Plant	Campus Loop	DDC

Physical Sciences - North

Chemistry

Early Project Concepts

- Ventilation Rate Optimization
- Wireless Pneumatic Thermostats
- Night Heating Setback
- Lighting Retrofits

High Opportunity Project & Programs (HOPPs)

- SCE and SoCal Gas Co-Funded Investigation
- Goals:
  1. Confirm the potential for large energy savings (>10% on meter)
     - Conduct energy audit
     - Review trends
     - Calculate savings potential
  2. Verify energy savings using the Normalized Metered Energy Consumption (NMEC) approach.
     - Uses building-level metered energy data to verify savings
     - Well-established for office buildings. Viable in labs?

EEMs Installed

- **RCx-1: Re-Balance Constant Volume Hood Airflow**
  - Re-balancing the supply and exhaust fans in PSB-N to maintain 100 fpm across 18“ sashes
- **CIM-1: Install Wireless Pneumatic Thermostats**
- **RCx-2: Implement Supply Air Temperature Reset**
- **RCx-3: Implement Heating Hot Water Temperature Reset**
- **RCx-4: Implement Nighttime Space Temperature Setbacks**
- **CIM-2: Replace HID Fixtures with Low Power LEDs in Chemistry Machine Shop**
- **CIM-3: Replace Linear Fluorescent Lamps with LED Ballast Bypass Lamps**
- **CIM-4: Install Occupancy Sensors for Lab, Office, and Lecture Hall Lighting**
- **CIM-6: Supplement Backup Generator Block Heaters with Heat Pumps**

Project Energy Savings Expectations

ECM	Measure Description	Wing	Annual Energy & Cost Savings				Financial Metrics			
			Peak Savings (kW)	Electricity Savings (kWh/yr)	Gas Savings (therms/yr)	Total Cost Savings	Measure Cost	HOPPs Incentives	Net Measure Cost	Simple Payback (years)
RCx-1	Re-Balance Constsant Volume Hood Airflow	PSBN	91.9	579,086	11,573	$ 72,379	$ 31,000	$ 116,804	$ (85,804)	(1.2)
CIM-1	Install Wireless Pneumatic Thermostats	PSBN	-	-	11,183	$ 8,387	$ 160,000	$ 27,958	$ 132,042	15.7
RCx-2	Implement Supply Air Temperature Reset	Chem & PBSN	-	59,116	34,268	$ 32,20			65)	(1.8)
RCx-3	Implement HHWT Reset			-	3,123	$ 2,34			93	1.8
RCx-4	Implement Nighttime Spa			4,156	23,672	$ 18,21			78)	(2.1)
CIM-2	Replace HID Fixtures wit Machine Shop			18,060	-	$ 1,987			29	3.7
CIM-3	Replace Linear Fluoresc Ballast Bypass Lamps			557,456	-	$ 61,320	$ 287,500	$ 79,622	$ 207,878	3.4
CIM-4	Install Occupancy Senso Lecture Hall Lighting			122,017	-	$ 13,422	$ 125,400	$ 14,642	$ 110,758	8.3
CIM-5	Replace HHWP Motors, Balancing Valves			6,452	-	$ 710	$ 30,200	$ 922	$ 29,278	41.3
CIM-6	Supplement Backup Gen Heat Pumps	PBSN	-	24,872	-	$ 2,736	$ 23,100	$ 2,985	$ 20,115	7.4
LCM-1	Install Time Clocks on DHW Pumps	Chem & PBSN	-	-	1,435	$ 1,077	$ 4,600	$ 3,589	$ 1,011	0.9
WB-20125 TOTALS			**161.6**	**1,242,745**	**85,254**	**$ 200,643**	**$ 585,100**	**$ 394,578**	**$ 190,522**	**0.9**

Electric Savings:
Chem – 14%
PSBN – 25%

Gas Savings:
Chem – 28%
PSBN – 36%

Utility Incentives:

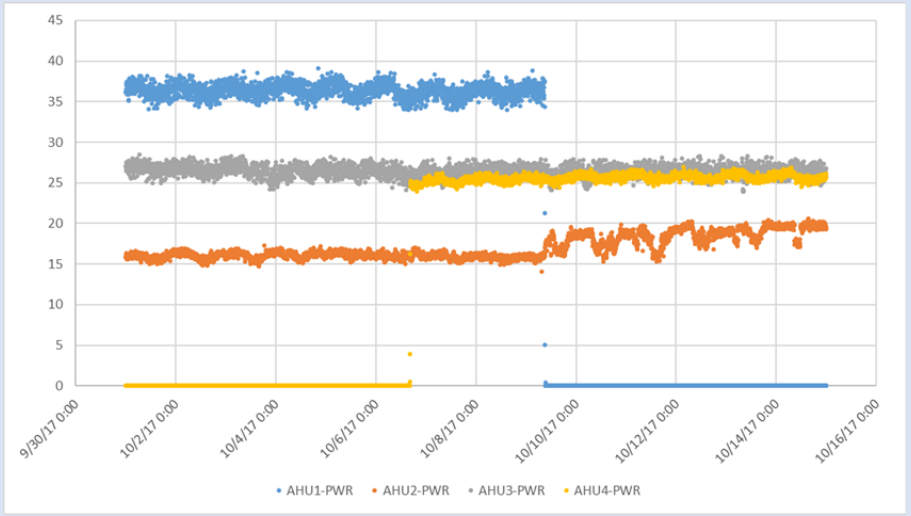
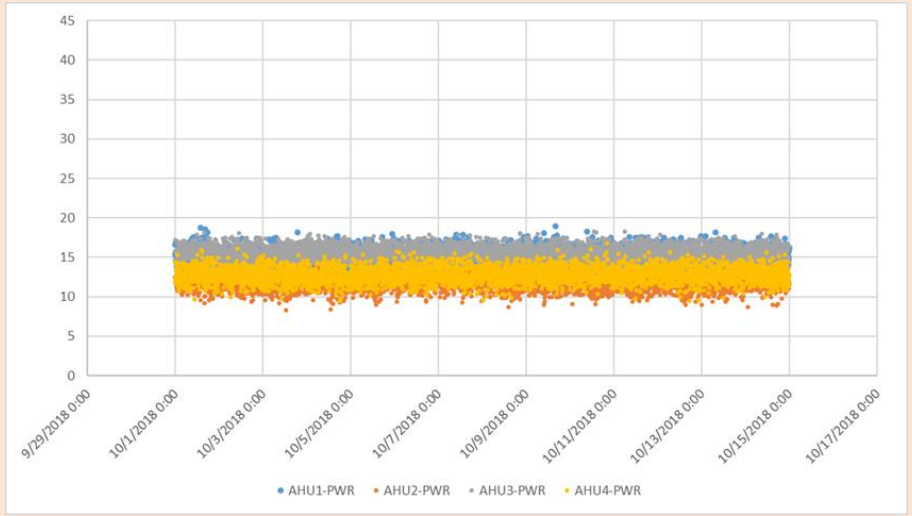
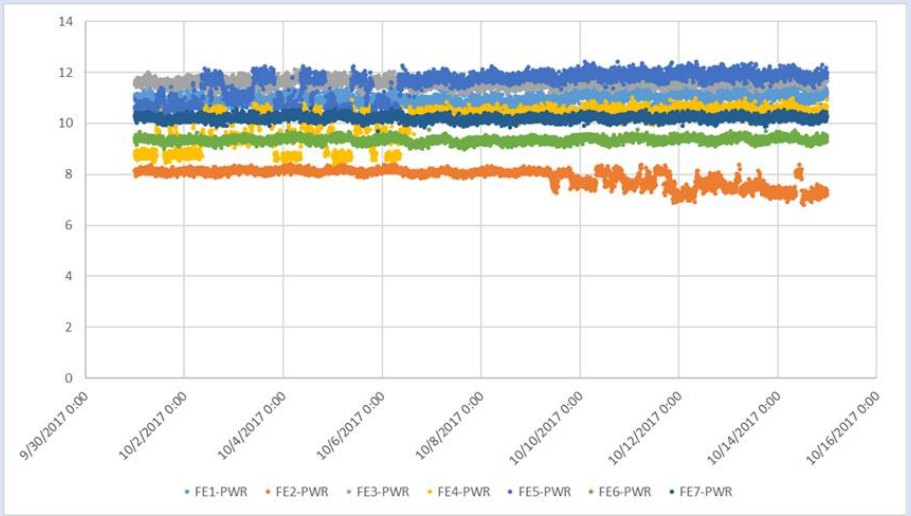
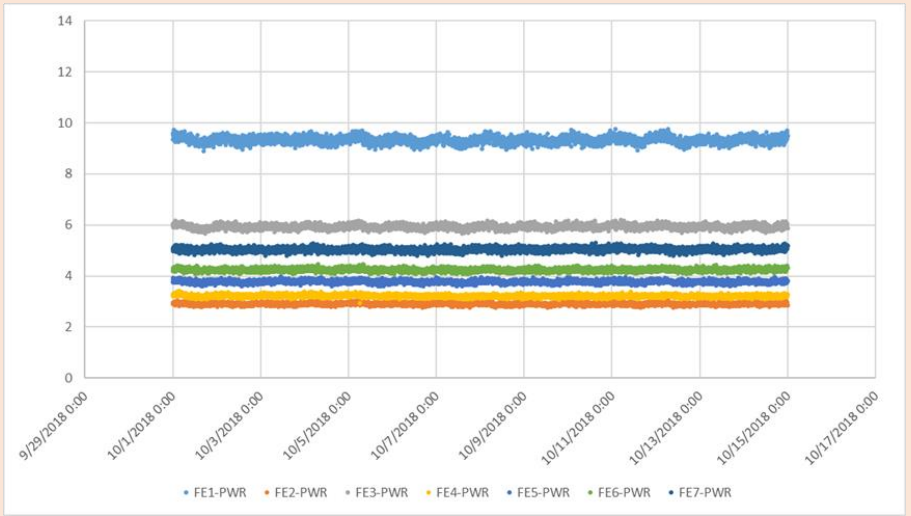
Covered almost 70% of Project Cost

Standard Verification Approach – Example #1

- RCx-1 Rebalance Fume Hoods

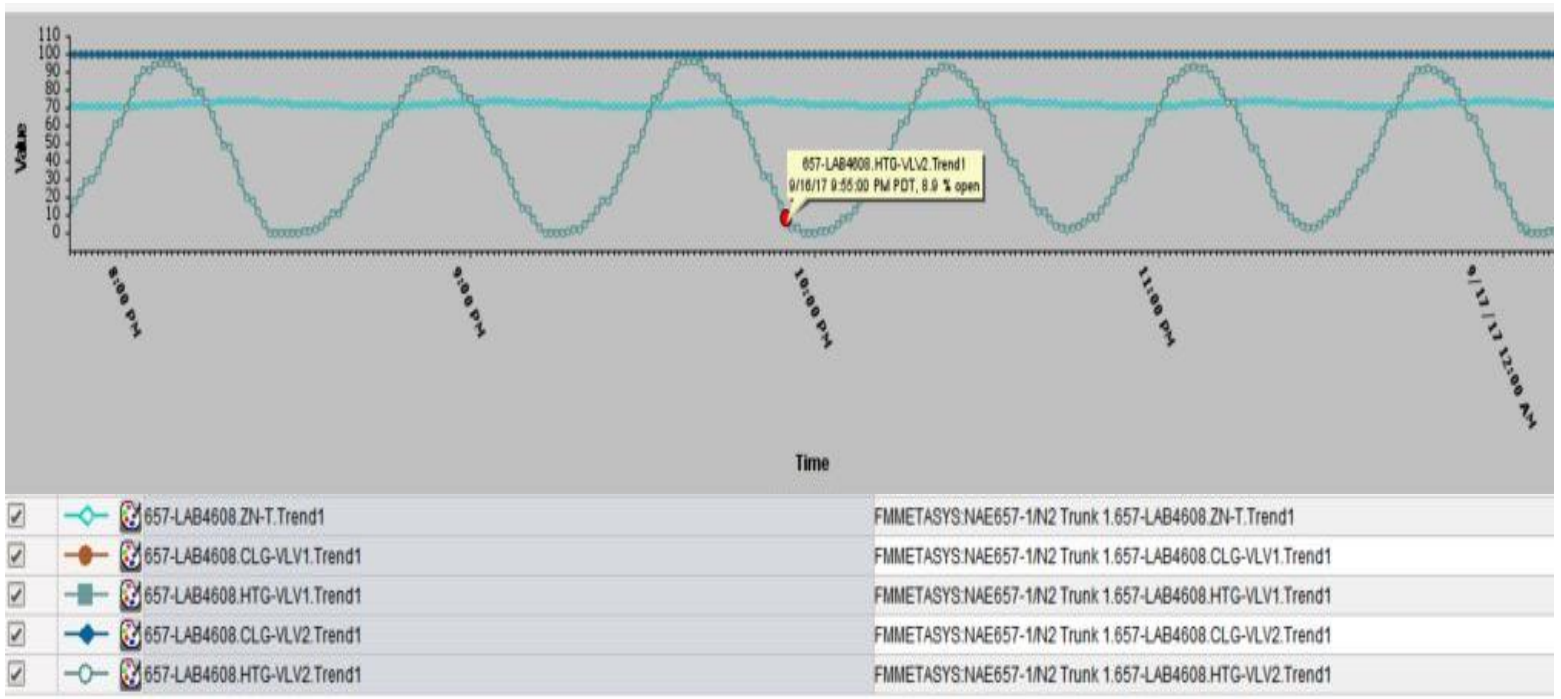
Building #	Room	Hood#	Old Flow Rate (Sash Heigt 24 - 30")	**New Flow Rate (Sash Height 18")**
657	1612	1	102	**113**
657	1612	2	120	**105**
657	1612	3	108	**111**
657	1612	4	121	**102**
657	1612	5	115	**105**
657	1612	6	108	**123**
657	1612	7	103	**141**
657	1612	8	109	**107**
657	1612	9	132	**150**
657	1622	1	114	**144**
657	1622	2	125	**105**
657	1622	3	92	**122**
657	1622	4	168	**113**
657	1622	5	96	**113**

Standard Verification Approach – Example #1

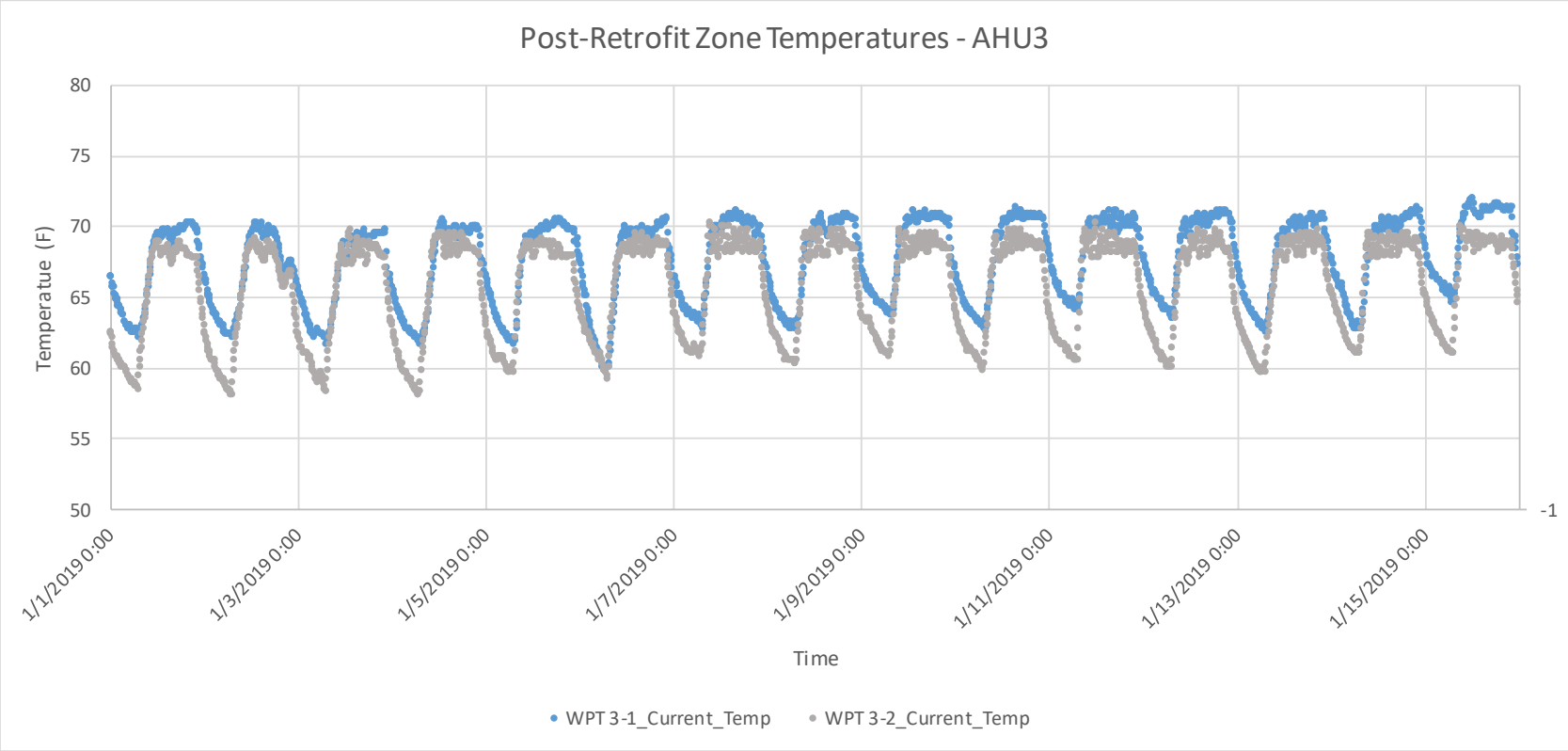
	Baseline Period	Performance Period
AHU 1 - 4 Fan Power		
Exh. Fan 1 – 7 Fan Power		

Standard Verification Approach – Example #2

- CIM-1 Wireless Pneumatic Thermostats



Standard Verification Approach – Example #2

Baseline Period	Very Little Data - Observed Set Points, assumed behaviors
Performance Period Confirmed Nighttime Set Back of Zone Temperatures	

Normalized Metered Energy Consumption (NMEC)

- Utilize building-level meter data from before and after the project to verify savings
  - Building Electric & Gas Meters
  - Chilled Water & Hot Water BTU meters
- Develop statistical model of variables above based on independent variables (outside temperature & schedule – typ.)
  - LBNL TTOW Model
- Normalized to standard weather data to provide apples-to-apples comparison
  - Account for variation in annual weather patterns
- Quantify the Uncertainty
  - R-squared, CV(RMSE), NDBE, ASHRAE Guideline 14

Baseline Period

1. Project Pre-Screening
   - Facility condition
   - Savings potential (e.g. deep savings)
   - 'Predictable' energy use patterns
   - Non-routine events (NREs)

2. Develop Energy Audit / Energy Management Plan
   - Document baseline equipment and conditions
   - List of measures, savings, costs, measure life

3. M&V Plan
   - Define baseline period
   - List data to be collected
   - Describe analysis procedures
     - incl. NRE treatment
   - Savings reporting & frequency

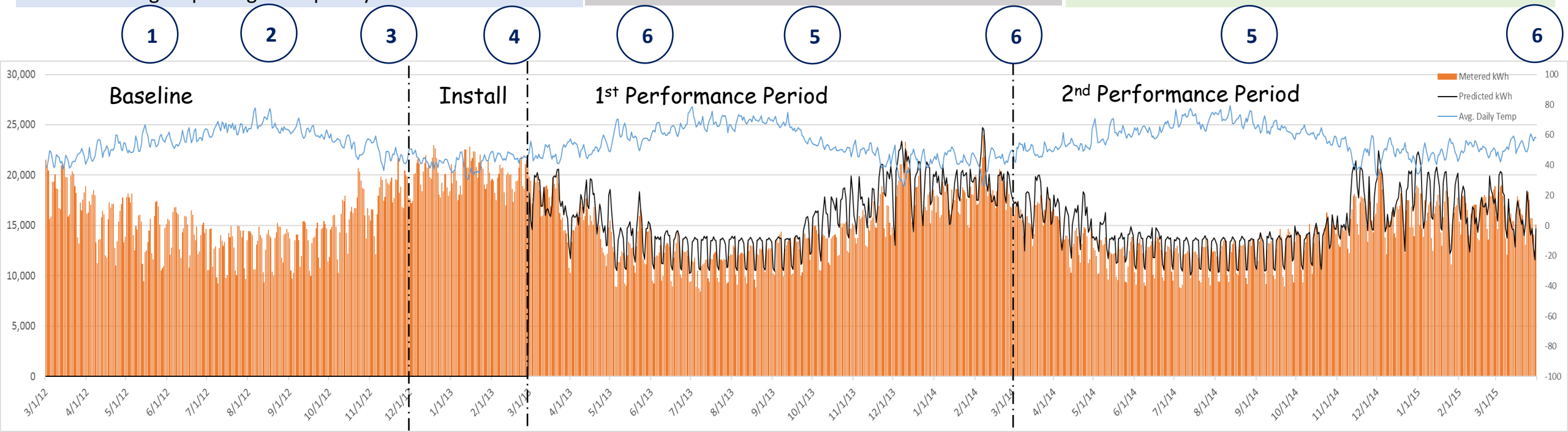
Installation Period

4. Measure Verification
   - Document installation & proper operation
     - Inspection
     - Functional testing
     - Trend analysis

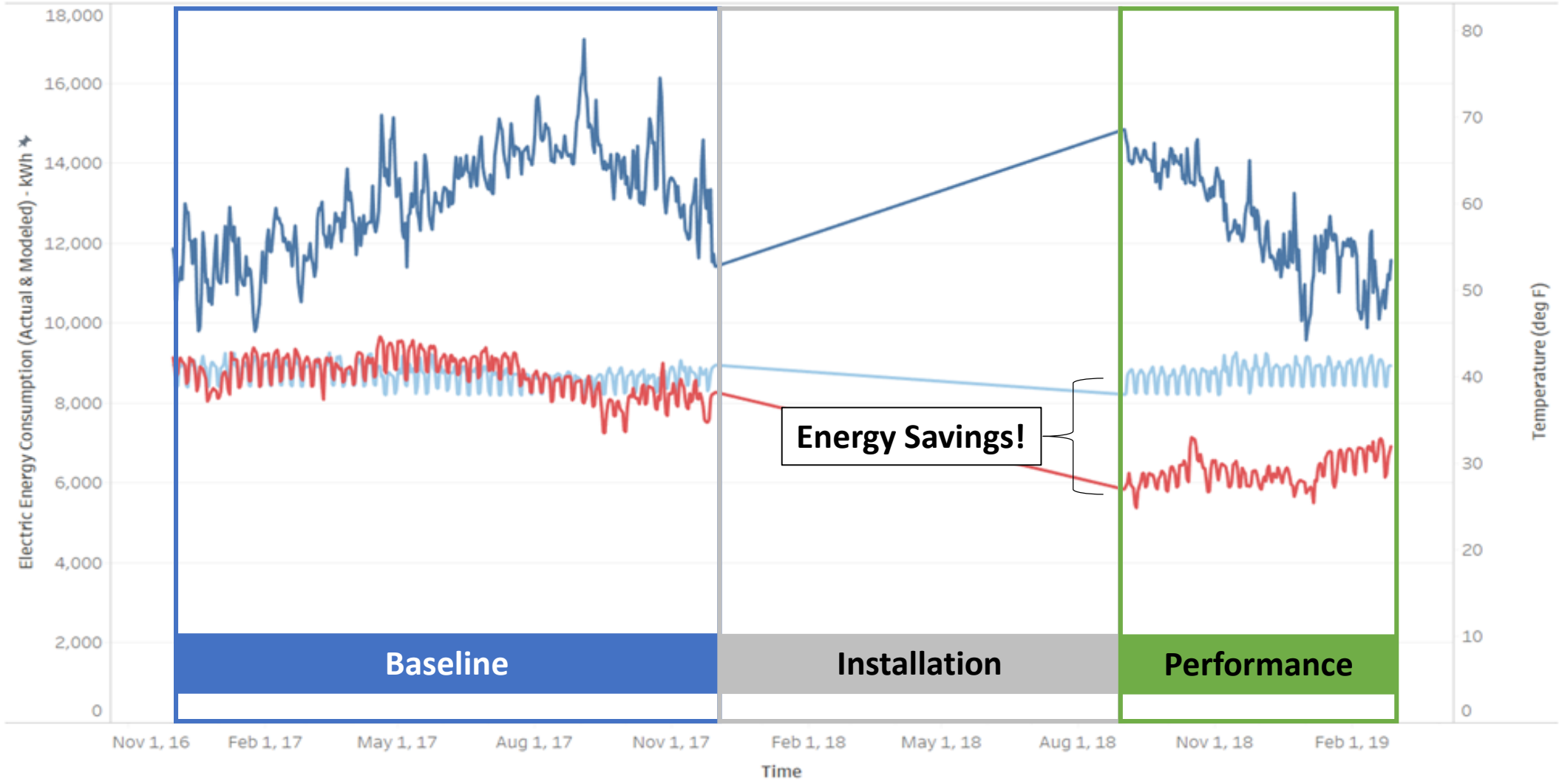
Performance Period

5. Savings Performance Check
   - Periodically during performance period
   - QA check that savings are accruing
   - Detect presence of NREs

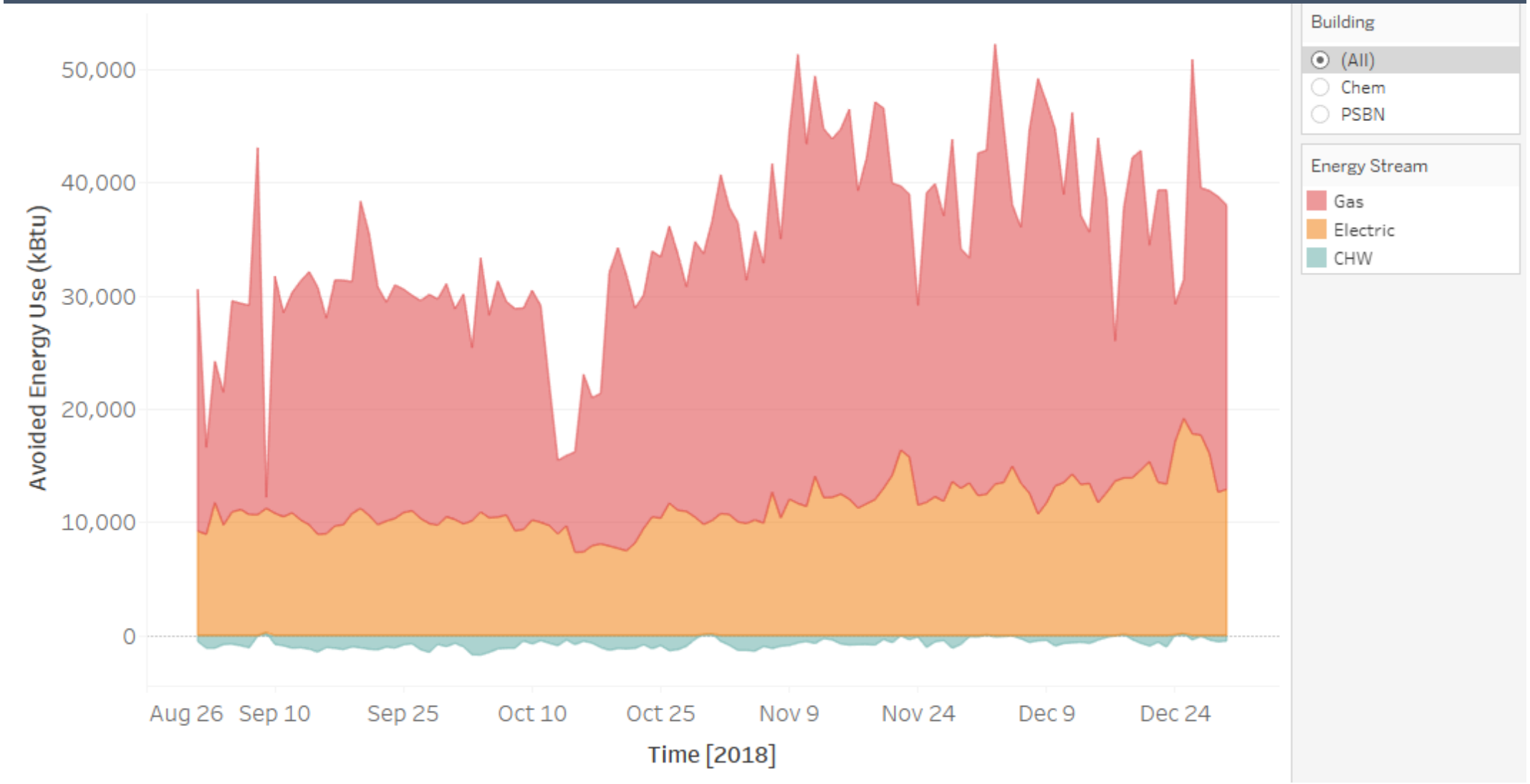
6. Savings Reporting
   - Per M&V Plan
   - A to Z report on savings
     - Raw data to final savings
     - NRE impacts included



NMEC Results – PSBN Avoided Energy Use



NMEC Data – Combined Results



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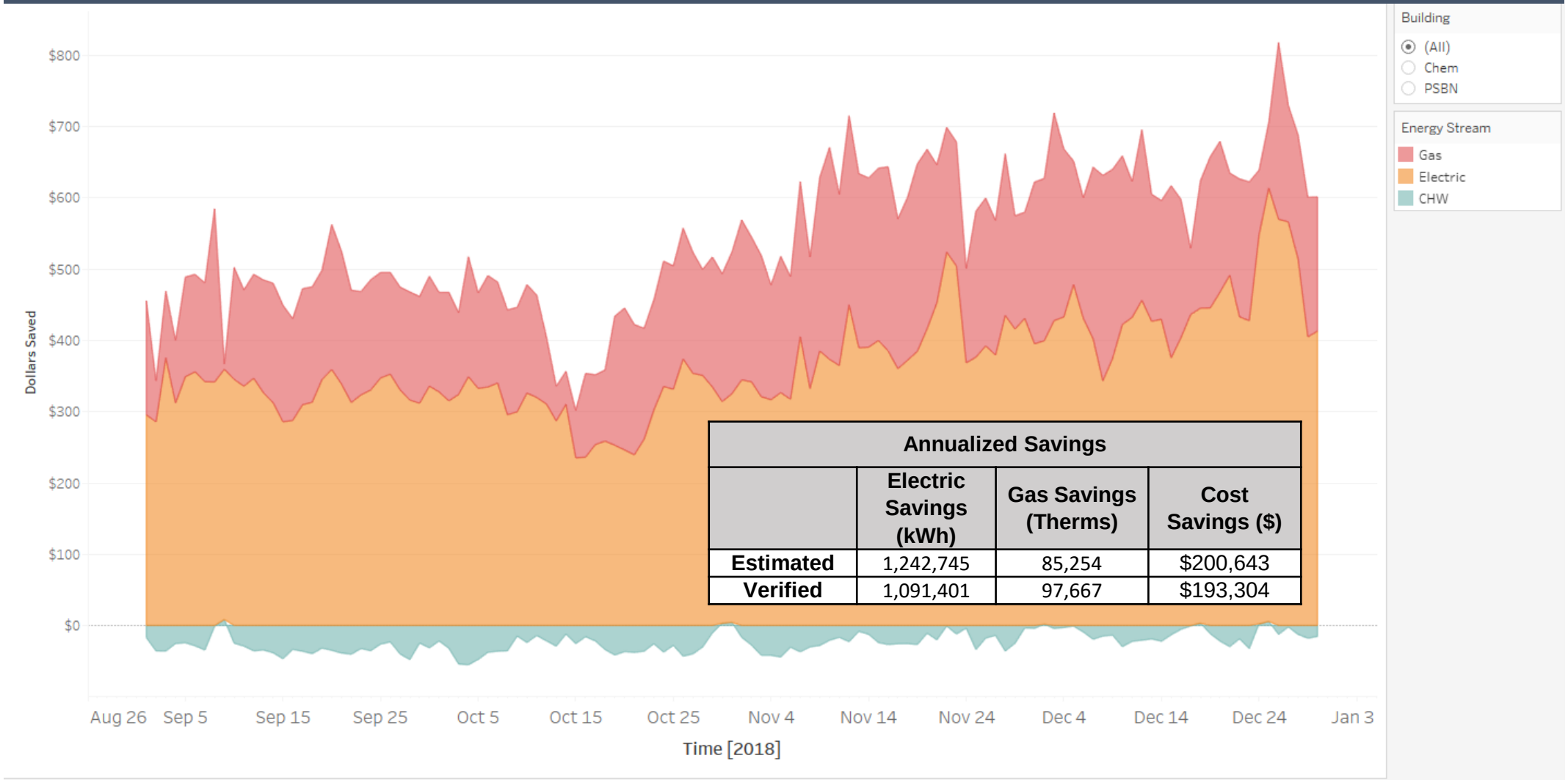

Annualized Savings			
	Electric Savings (kWh)	Gas Savings (Therms)	Cost Savings ($)
Estimated	1,242,745	85,254	$200,643
Verified	1,091,401	97,667	$193,304

NMEC Data – Combined Results

Wing	Energy Source	Analysis Time Interval	Normalized Savings	Normalized Savings %	Uncertainty (at 90% confidence)
Chemistry	Electric (kWh)	Daily	299,878	10%	15.0%
Chemistry	Natural Gas (therms)	Daily	17,158	21%	15.5%
PSBN	Electric (kWh)	Daily	862,924	27%	7.7%
PSBN	Natural Gas (therms)	Daily	80,509	46%	10.6%
PSBN	Chilled Water (kWh)	Daily	-71,401	-20%	20.5%

Study Conclusions

- Significant (>10% on-meter) savings are achievable in lab buildings
  - Perhaps even more so than in standard buildings!
- The NMEC approach is viable for labs, under the right conditions
  - Bio labs, chem labs, etc… good!
  - Particle accelerators… not so good. ☹
- The following potential barriers to NMEC still remain
  - Proper sub-metering on all energy streams
  - Complexity of laboratory energy streams
  - M&V time commitment

Who Cares?

- Facilities Staff / Building Operators
  - Helps target investigation of issues
- Energy Managers
  - Mechanism to ensure persistence of savings
- Financial Decision-Makers
  - Direct link between metered energy savings and on-bill cost savings
- Utilities
  - Enables AB802 incentive programs
  - Pay for performance

Appendices

UCSB Key Takeaways

- Safety Measures

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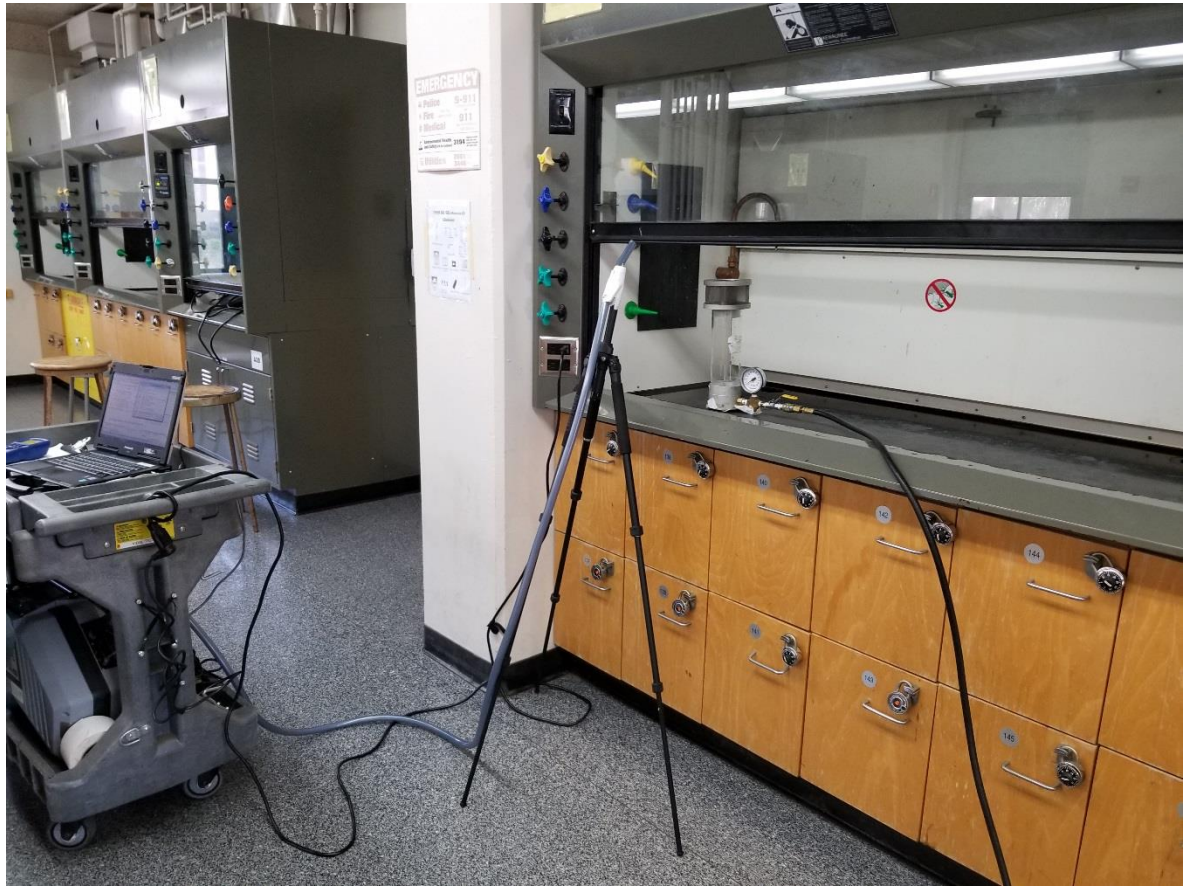

UCSB Key Takeaways

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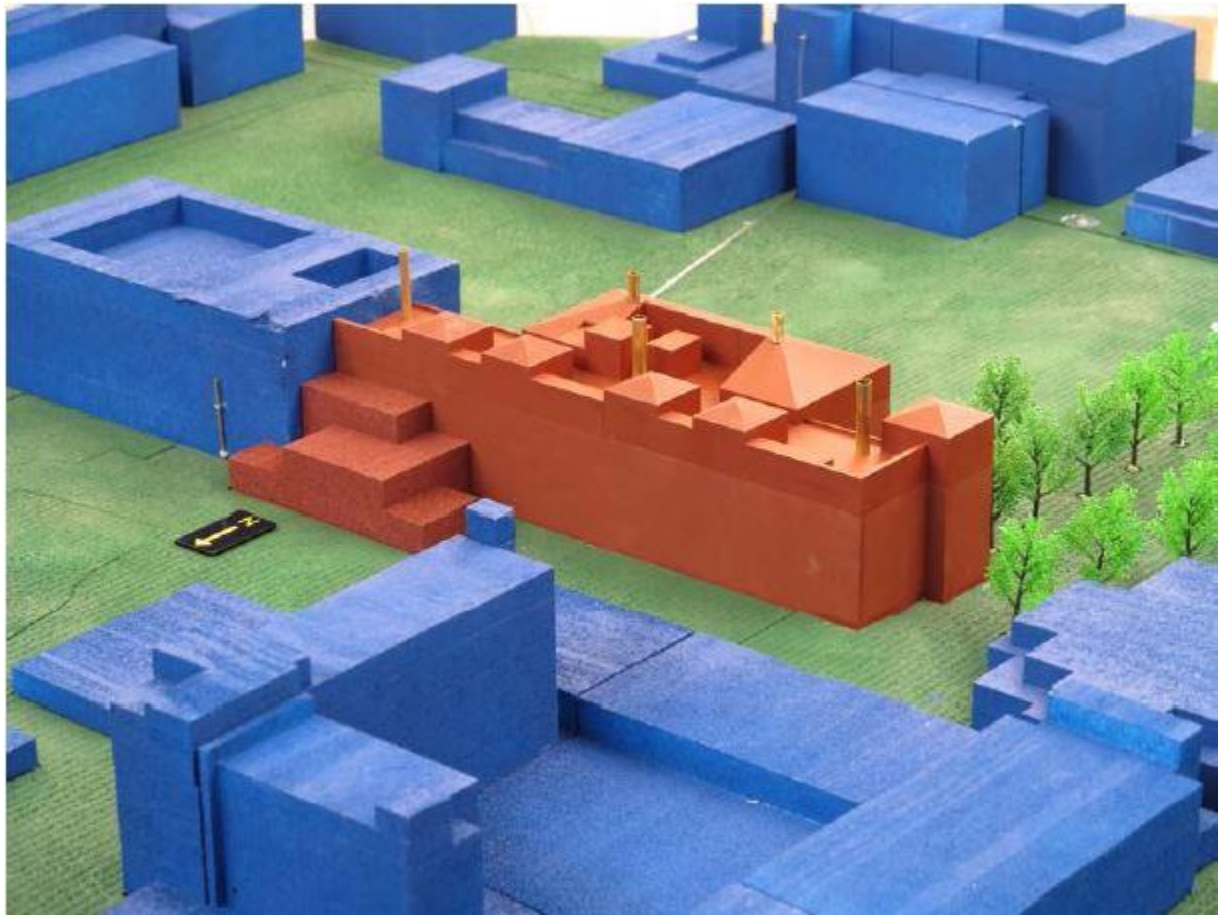

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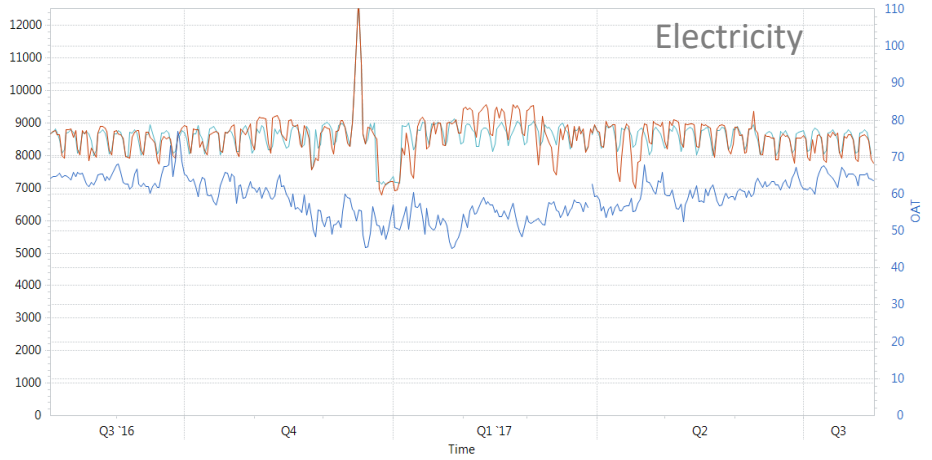
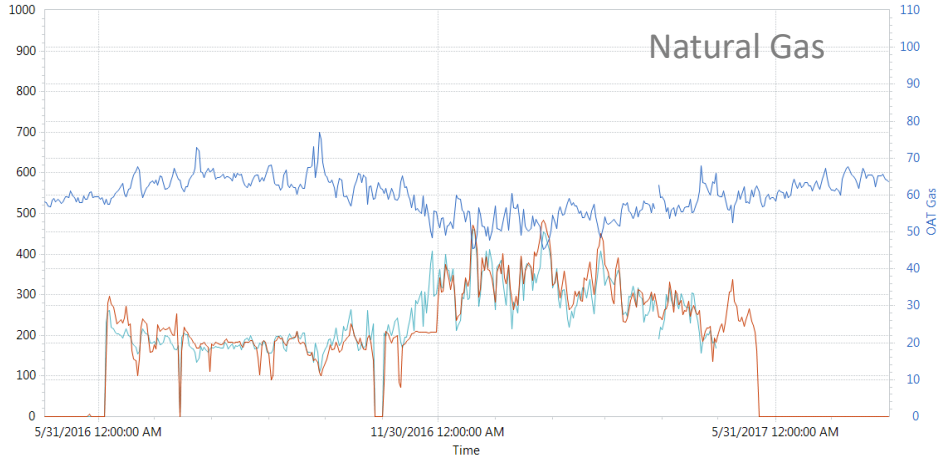
- Data Management

Baseline Period - Pre-Screening

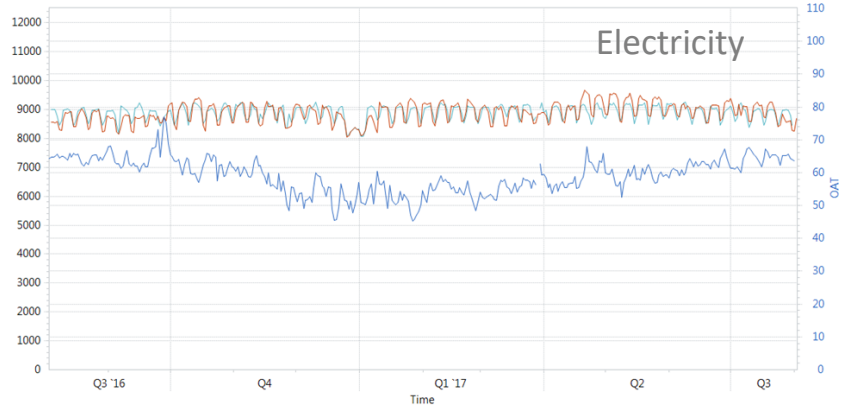
Chemistry

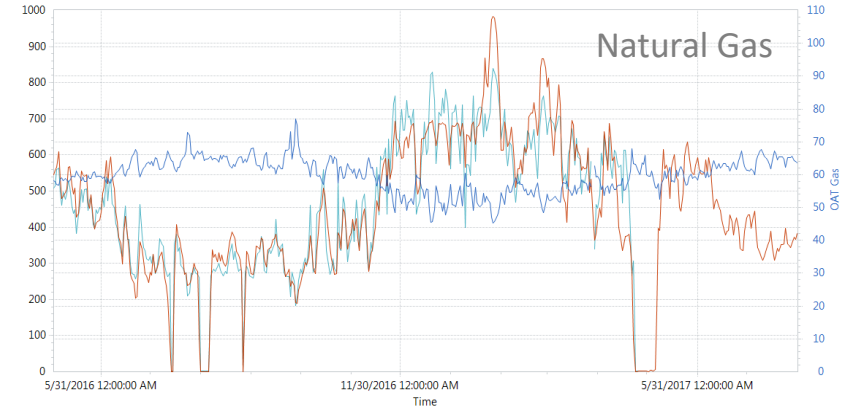


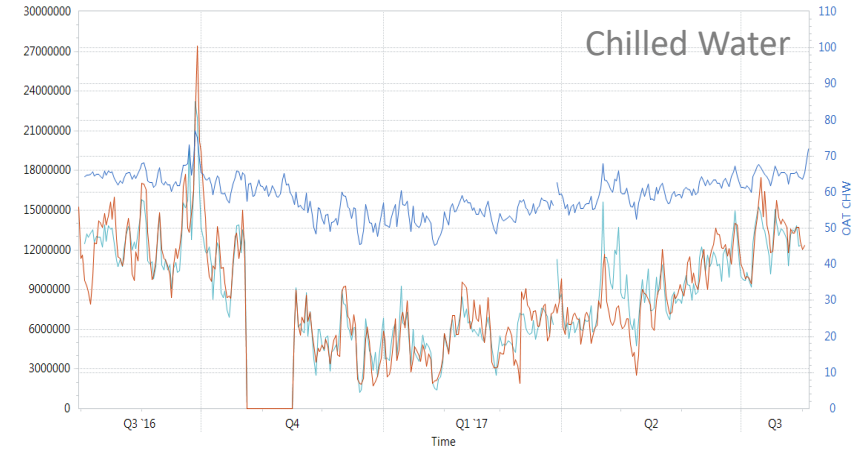


Model	Building Wing	Analysis Time interval	Baseline Period	R^2	CV(RMSE)	NDBE	U (15% savings est., 90% CI)
Electric, kWh	Chemistry	Day	8/1/2016 – 7/31/2017	65%	4%	0.00%	4%
Electric, kWh	PSB-N	Day	8/1/2016 – 7/31/2017	54%	3%	0.00%	4%
Gas, therms	Chemistry	Day	6/4/2016 – 5/21/2017	90%	16%	0.00%	23%
Gas, therms	PSB-N	Day	5/1/2016 – 4/30/2017	90%	14%	0.00%	25%
Chilled Water, B	PSB-N	Day	8/1/2016 – 7/31/2017	88%	19%	0.00%	24%

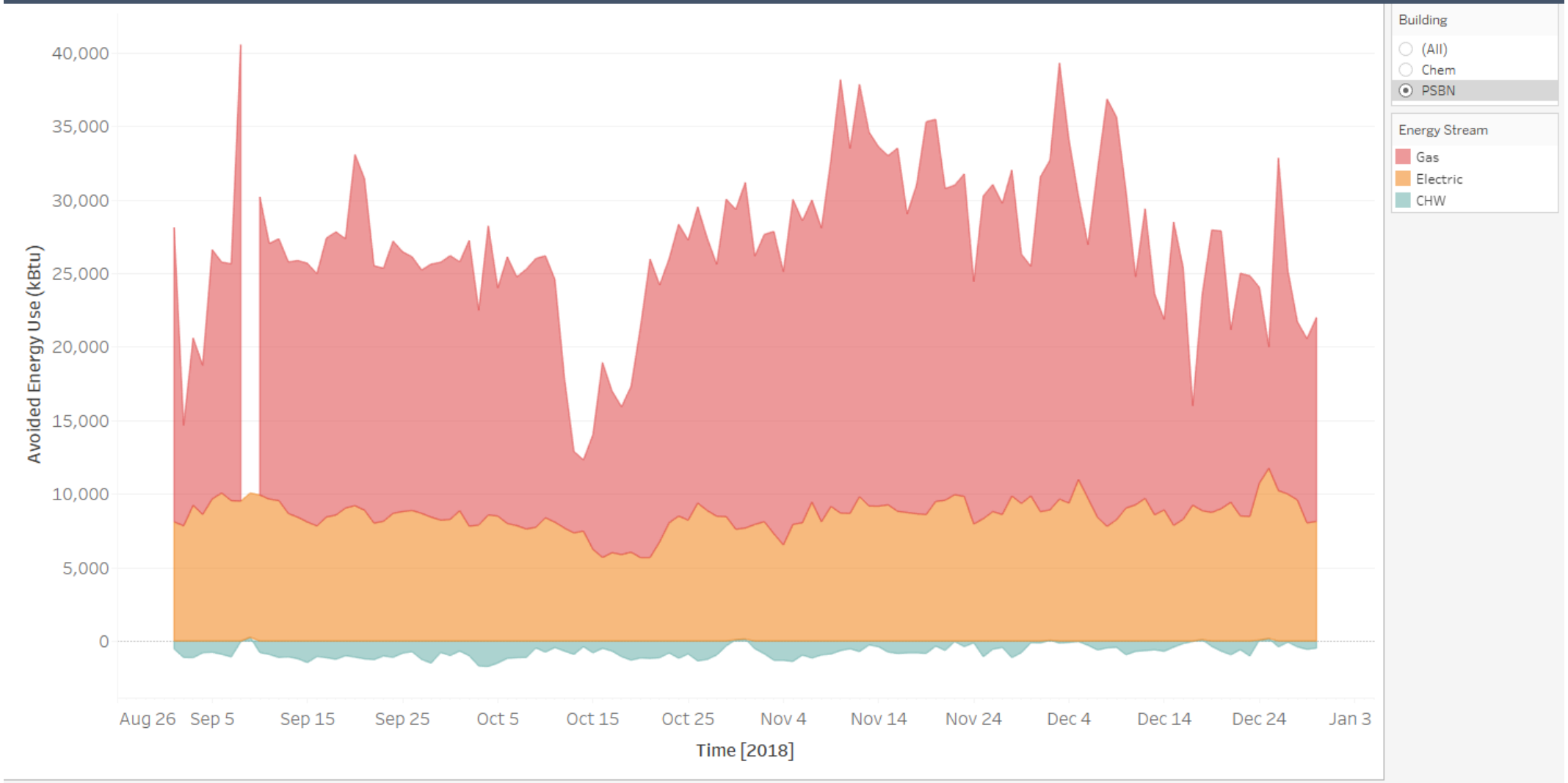
PSB-N







NMEC Data – PSB-N Results



NMEC Data – Chem Results