CATALYST

M&V Best Practices: Measuring & Verifying Energy Savings with Confidence

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Agenda

- ✓ What is M&V?
- ✓ Available IPMVP Options
- ✓ Benefits of Option B
- ✓ Case study of Option B
- ✓ Benefits of Option C
- ✓ Case study of Option C
- ✓ How to save now

What is M&V?

What is M&V?

M&V is a standardized procedure, regulated by ISO 50015:2014 (Measurement and Verification of Energy Performance) and included in the framework of ISO 50001:

"The purpose of M&V is to provide confidence to interested parties that reported results are credible... [including] appropriate accuracy and management of uncertainty" (ISO 50015)

Why is M&V important?

"Measurement and verification" (M&V) of energy and cost savings resulting from an energy efficiency initiative is necessary because you can't simply compare year-to-year out of pocket expenditures.

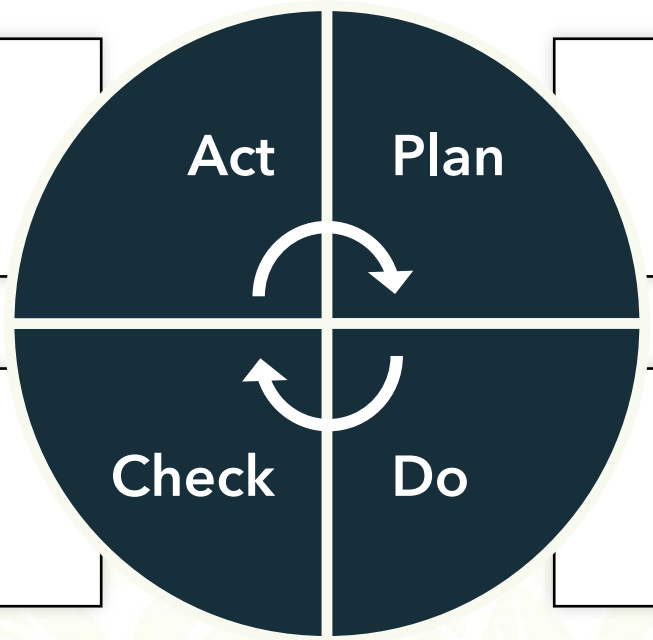
You have to compare **what you did spend** with how much **you would have spent** in the absence of energy efficiency, in other words how much you avoided spending.

What	The measurement and verification of energy and cost savings due to energy projects.
Why	To show the dollars you avoided spending due to energy projects.
How	By comparing current bills with an adjusted baseline year. Taking into account weather, billing period length, floor area changes, commodity price, and special adjustments.

ISO 50001: 2011 Energy Management

ISO 50001 creates a broad framework for an organization to implement an energy reduction program using the ISO PDCA continuous improvement process.

Decide on changes needed to improve process.



Identify aspects and impacts by implementing goals and objectives

Assess the measurements and report results to decision makers.

Implement; including training and operational control measures.

Available IPMVP Options

ISO 50001 and IPMVP

ISO 50001 “does not specify calculation methods”, it only establishes a common set of principles and guidelines.

The M&V practitioner selects the calculation methods and obtains approval by the parties involved via the M&V Plan.

Historically the most common calculation methods have been those in IPMVP, managed by an international nonprofit agency called The Efficiency Valuation Organization.
www.EVO-World.org

IPMVP Options

Retrofit Isolation

OPTION A
Retrofit Isolation:
Key Parameter(s) Measurement

OPTION B
Retrofit Isolation:
All Parameter Measurement

Whole Facility

OPTION C
Whole Facility

OPTION D
Calibrated Simulation

Benefits of Option B

Option B // Retrofit isolation

All parameters associated with the energy conservation measure must be measured and cannot be estimated. In other words, you are creating an M&V project which focuses only on some appliances/circuits and not on the entire building's power consumption.

For example, consider the installation of a variable speed drive. The power drawn as well as the hours of operation will have to be measured in order to determine any energy savings.

Option B // Retrofit isolation pros and cons

PROS:

- \+ Savings reports correlate closely with production changes
- \+ Actual savings determined from direct metered usage

CONS:

- — Not reconciled to total facility utility costs
- — The calculation of baselines for complex processes can be challenging

× Requires extensive metering

Case Study Option B

Success story // The project

Auckland University of Technology, WO Building (Student Association)

Area: 113,000 sq ft

Energy Usage: 1,302,821 kWh/year

Energy Cost: $110,000/year

Optimization Target: 10% savings

The ECMs

Replacement of chiller and cooling tower

Adjustments to Air Handling Units (AHU)

- Supply air pressure and temperatures setpoints reset
- Disabled after-hours AHU requirement during weekends
- AHU Modulation Controller changed from PI to PID

Results

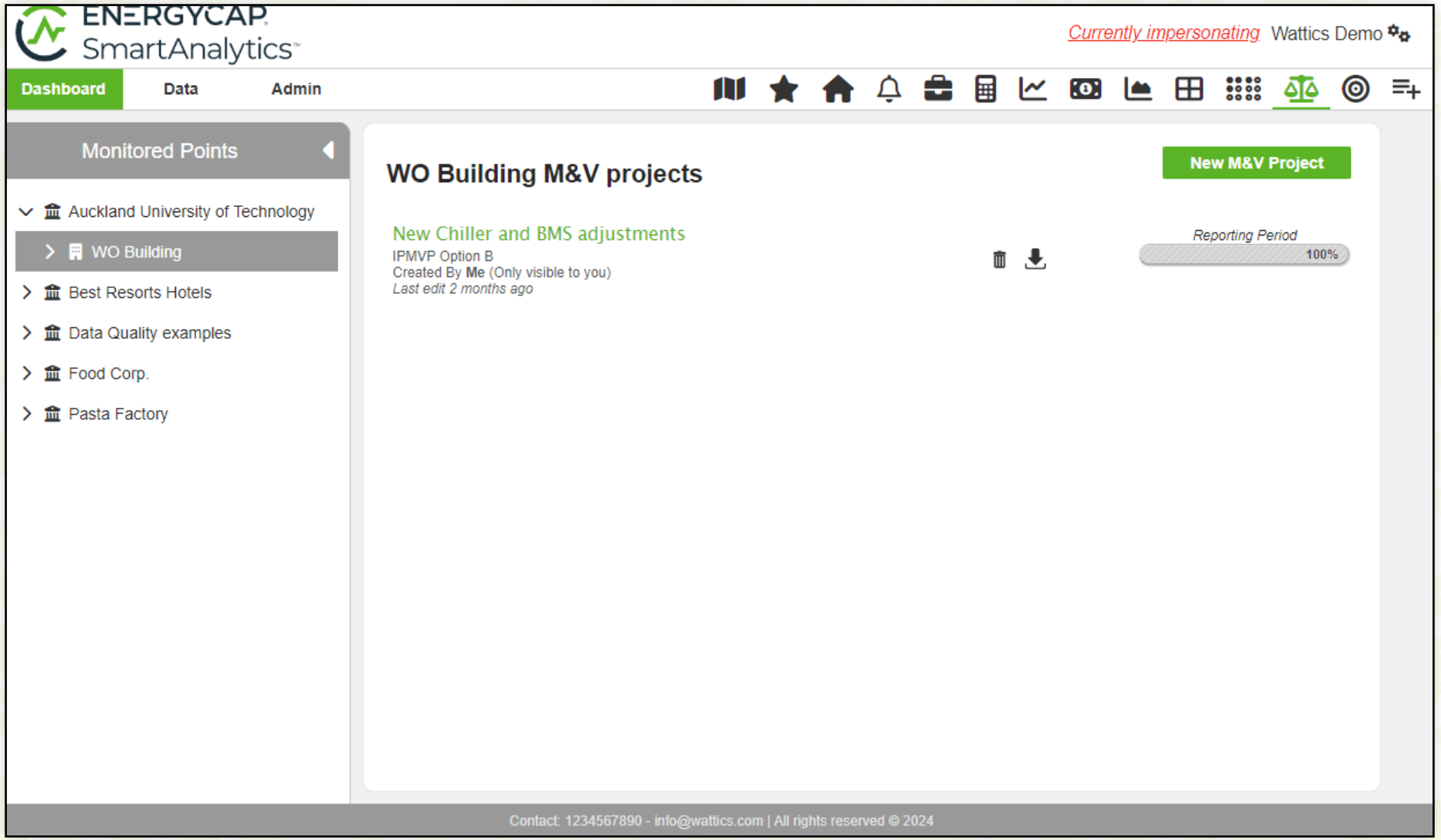
20.4%
Energy and
CO2e emission saved

$23,000
Annual savings

7.5 years
Est. Payback period

Next steps

Option B (screenshots): Measurements & Verification Tool



Option B (screenshots): Step by Step Process

1 - Project Definition

2 - ECM

3 - Baseline Period

4 - Reporting Period

5 - Routine Adjustments

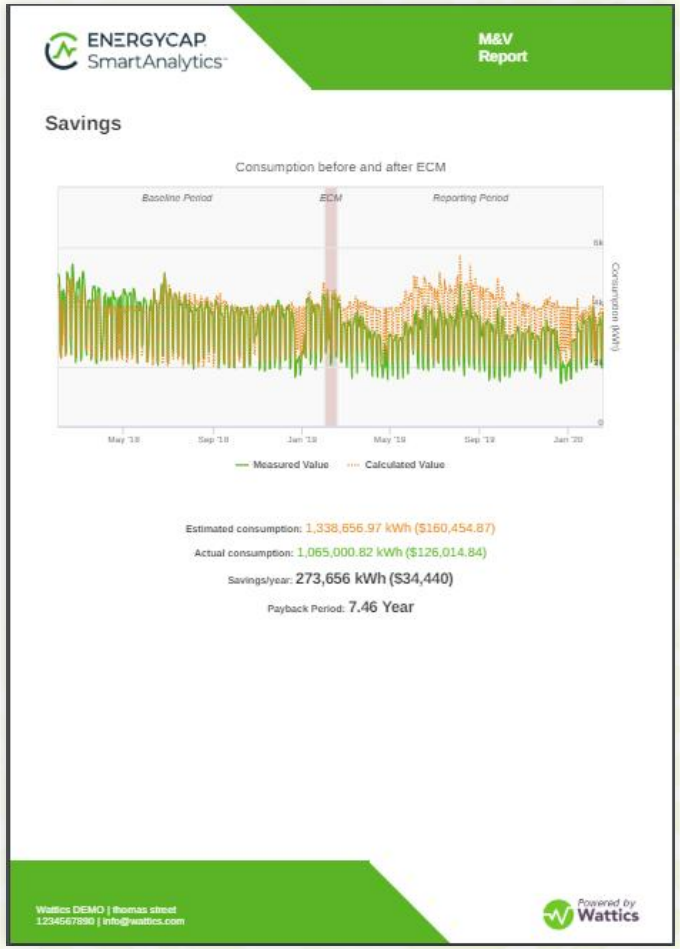
6 - Non-Routine Adjustments

7 - Model

8 - Savings

9 - Executive Summary

Download Report



Option B (screenshots): Step 1 - Project Definition

Define the project's general overall parameters.

Name * New Chiller and BMS adjus

Methodology * IPMVP Option B

Cost 257000 $

Visible to other people ☐

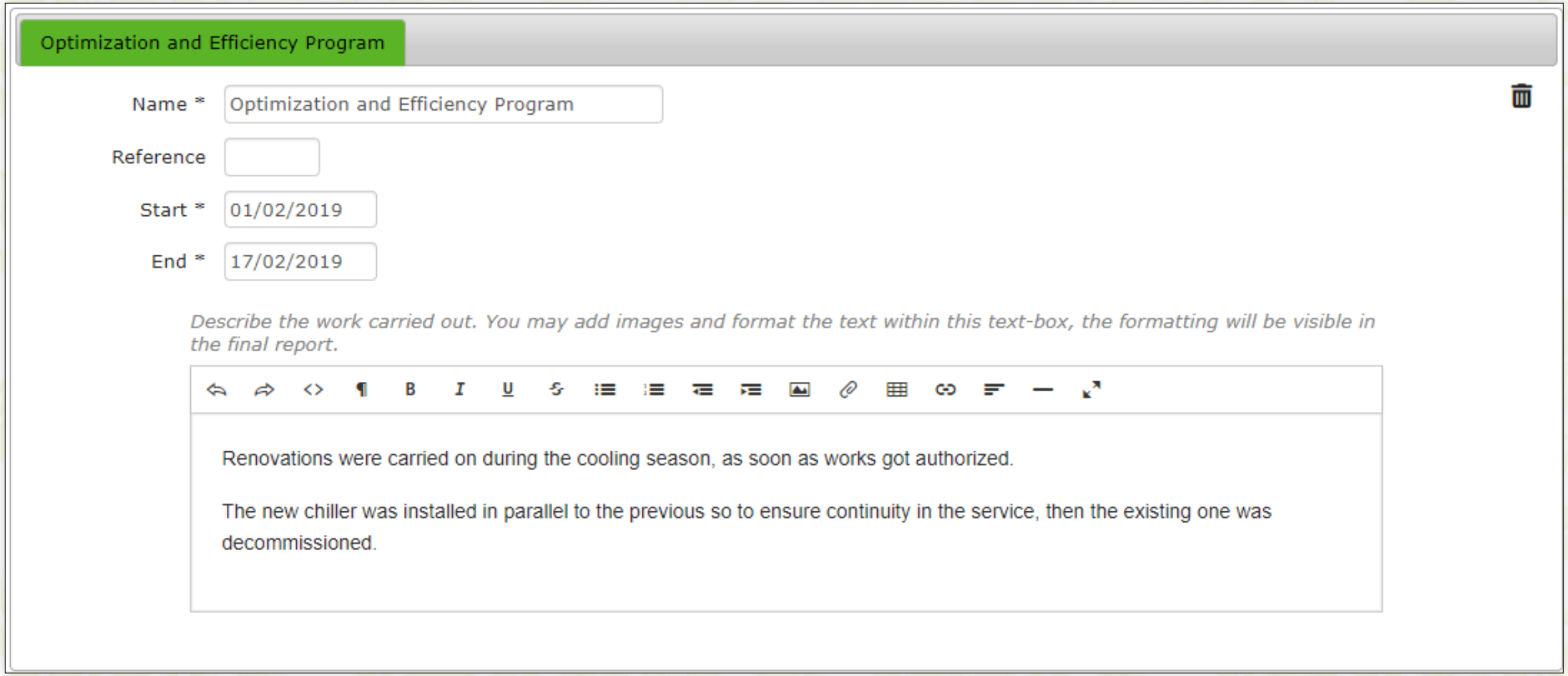
The following text should describe the motivation for the project and provide some context. It does not need a summary as one can be entered in the M&V tools last step. You may add images and format the text within this text box, the formatting will be visible in the final report.

M&V Plan for Auckland University of Technology WO Building, located in Auckland Central Business District.

Actions taken on included:

- Replacing the Chiller and cooling tower (see picture)
- Disable after-hours and weekend AHU requirements
- Switch AHU modulation control from PI to PID
- Reset supply air pressure and temperatures set points

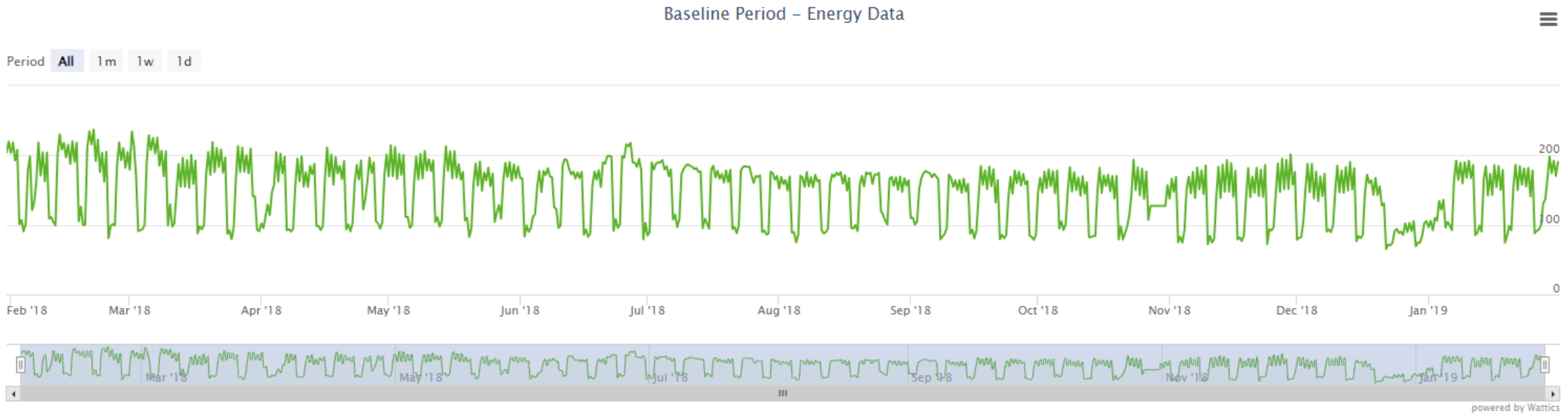
Option B (screenshots): Step 2 - ECM



Option B (screenshots): Step 3 – Baseline Period

Specify the dates that represent typical energy usage before the ECMs for the selected project. Add the energy data to your project in this step.

Energy Data **Main Incomer** Link Start 31/01/2018 End 31/01/2019



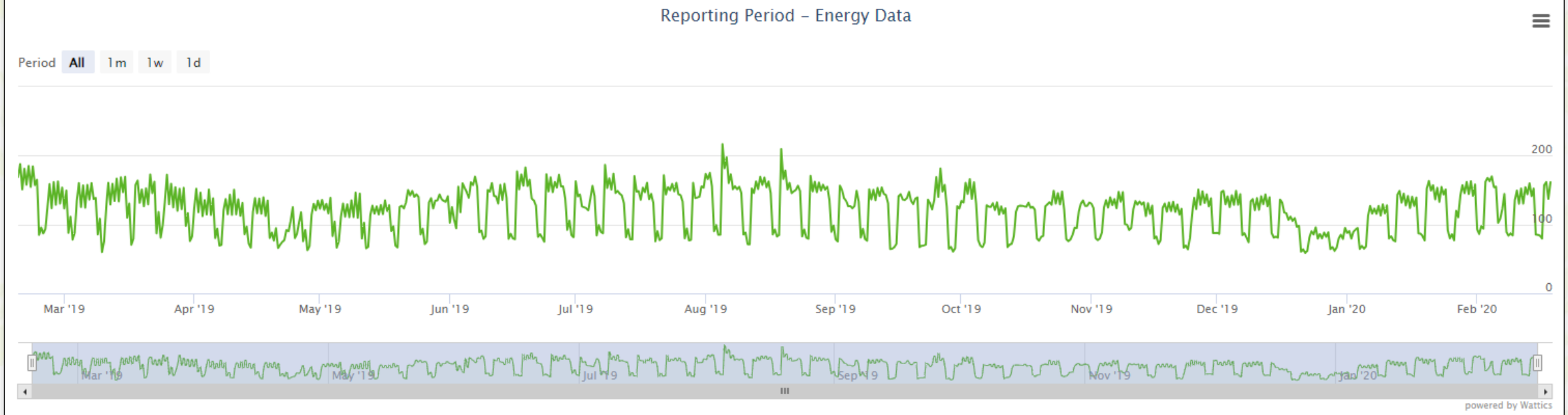
Describe why this period of time was selected.

Baseline period was set to one full year to take seasonality into account

Option B (screenshots): Step 4 – Reporting Period

Specify the dates that represent the time to be monitored after the ECMs.

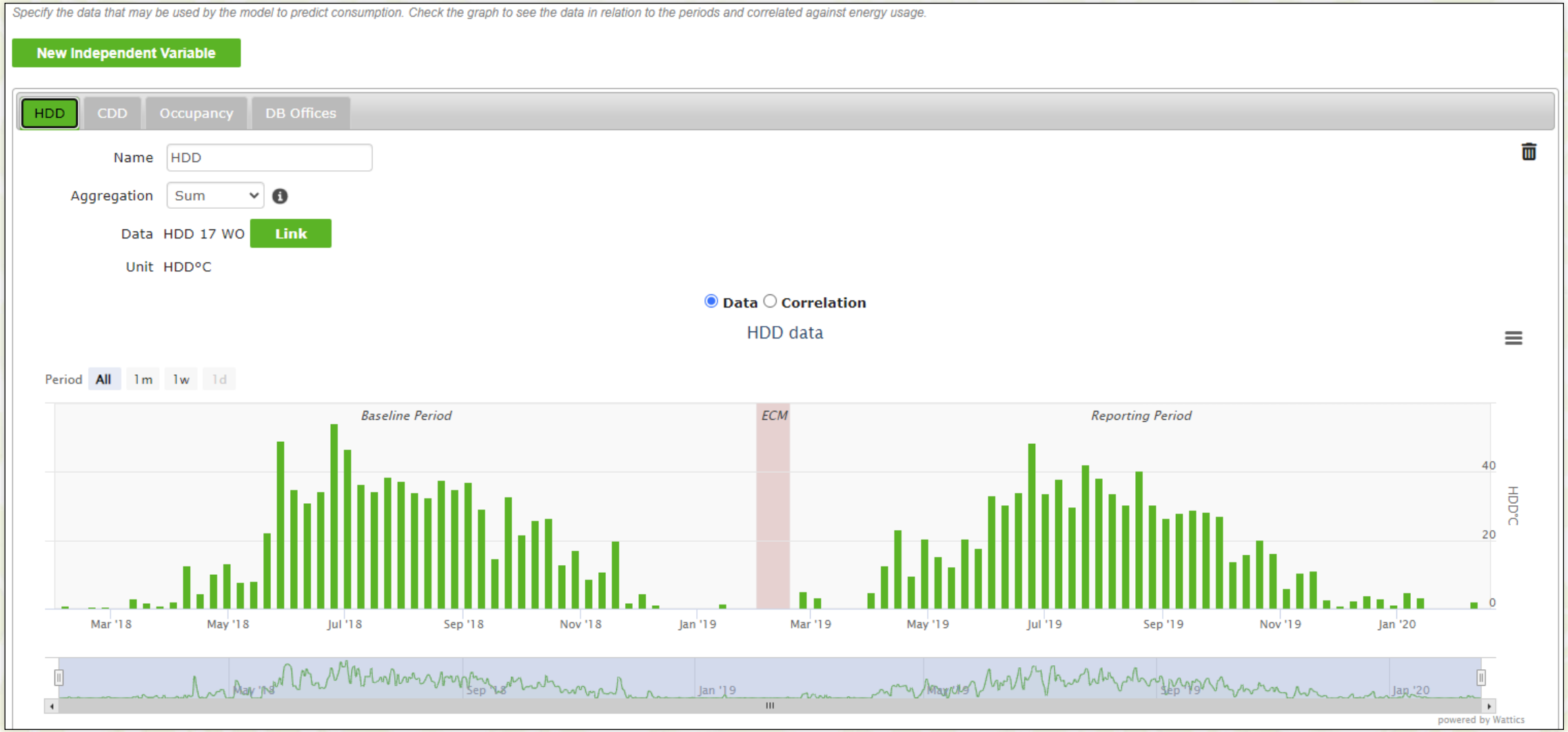
Energy Data **Main Incomer** Start 18/02/2019 End 18/02/2020



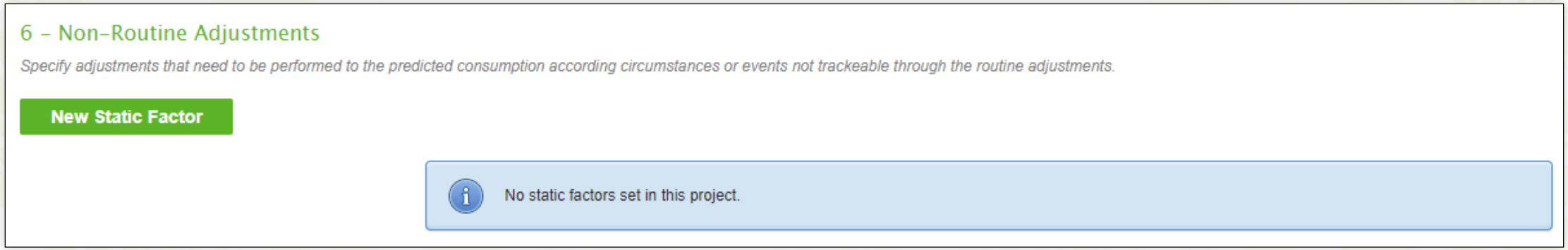
Describe why this period of time was selected.

Reporting period was set to one full year to take seasonality into account

Option B (screenshots): Step 5 – Routine Adjustments



Option B (screenshots): Step 6 – Non-Routine Adjustments



Option B (screenshots): Step 7 – Model

Define the model by which consumption during the reporting period will be estimated. This estimation is the basis for determining how the consumption would have continued had the ECMs not been implemented.

Type: Linear Regression | days grouping: All days (1 model)

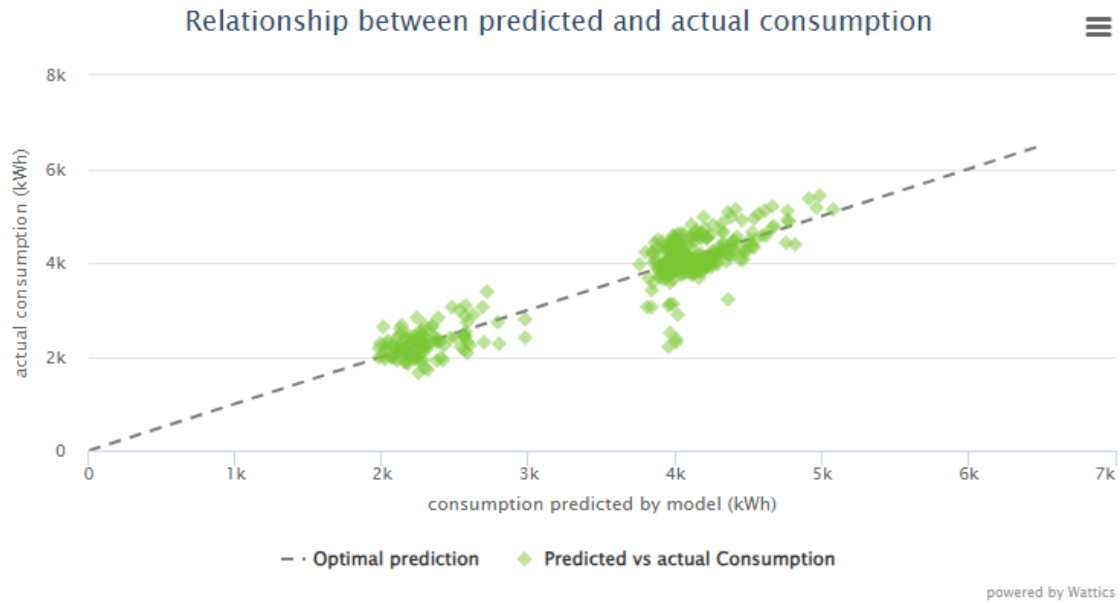
Variable(s) to use:
- [x] HDD
- [x] CDD
- [x] Occupancy
- [x] DB Offices

Generate Model

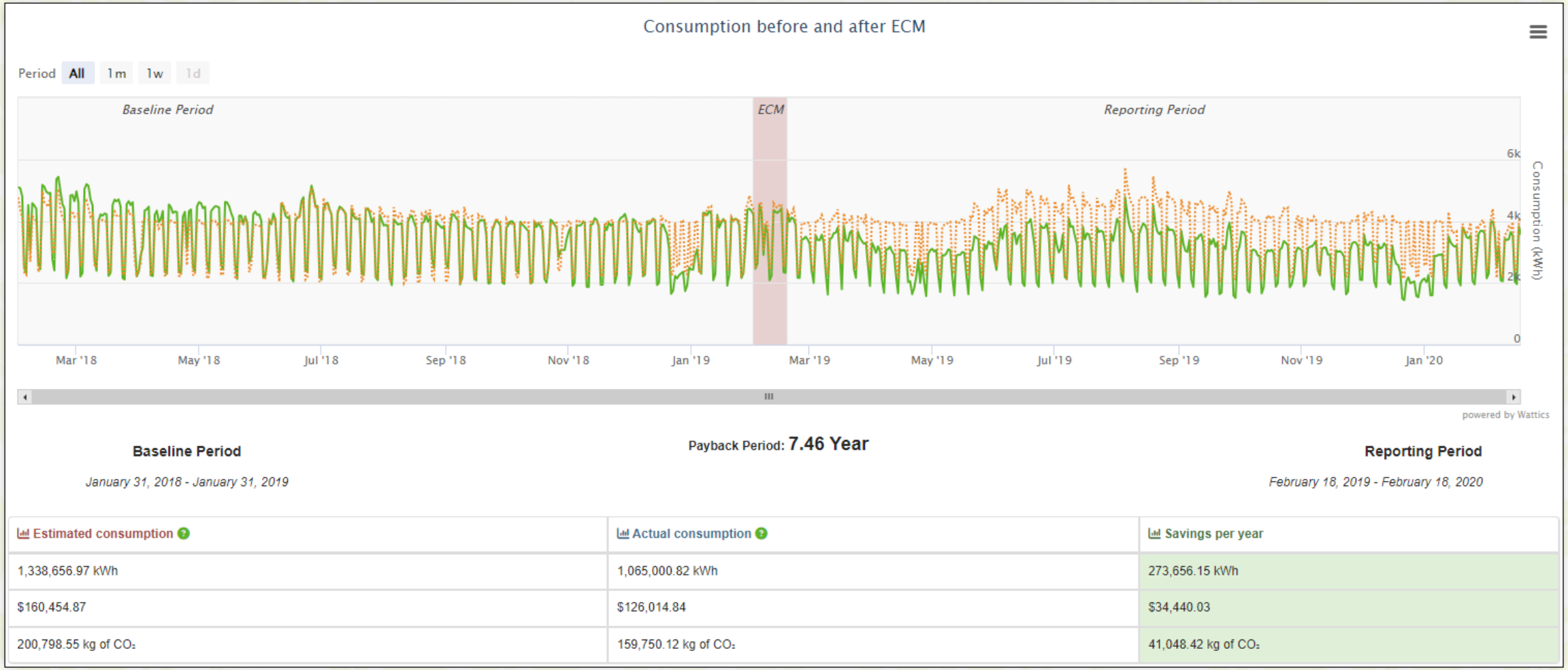
Output

Formula: **-42.28 * HDD + 320.33 * CDD + 30.91 * Occupancy + 1.26 * DB Offices + 2176.13**

R^2: **0.86**



Option B (screenshots): Step 8 – Savings



Baseline Period

January 31, 2018 - January 31, 2019

Payback Period: **7.46 Year**

Reporting Period

February 18, 2019 - February 18, 2020

Estimated consumption	Actual consumption	Savings per year
1,338,656.97 kWh	1,065,000.82 kWh	273,656.15 kWh
$160,454.87	$126,014.84	$34,440.03
200,798.55 kg of CO_2	159,750.12 kg of CO_2	41,048.42 kg of CO_2

Option B (screenshots): Step 9 – Executive Summary

The energy conservation measures implemented resulted in savings that far exceed the initial target of 10% kWh savings per year. Project results demonstrate a 20% reduction in energy use after 1 year; NZ$ 37,272 per annum (US$ 23,477 / €21,446) in cost savings and a payback period for HVAC optimization of 6.9 years.

The personnel on site and energy analysts involved are dedicated toward maintaining the savings achieved so far, through continuous monitoring and analysis, also investigating further energy-using entities to improve savings while maintaining optimal performance within the WO building.

As a result of the savings achieved under the pilot project, AUT has committed to work on additional buildings located at the university campus.

Benefits of Option C

Option C // Whole facility

This approach is taken where the energy use of the whole facility needs to be measured. Several independent variables may need to be considered such as heating/cooling degree days, changes in floor area, hours of operation, use of spaces, occupancy, etc…

Option C is of value where several energy conservation measures have been introduced and the overall picture for the facility is required or you only have utility bill information.

Easy to get started and to do portfolio-wide savings reporting.

Option C // Whole facility pros and cons

PROS:

- Evaluates performances of the entire facility
- Factors in interactions amongst ECMs and between ECMs and the rest of the facility

CONS:

- No separation of impacts from different ECMs
- Impact on savings coming from unexplained variations of energy usage can be difficult to capture

✓ Easy access to utility bill data

Option C Methodology

Establish baseline from utility bills

Determine weather sensitivity

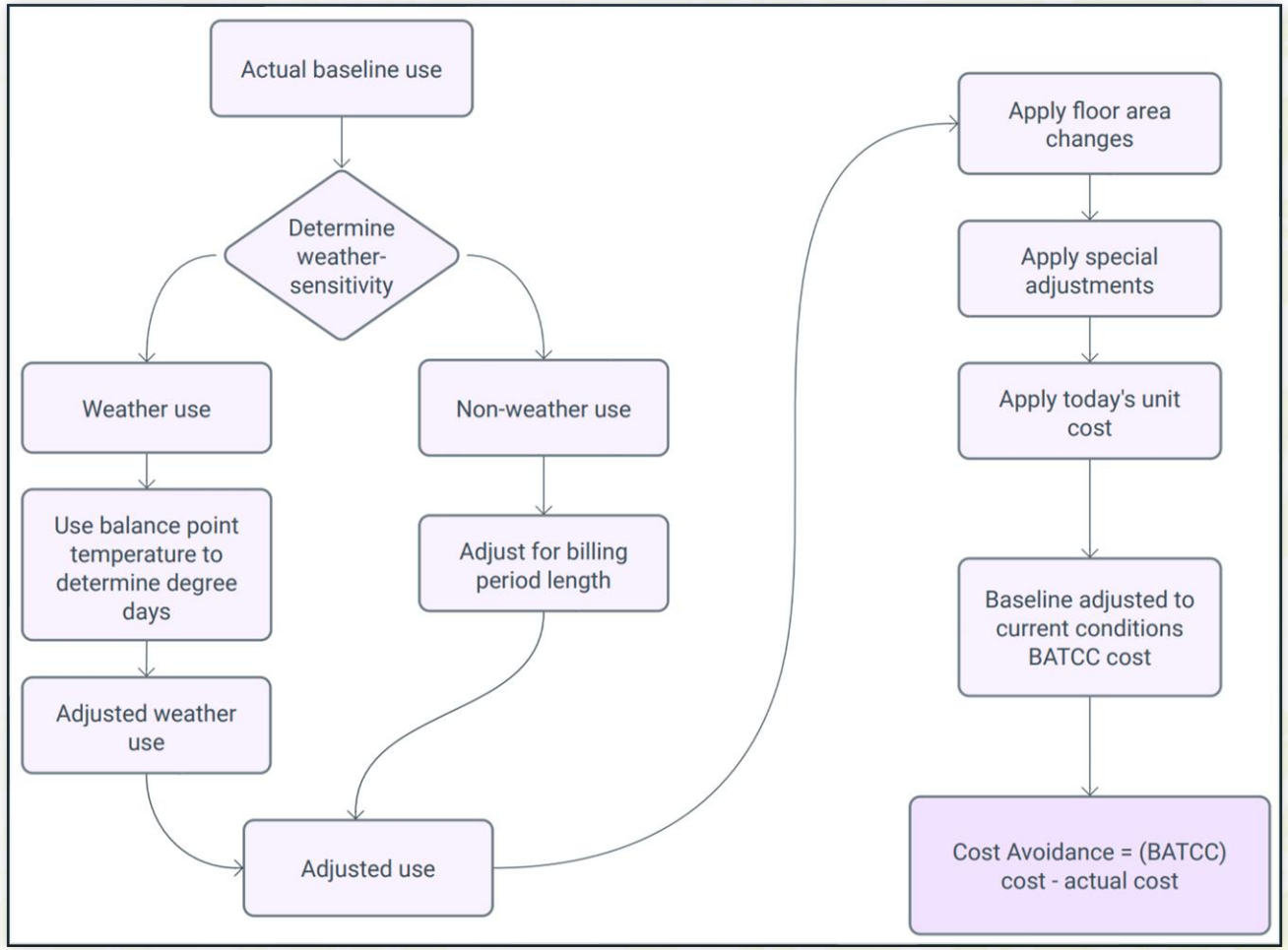
Calendarize bills – adjust for billing length

Adjust for floor area

Special adjustments

Apply cost – today's unit cost

Consider other savings – rebates, refund, demand response, rate reduction…



Case Study Option C

Neil Armstrong Elementary School

Utility Management M&V verifies energy savings from behaviour-based program for Virginia school district

Success story // The project

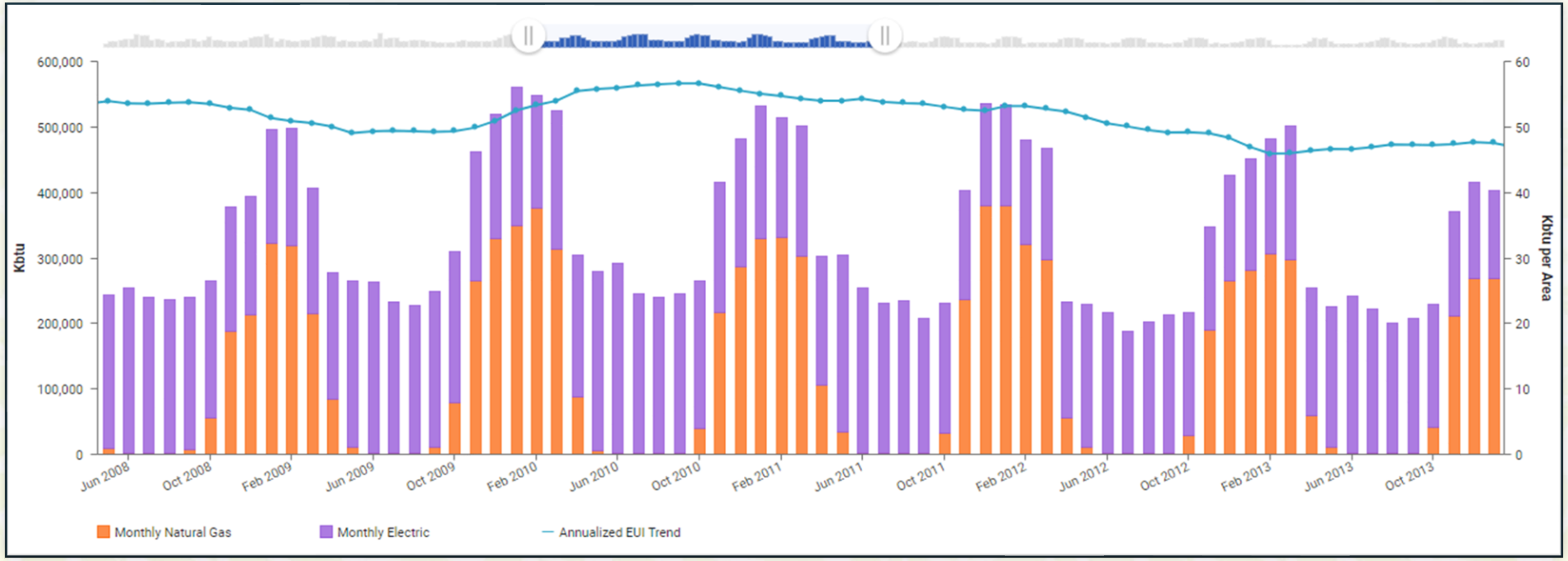
Neil Armstrong Elementary School

Area: 80,000 ft2 = ~7,432 m2

Energy Usage in Base Year: 3,805,228 Kbtu/year

Energy Cost in Base Year: $81,608

Optimization Target: 15% savings



Success story // The project

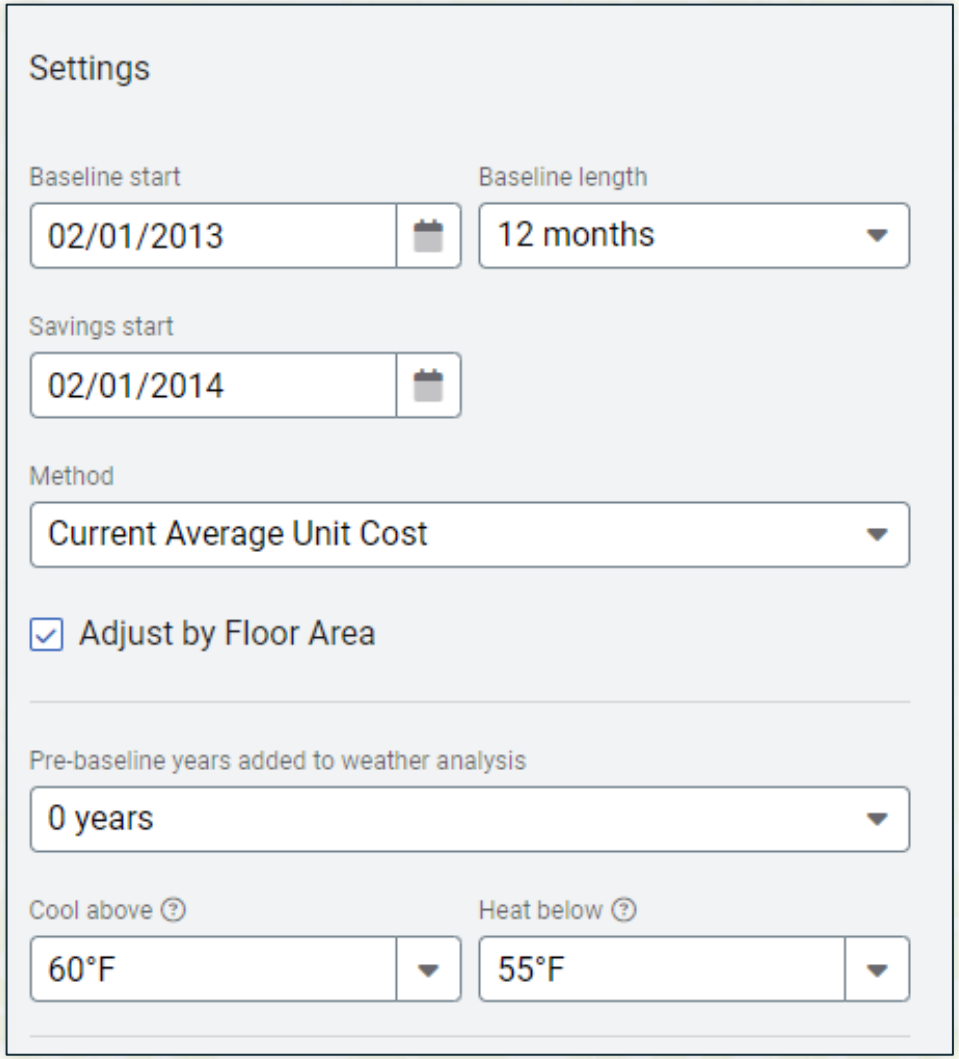
Zero-Cost Energy Conservation Opportunities

- System schedules
- Turn off lights
- Turn off computers and monitors
- Seasonal water temperature adjustments
- Economizers
- Take advantage of natural light

Low-Cost Energy Conservation Opportunities

- Programmable thermostats
- Repair broken valves
- Occupancy sensors for lighting, HVAC
- Reduce lamps in over-lighted areas
- Use rebated programs for lighting upgrades
- Calibrate sensors

Establish Baseline

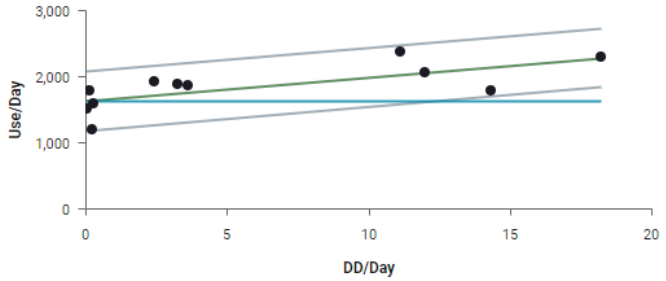


Adjust for weather

Electricity

Cooling Adjustment

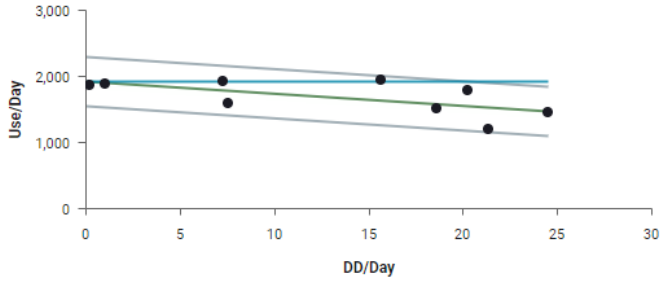
Off On



Base load	1,623.21 kWh/day
Weather factor	36.26 kWh/CDD 3.07 (t-stat)
R2	0.51
Minimum R2	0.27
Adjusted R2	0.51
CVRMSE	0.13
NDB	0.00
Standard Error	248.63

Heating Adjustment

Off On

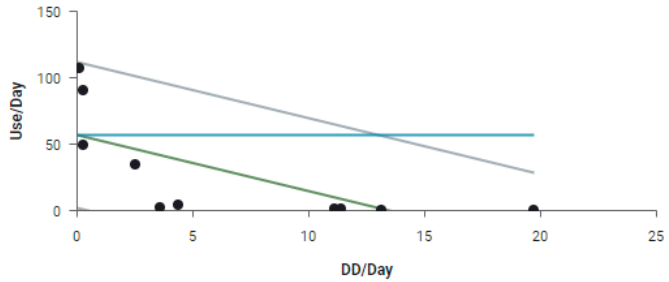


Base load	1,913.90 kWh/day
Weather factor	-18.07 kWh/HDD 0.00 (t-stat)
R2	0.00
Minimum R2	0.34
Adjusted R2	0.00
CVRMSE	0.00
NDB	0.00
Standard Error	0.00

Natural Gas

Cooling Adjustment

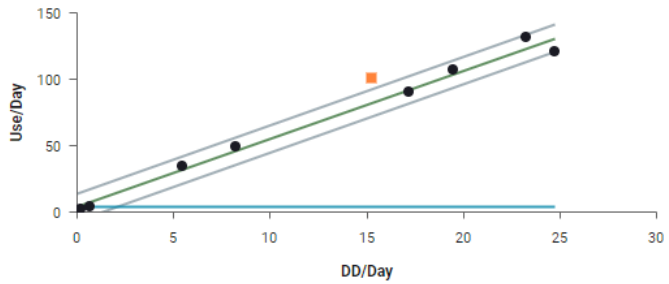
Off On



Base load	57.05 THERM/day
Weather factor	-4.22 THERM/CDD 0.00 (t-stat)
R2	0.00
Minimum R2	0.30
Adjusted R2	0.00
CVRMSE	0.00
NDB	0.00
Standard Error	0.00

Heating Adjustment

Off On



Base load	3.64 THERM/day
Weather factor	5.14 THERM/HDD 23.21 (t-stat)
R2	0.99
Minimum R2	0.39
Adjusted R2	0.99
CVRMSE	0.08
NDB	0.00
Standard Error	5.84

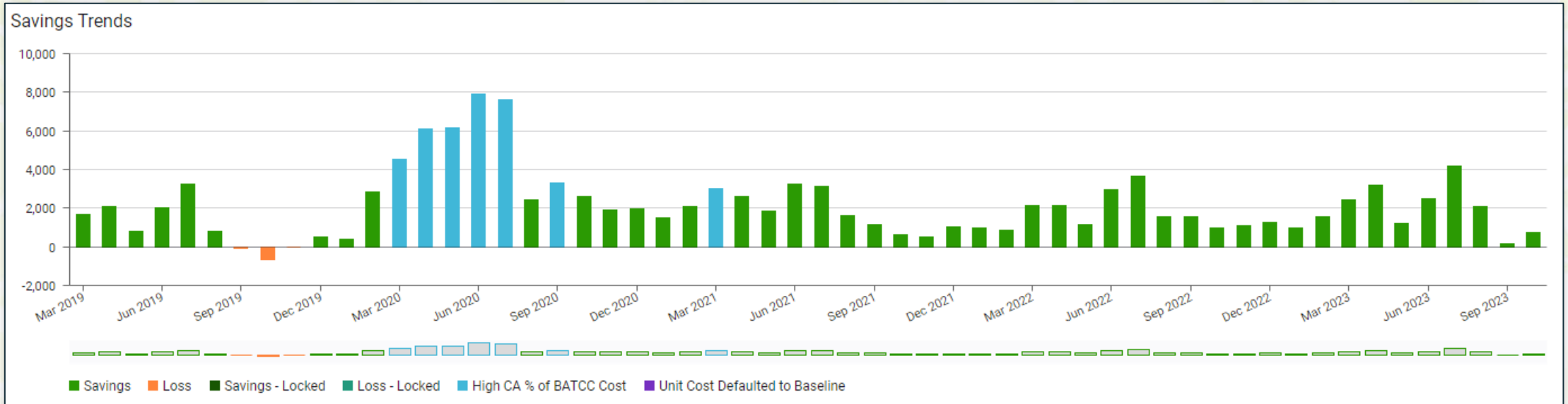
data point · outlier · user-removed · best fit · 2 standard deviations · base load

Statistics are compliant with **IPMVP Option C**

Make special adjustments

	Start	End	Frequency	Value	Category	Method
1	06/01/2014	06/30/2014	Continuous	15.5000	Schedule Change	Add 15.5% to the total BATCC use
AST Additional Occupied Days - CE						
2	10/01/2016	12/31/2016	Continuous	1.7000	Occupancy	Add 1.7% to the total BATCC use
A-170727-4777 Community Use JWN 170727*updated per FCPS. Ssmith 05142019						
4	01/01/2018	01/31/2018	Continuous	160.0300	Extreme Weather	Add 160.03 per day to the BATCC non-weather use
January 2018 additional runtime						

Calculate the savings



Billing Period	Cost			Cost Avoidance		Cooling		Heating		Use			Use Avoidance	
	Baseline	BATCC	Actual	Amount	%	DD	Adj.	DD	Adj.	Baseline	BATCC	Actual	Amount	%
Nov 2023	$ 4,500	$ 6,720	$ 5,942	$ 778	11.6%	38	✓	134		50,312	51,110	45,193	5,917	11.6%
Sep 2023	$ 6,076	$ 8,972	$ 8,783	$ 189	2.1%	470	✓	0		65,626	68,056	66,624	1,432	2.1%
Aug 2023	$ 4,815	$ 7,297	$ 5,216	$ 2,082	28.5%	485	✓	0		51,611	54,040	38,625	15,415	28.5%
Jul 2023	$ 6,393	$ 8,793	$ 4,607	$ 4,185	47.6%	489	✓	0		68,942	66,295	34,738	31,557	47.6%
Jun 2023	$ 6,928	$ 8,675	$ 6,161	$ 2,513	29.0%	231	✓	0		73,040	68,616	48,735	19,881	29.0%
May 2023	$ 4,388	$ 5,876	$ 4,679	$ 1,197	20.4%	55	✓	29		48,308	47,836	38,091	9,745	20.4%
Apr 2023	$ 5,868	$ 8,078	$ 4,893	$ 3,185	39.4%	121	✓	73		64,979	66,248	40,124	26,124	39.4%

Calculate the savings

Explanation of Savings

Aug 2023

Close

FCPS [Fairfax County PS - VA] > ARMS-304 [Armstrong Elementary School] > ARMS - E - Main [210008589637]

Savings for Aug 2023

Non-weather use | Weather use | Locked adjustment | Actual current use | Use avoidance

51,611 KWH
Actual baseline use

54,040 KWH
BATCC use

\- 38,625 KWH
Actual current use

15,415 KWH
Use avoidance

$ 7,297
BATCC cost

\- $ 5,216
Actual current cost

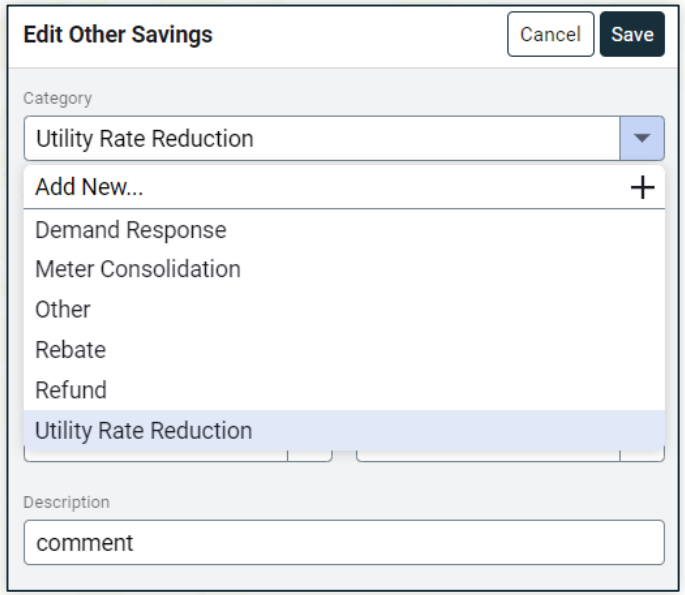
$ 2,082
Cost avoidance

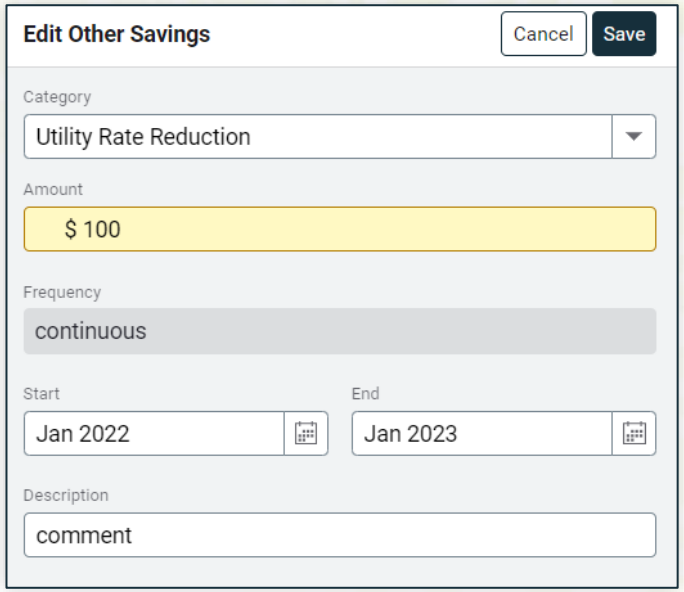
36.26 KWH/CDD
Cooling

N/A
Heating

Date	Non-weather use		Weather use		Cost		Adjustments				Cooling degree days		Heating degree days	
	Baseline	BATCC	Baseline	BATCC	BATCC	AUC	Floor area	Special	Other	Weather	Baseline	Current	Baseline	Current
07/20/2023	1,257.0 kWh	1,257.0 kWh	870.3 kWh	652.7 kWh	$ 257.88	$ 0.135				✓	24	18	0	0
07/21/2023	1,257.0 kWh	1,257.0 kWh	761.5 kWh	543.9 kWh	$ 243.19	$ 0.135				✓	21	15	0	0
07/22/2023	1,257.0 kWh	1,257.0 kWh	725.3 kWh	507.7 kWh	$ 238.29	$ 0.135				✓	20	14	0	0
07/23/2023	1,257.0 kWh	1,257.0 kWh	689.0 kWh	543.9 kWh	$ 243.19	$ 0.135				✓	19	15	0	0
07/24/2023	1,257.0 kWh	1,257.0 kWh	616.5 kWh	652.7 kWh	$ 257.88	$ 0.135				✓	17	18	0	0
07/25/2023	1,257.0 kWh	1,257.0 kWh	398.9 kWh	725.3 kWh	$ 267.67	$ 0.135				✓	11	20	0	0
07/26/2023	1,257.0 kWh	1,257.0 kWh	398.9 kWh	652.7 kWh	$ 257.88	$ 0.135				✓	11	18	0	0
07/27/2023	1,257.0 kWh	1,257.0 kWh	543.9 kWh	870.3 kWh	$ 287.26	$ 0.135				✓	15	24	0	0
07/28/2023	1,257.0 kWh	1,257.0 kWh	543.9 kWh	870.3 kWh	$ 287.26	$ 0.135				✓	15	24	0	0
07/29/2023	1,257.0 kWh	1,257.0 kWh	435.2 kWh	797.8 kWh	$ 277.46	$ 0.135				✓	12	22	0	0

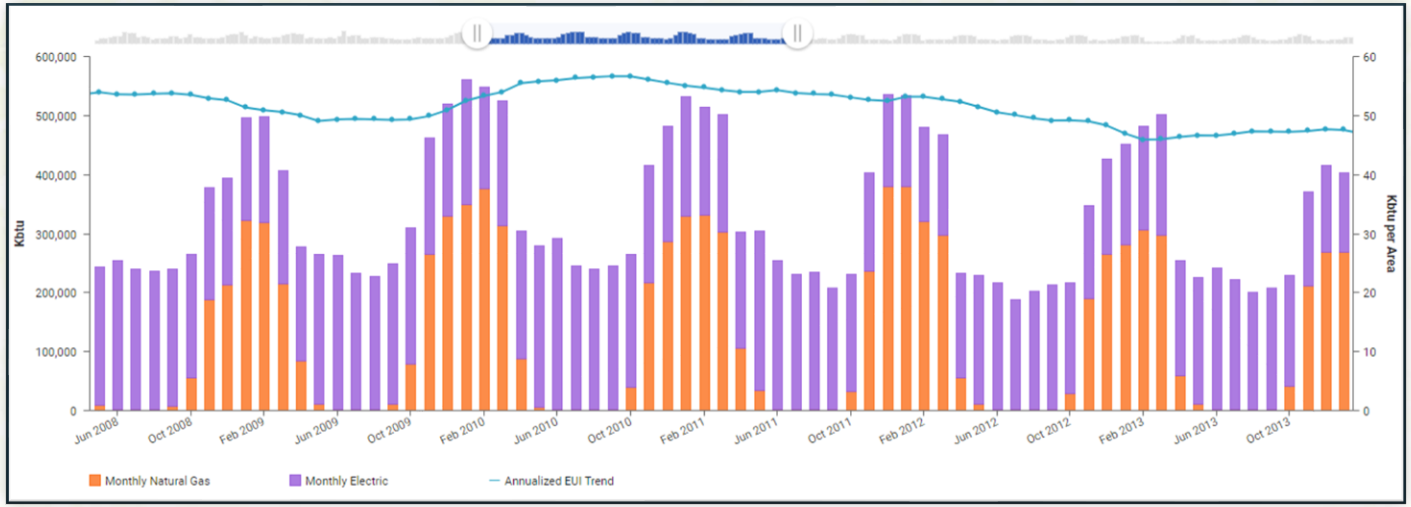
Other Savings



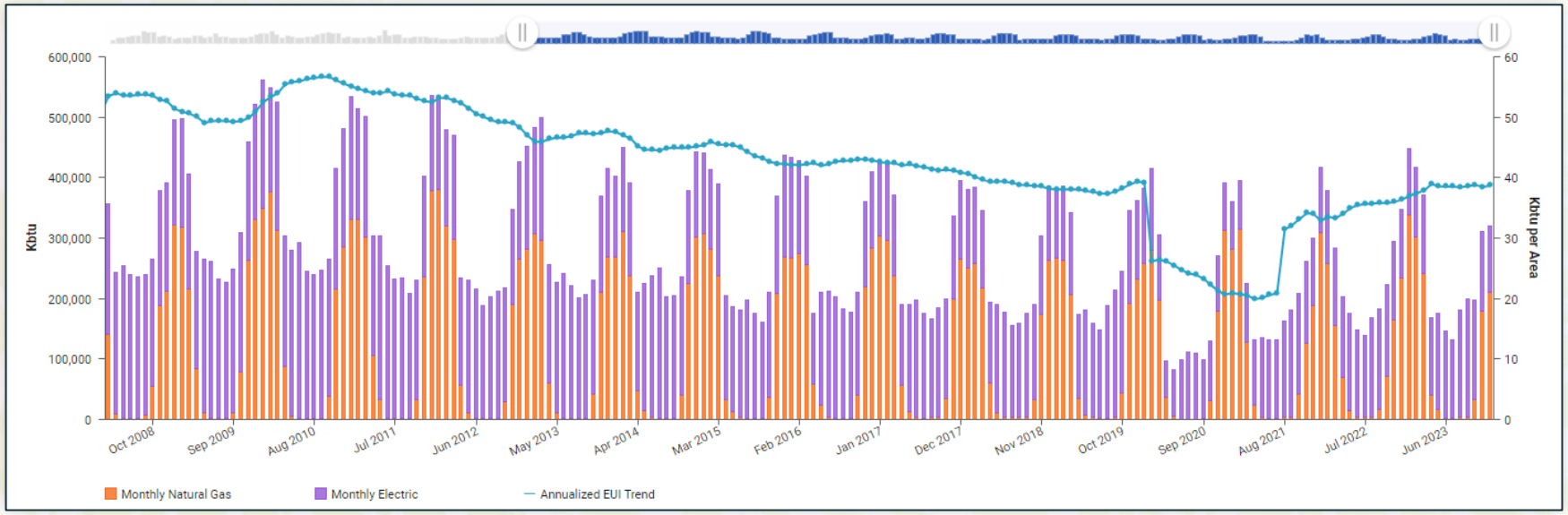


Date	Non-weather use		Weather use		Cost			Adjustments			Cooling degree days		Heating degree days	
	Baseline	BATCC	Baseline	BATCC	BATCC	AUC	Floor area	Special	Other	Weather	Baseline	Current	Baseline	Current
07/05/2022	2,069.2 kWh	2,654.2 kWh	2,318.8 kWh	0.0 kWh	$ 282.98	$ 0.107		✓	✓		10	0	0	0
07/06/2022	2,069.2 kWh	2,654.2 kWh	1,159.4 kWh	0.0 kWh	$ 282.98	$ 0.107		✓	✓		5	0	0	0
07/07/2022	2,069.2 kWh	2,654.2 kWh	463.8 kWh	0.0 kWh	$ 282.98	$ 0.107		✓	✓		2	0	0	0
07/08/2022	2,069.2 kWh	2,654.2 kWh	927.5 kWh	0.0 kWh	$ 282.98	$ 0.107		✓	✓		4	0	0	0
07/09/2022	2,202.1 kWh	2,787.1 kWh	695.6 kWh	0.0 kWh	$ 297.14	$ 0.107		✓	✓		3	0	0	0
07/10/2022	2,202.1 kWh	2,787.1 kWh	0.0 kWh	0.0 kWh	$ 297.14	$ 0.107		✓	✓		0	0	0	0

Report to stakeholders



Historical & Baseline

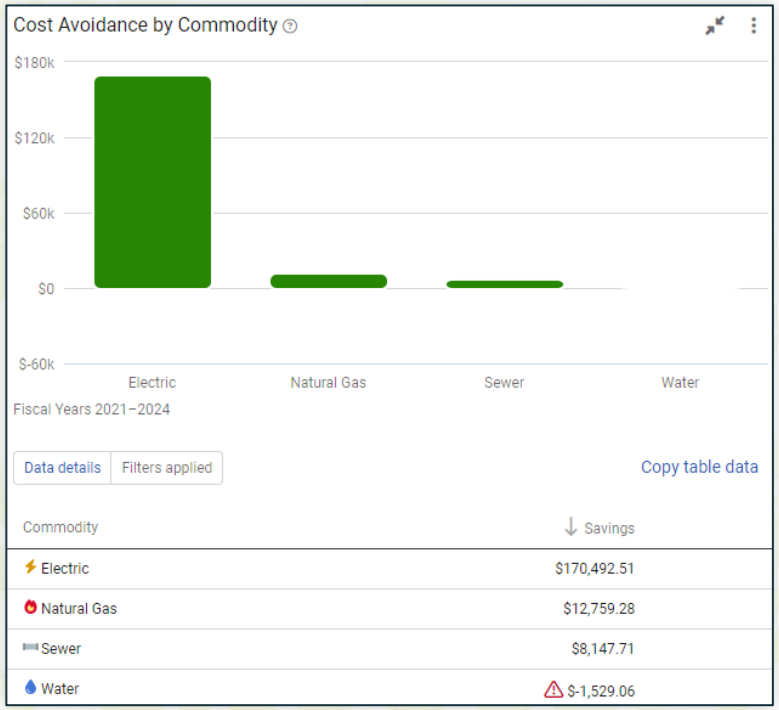


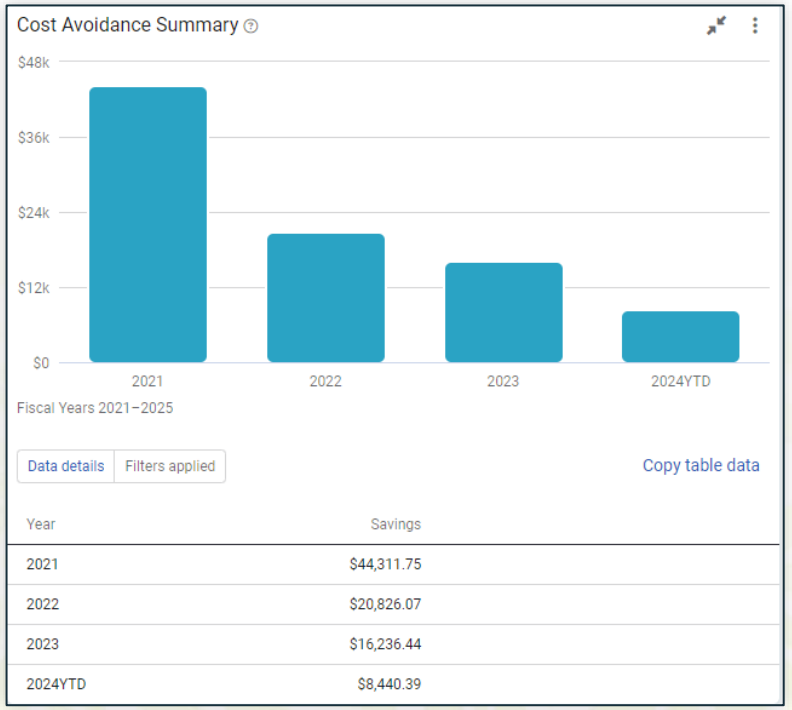
Performance

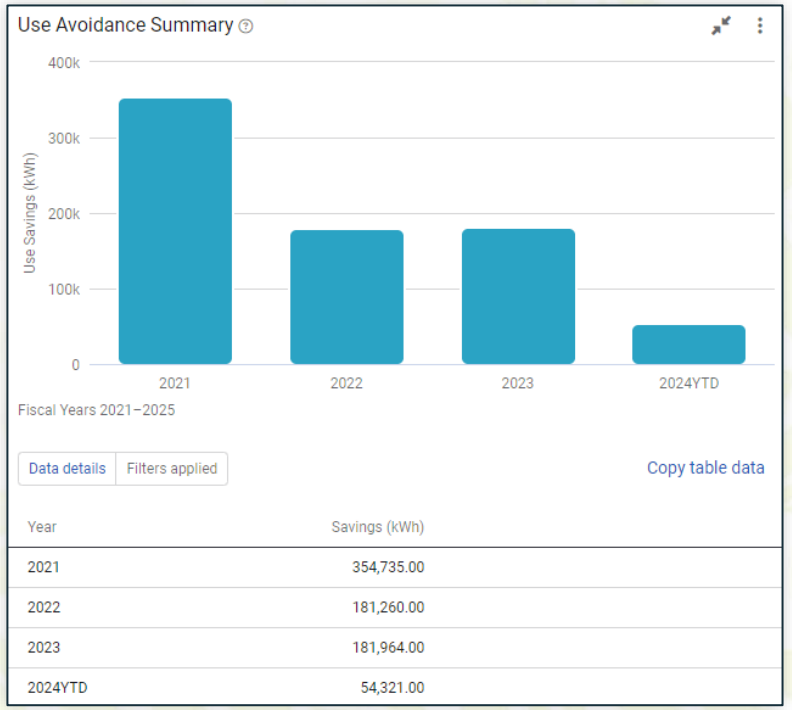
Report to stakeholders

Optimization Target: 15% savings

Realized Savings: 21.3% savings, $189,870







Report to stakeholders

Cumulative Cost Savings

Expected Cost	$889,664
Actual Cost	$699,794
Program Savings	$189,870
Percent Savings	21.3%
Other Savings	$0
Total Savings	$189,870

Expected Energy Cost

Anticipated expense without energy management.

Base year usage after adjustments for such variables as changes in weather, equipment, schedules, occupancy and prices.

Actual Energy Cost

Actual utility costs for electricity, gas, water, sewer, etc. obtained directly from bills.

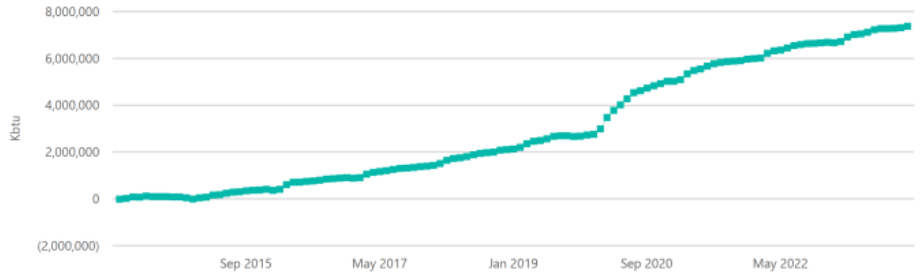
Other Savings

Additional documented savings attributable to Program activities but not the direct result of usage reductions, such as rebates, refunds, tariff changes, etc.

Program Savings

The difference between Expected and Actual Cost, calculated in accordance with the International Performance Measurement & Verification Protocol and ISO 50015. Does not include savings attributable to reduced equipment maintenance and replacement costs and other collateral benefits. These savings can increase the program savings up to 20%.

Cumulative Use Savings



Cumulative Greehouse Gas Reduction

Energy Reduction Impact: 7,375,784 Kbtu 607 equiv. metric tons of CO2

This is equivalent to the following:

Passenger cars not driven for one year:	126
Tree seedlings grown for 10 years:	15,552

Cost Avoidance by Building

	BATCC Cost	Actual Cost	Cost Avoidance	Cost Avoidance %
Hayfield Secondary School [HAYFS-180]	$8,805,768	$5,799,630	$3,006,138	34.1%
Woodson High School [WO-130]	$8,498,292	$6,053,448	$2,444,844	28.8%
Lake Braddock Secondary School [LAKEB-400]	$10,642,732	$8,249,676	$2,393,056	22.5%
Chantilly High School [CHAN-250]	$7,492,762	$5,307,614	$2,185,148	29.2%
Westfield High School [WESTFHS-240]	$7,912,566	$5,780,307	$2,132,259	26.9%
Fairfax High School [FAIR-500]	$7,527,953	$5,469,121	$2,058,832	27.3%
Sandburg Middle School [SAND-231]	$4,803,949	$2,901,226	$1,902,723	39.6%
South County High School [SOCOHS-420]	$6,637,646	$5,028,835	$1,608,811	24.2%
Robinson Secondary School [ROBI-390]	$8,437,283	$6,832,473	$1,604,809	19.0%
Edison High School [ED-120]	$6,233,094	$4,710,029	$1,523,065	24.4%
West Potomac High School [WESTP-200]	$6,712,666	$5,286,071	$1,426,596	21.3%
Kilmer Middle School [KILM-071]	$3,452,068	$2,026,381	$1,425,687	41.3%
Mount Vernon High School [MTVE-220]	$6,891,600	$5,474,620	$1,416,980	20.6%
South Lakes High School [SOUT-320]	$6,548,885	$5,177,641	$1,371,244	20.9%
Liberty Middle School [LIBER-411]	$3,494,269	$2,190,545	$1,303,724	37.3%
Marshall High School [MARS-070]	$5,327,331	$4,024,304	$1,303,027	24.5%
Annandale High School [ANNA-140]	$5,404,948	$4,264,075	$1,140,874	21.1%
Poe Middle School [POE-141]	$3,245,123	$2,158,872	$1,086,251	33.5%
Jefferson High School for Science and Technology [JEFF-340]	$4,891,405	$3,841,085	$1,050,320	21.5%
Lewis High School [LEWI-160]	$5,240,593	$4,260,360	$980,233	18.7%
Centreville High School [CENTHS-410]	$4,609,621	$3,689,946	$919,676	20.0%
Whitman Middle School [WHITM-221]	$2,924,856	$2,017,082	$907,774	31.0%
McLean High School [MCLE-030]	$4,699,894	$3,819,481	$880,413	18.7%
Carson Middle School [CARS-171]	$3,464,641	$2,624,765	$839,876	24.2%
Madison High School [MADI-060]	$5,013,273	$4,196,451	$816,822	16.3%
Fort Belvoir Primary Elementary School [FTBV-197]	$2,465,178	$1,685,886	$779,292	31.6%
Franklin Middle School [FRANM-331]	$2,193,648	$1,443,207	$750,441	34.2%
Holmes Middle School [HOLM-111]	$2,941,223	$2,234,403	$706,820	24.0%

Live Example

Penn State // Smeal School of Business

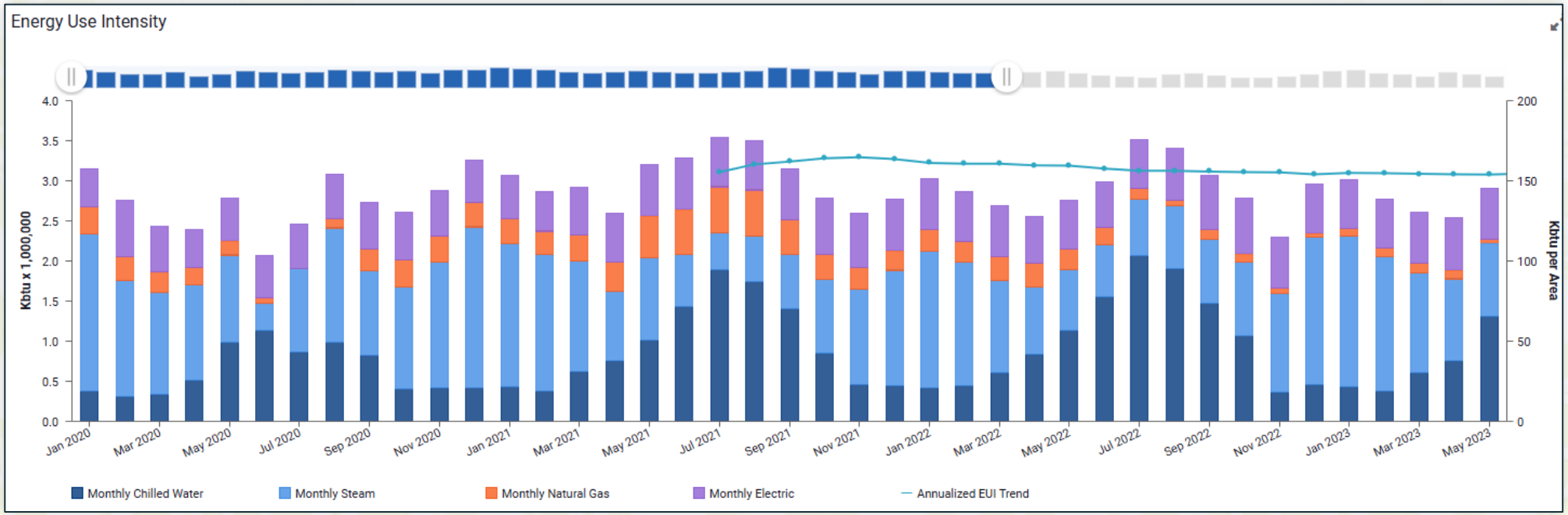
Project focus of controls retro commissioning to recalibrate the building to optimize settings

Building was dedicated in 2005 and is 225,427 ft^2

Usage increasing or flat YOY

Project completed in July 2023

Was the project a success?



Start Today

Start today!

Start with the culture

Establish an energy policy and guidelines

Identify targets

Implement simple projects/strategies

- Align building HVAC operation with occupancy
- Standardize (within reason) heating and cooling set points
- Aggressively set back buildings during unoccupied time
- Identify broken HVAC equipment and develop a plan for repair

Track the projects, calculate the savings, report to stakeholders

Resources

Become a member of EVO (**www.EVO-World.org**)

Download IPMVP from EVO

Purchase ISO standards at iso.org

Become a CMVP–Certified Measurement & Verification Professional (**www.AEECenter.org**)

Check out EnergyCAP's resources and have a tour of ESA and EUM

Questions?

CATALYST

We'd love to hear your thoughts!

Take a moment to share your feedback for this session in the **Sched app.**

Your input helps us make future events even better.