Efficient and Healthy Schools Recognition Program

Energy Efficiency + Health

March 14, 2023

EFFICIENT AND HEALTHY SCHOOLS

EE+Health Recognition Webinar 3:

Building Assessment Tools for School Energy Retrofits

EFFICIENT AND HEALTHY SCHOOLS

Today's Presenters

Carolyn Szum
Energy and Environmental Policy Researcher
Lawrence Berkeley National Lab

Han Li
Scientific Engineering Associate
Lawrence Berkeley National Lab

Juan Gonzales
Staff Scientist
Pacific Northwest National Lab (PNNL)

EFFICIENT AND HEALTHY SCHOOLS

Today's Agenda

- Introductions and Level Setting
- Session Recap
- Building Efficiency Target Tool for Energy Retrofits (BETTER): *Carolyn Szum and Han Li*
- Quick Building Assessment Tool (QBAT) for School Needs Assessment: *Juan Gonzalez*
- Developing your plan breakout groups

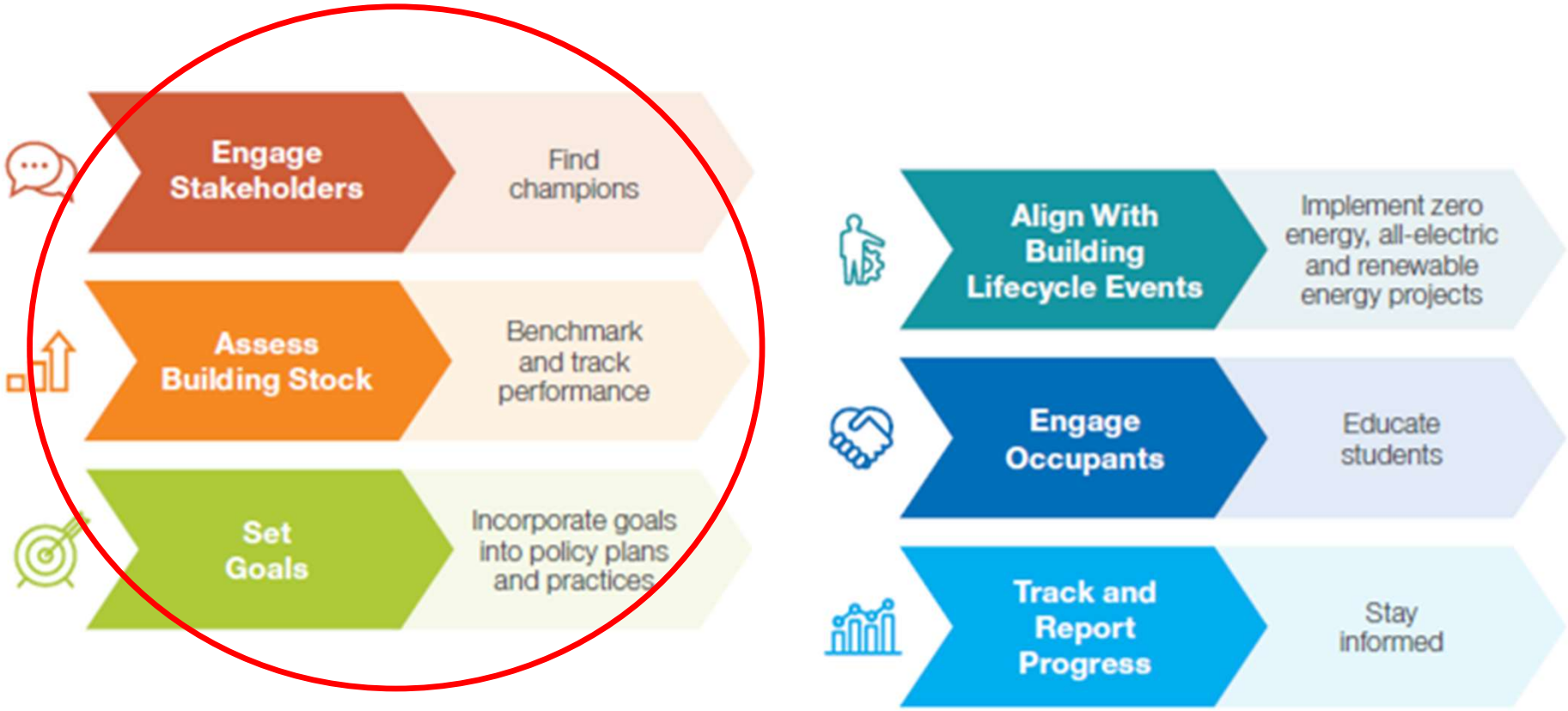
EFFICIENT AND HEALTHY SCHOOLS

Let us know who is here!

Introduce yourselves in the chat with your **name**, **title**, and **school district**

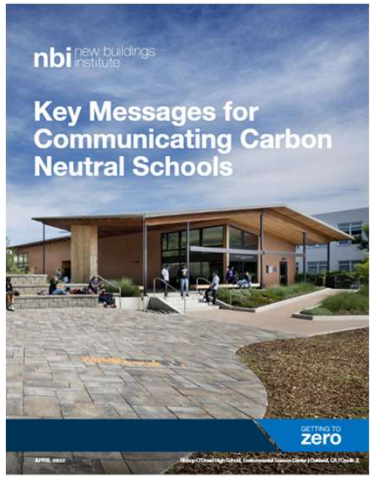
Quick Session Recap

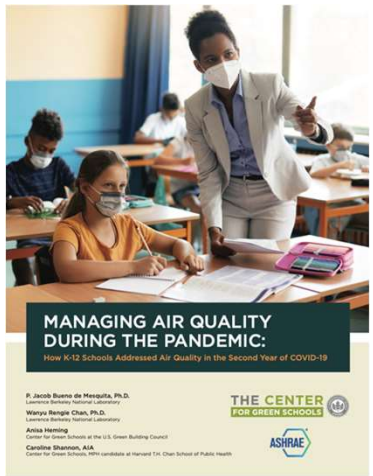
Key Approaches and Outcomes in Achieving Efficient and Healthy Schools

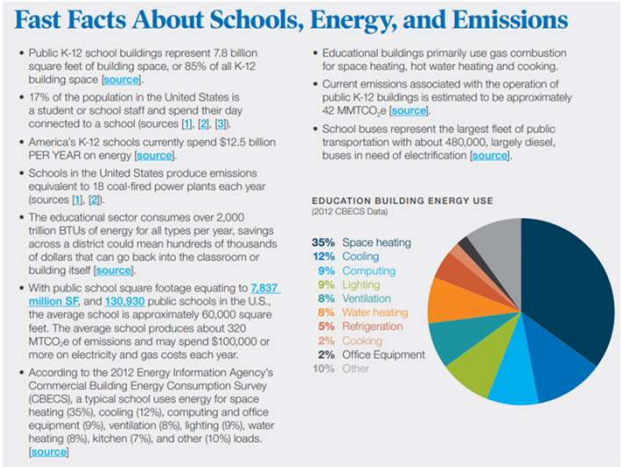


Stakeholder Engagement and Visioning

Making the case for efficiency and health





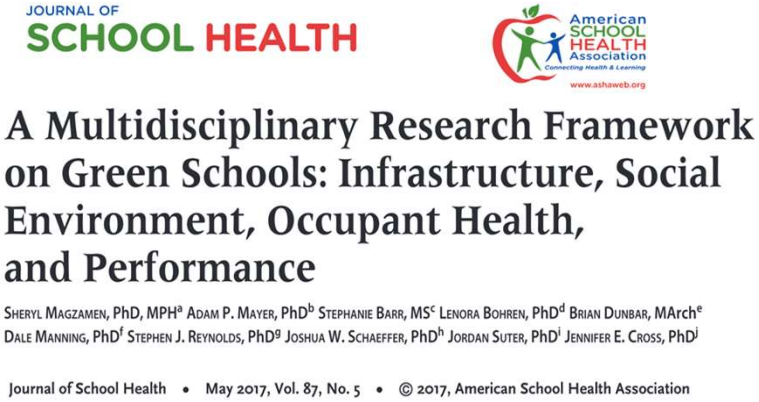


Fast Facts About Schools, Energy, and Emissions

- Public K-12 school buildings represent 7.8 billion square feet of building space, or 85% of all K-12 building space [source].
- 17% of the population in the United States is a student or school staff and spend their day connected to a school (sources [1], [2], [3]).
- America's K-12 schools currently spend $12.5 billion PER YEAR on energy [source].
- Schools in the United States produce emissions equivalent to 18 coal-fired power plants each year (sources [1], [2]).
- The educational sector consumes over 2,000 trillion BTUs of energy for all types per year, savings across a district could mean hundreds of thousands of dollars that can go back into the classroom or building itself [source].
- With public school square footage equating to 7,837 million SF, and 130,930 public schools in the U.S., the average school is approximately 60,000 square feet. The average school produces about 320 $MTCO_2e$ of emissions and may spend $100,000 or more on electricity and gas costs each year.
- According to the 2012 Energy Information Agency's Commercial Building Energy Consumption Survey (CBECS), a typical school uses energy for space heating (35%), cooling (12%), computing and office equipment (9%), ventilation (8%), lighting (9%), water heating (8%), kitchen (7%), and other (10%) loads. [source]
- Educational buildings primarily use gas combustion for space heating, hot water heating and cooking.
- Current emissions associated with the operation of public K-12 buildings is estimated to be approximately 42 $MMTCO_2e$ [source].
- School buses represent the largest fleet of public transportation with about 480,000, largely diesel, buses in need of electrification [source].

EDUCATION BUILDING ENERGY USE
(2012 CBECS Data)

35% Space heating
12% Cooling
9% Computing
9% Lighting
8% Ventilation
8% Water heating
5% Refrigeration
2% Cooking
2% Office Equipment
10% Other



JOURNAL OF SCHOOL HEALTH

American School Health Association
Connecting Health & Learning
www.ashaweb.org

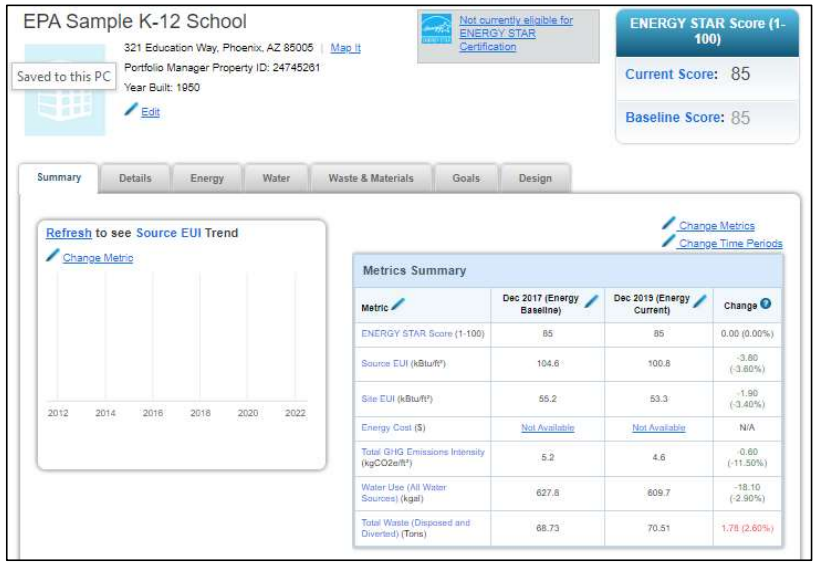
A Multidisciplinary Research Framework on Green Schools: Infrastructure, Social Environment, Occupant Health, and Performance

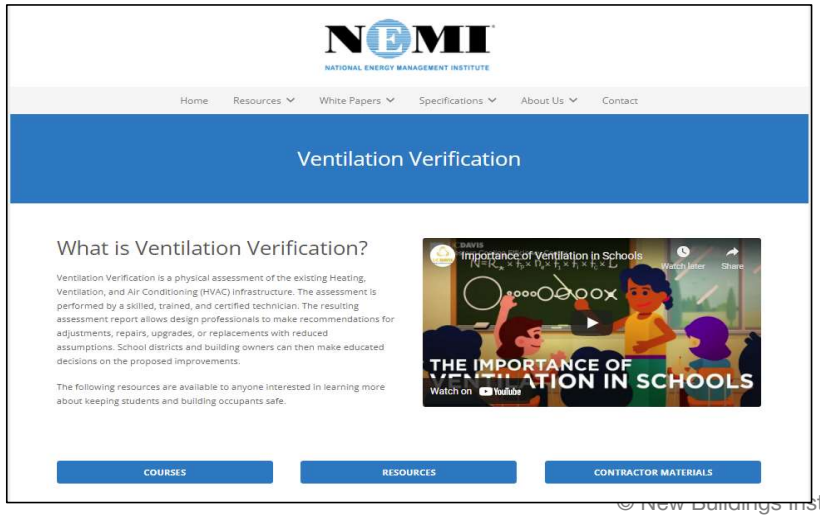
Sheryl Magzamen, PhD, MPH[a] Adam P. Mayer, PhD[b] Stephanie Barr, MS[c] Lenora Bohren, PhD[d] Brian Dunbar, MArch[e] Dale Manning, PhD[f] Stephen J. Reynolds, PhD[g] Joshua W. Schaeffer, PhD[h] Jordan Suter, PhD[i] Jennifer E. Cross, PhD[j]

Journal of School Health • May 2017, Vol. 87, No. 5 • © 2017, American School Health Association

Assessing Building Stock

Energy benchmarking and ventilation assessments





Goal Setting

Portfolio Goals

Goals require clear ways to measure progress. The baseline leverages benchmarking data and documents energy performance and carbon emissions in the school district's facilities for a specific year. This baseline year is then used for future comparisons and to track changes over time. Ideally, it is a specified time in the past for which your district has a complete dataset on its buildings. For many of the example below we have suggested using a 2019 baseline.

Individual Building Goals and Targets

Having absolute energy goals measured as an EUI (as opposed to a percent better than code goal) in place early—before design even begins—is a helpful way to ensure buy in from the design team and manage costs. Use the Advanced Energy Design Guide for Zero Energy K-12 Schools (Table 3-1: Target EUI) to set climate-specific, new construction and major modernization EUI targets and goals. Appendix B in the Advanced Energy Design Guide for Zero Energy K-12 Schools can be utilized to identify the appropriate climate zone.

New Construction:

- Achieve LEED, CHPS, or another broad sustainability goal
- Be energy efficient and achieve a site energy use intensity of 17-25 kBtu/square foot/year
- Be all-electric and have no on-site fossil gas combustion
- Incorporate renewable energy sources to offset annual electricity use
- 5 total air changes per hour (ACH) for high indoor air quality
- Reduce life cycle impacts associated with high embodied carbon materials (like steel and concrete)
- Utilize low global warming refrigerants
- Integrate electric vehicle (EV) charging and fleet infrastructure
- Consider grid harmonization and battery storage

Major Modernization:

- Achieve LEED, CHPS, or some other sustainability goal
- Achieve a site energy use intensity of 25-35 kBtu/square foot/year or better
- 5 total air changes per hour (ACH) for high indoor air quality
- Eliminate on-site gas combustion or have a plan to eliminate gas by a target year signed off by the department director
- Reduce life cycle impacts associated with high embodied carbon materials (like steel and concrete),
- Utilize low global warming refrigerants

Retrofits:

- Improve the site energy use intensity by a minimum of 20%, targeting 50% from a YEAR *(decide on baseline year from benchmarking data. 2019 or 2018 suggested)* baseline.
- Include a written plan for future removal of all gas-combusting equipment, specify low global warming potential equipment and low embodied carbon materials

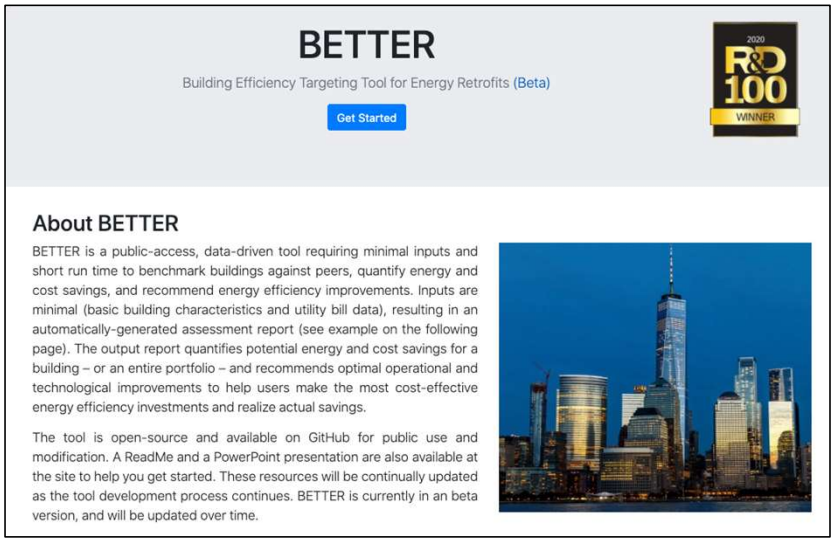
System Replacement:

- Phase out gas infrastructure where possible incorporate efficient, all-electric systems.

Assessing Building Stock

Building Assessment Tools for School Energy Retrofits

TODAY!



BETTER

Building Efficiency Targeting Tool for Energy Retrofits (Beta)

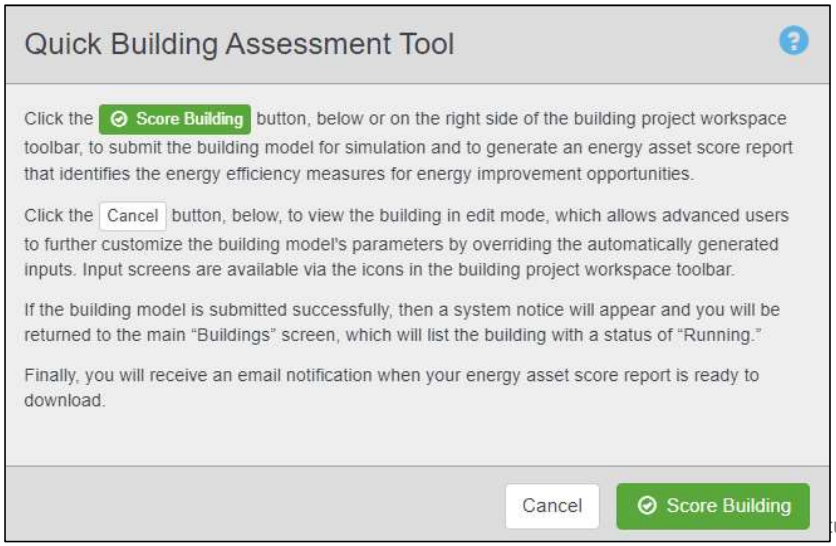
Get Started

2020 R&D 100 WINNER

About BETTER

BETTER is a public-access, data-driven tool requiring minimal inputs and short run time to benchmark buildings against peers, quantify energy and cost savings, and recommend energy efficiency improvements. Inputs are minimal (basic building characteristics and utility bill data), resulting in an automatically-generated assessment report (see example on the following page). The output report quantifies potential energy and cost savings for a building – or an entire portfolio – and recommends optimal operational and technological improvements to help users make the most cost-effective energy efficiency investments and realize actual savings.

The tool is open-source and available on GitHub for public use and modification. A ReadMe and a PowerPoint presentation are also available at the site to help you get started. These resources will be continually updated as the tool development process continues. BETTER is currently in an beta version, and will be updated over time.



Quick Building Assessment Tool

Click the Score Building button, below or on the right side of the building project workspace toolbar, to submit the building model for simulation and to generate an energy asset score report that identifies the energy efficiency measures for energy improvement opportunities.

Click the Cancel button, below, to view the building in edit mode, which allows advanced users to further customize the building model's parameters by overriding the automatically generated inputs. Input screens are available via the icons in the building project workspace toolbar.

If the building model is submitted successfully, then a system notice will appear and you will be returned to the main "Buildings" screen, which will list the building with a status of "Running."

Finally, you will receive an email notification when your energy asset score report is ready to download.

Cancel | Score Building

Building Efficiency Target Tool for Energy Retrofits (BETTER)

Carolyn Szum and Han Li

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

BETTER: A Tool to Achieve Cost-Saving Energy and Emissions Reductions in Public and Private Buildings and Portfolios

2020 R&D 100 WINNER

Carolyn Szum, Energy and Environmental Policy Researcher
Han Li, Scientific Engineering Associate

Energy Energy Technologies Area, Lawrence Berkeley National Laboratory

March 14, 2023

Acknowledgments:

- Funding for BETTER comes from the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) Building Technologies Office (BTO) and the U.S. Agency for International Development (USAID).
- BETTER is being developed under Cooperative Research and Development Agreement (CRADA) No. FP00007338 between the Regents of the University of California Ernest Orlando Lawrence Berkeley National Laboratory and Johnson Controls.

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY
BUILDING TECHNOLOGIES OFFICE

BETTER

USAID FROM THE AMERICAN PEOPLE

BERKELEY LAB

A Key Strategy is Building Energy Efficiency Retrofits

- Yet, 0.5 – 1% retrofit each year.[2]
- In-person audits are costly, $0.08 to $0.24 per ft^2, and can pose health risks.[3]
- Modeling typically requires domain expertise and detailed data on buildings.

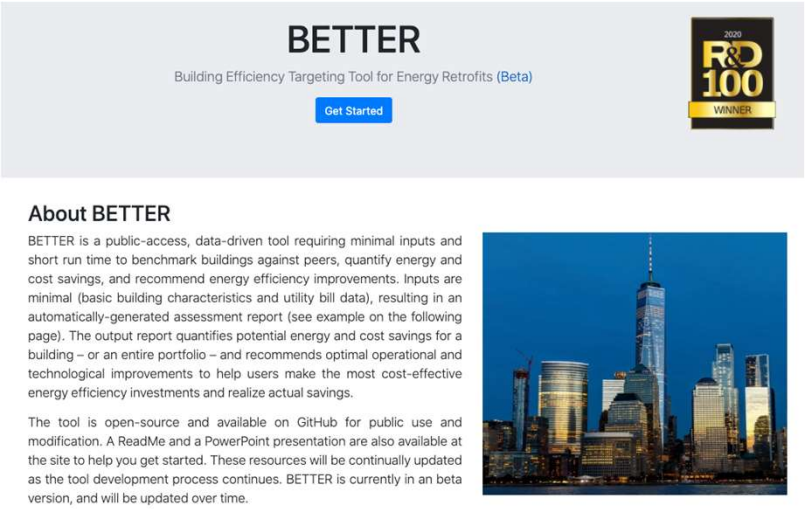
1. The White House. (2021, April). *FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies.* Retrieved May 11, 2021, from https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/
2. Architecture 2030. (2021, May). *Why the Buildings Sector?* Retrieved May 6, 2021, from https://architecture2030.org/buildings_problem_why/
3. The R Group Energy & Consulting. (2021, May 6). *Energy Auditing*. Retrieved from https://thergroupllc.com/services/energy-consulting/energy-auditing-service/

Problem: Audit Costs for Portfolios

No. of Buildings	Square Footage[1]	Total Level I Audit Cost[2]
10	164,000	$ 13,120
100	1,640,000	$ 131,200
1,000	16,400,000	$ 1,312,000
10,000	164,000,000	$ 13,120,000

1. U.S. Energy Information Administration (EIA). (2021, May 3). *Commercial Building Energy Consumption Survey (CBECS)*. Retrieved from 2018 CBECS Survey Data: Preliminary Building Characteristics Information: https://www.eia.gov/consumption/commercial/data/2018/index.php?view=characteristics. Mean U.S. commercial building size is 16,400 ft^2.
2. The R Group Energy & Consulting. (2021, May 6). *Energy Auditing*. Retrieved from https://thergroupllc.com/services/energy-consulting/energy-auditing-service/. NightDog Energy Management. (2021, May 3). Commercial Energy Audit. Retrieved from https://www.nightdogenergy.com/services/commercial-energy-audit/. FIXR. (2021, May 6). How Much Does an Energy Audit Cost? Retrieved from https://www.fixr.com/costs/energy-auditAudit costs range from $0.08 to $0.24 per ft^2.

Building Efficiency Targeting Tool for Energy Retrofits (BETTER)



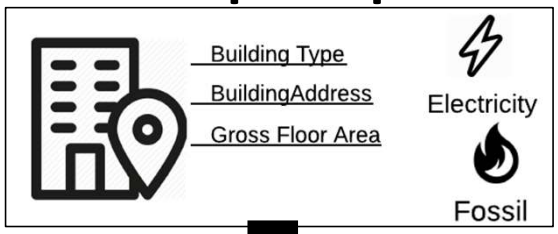
https://better.lbl.gov/

- Replaces level 1 audits.[1]
- Streamlines level 2 audits.
- Uncovers simple no-/low-cost measures to immediately cut energy costs 5-10% portfolio-wide.
- Targets buildings for net zero energy (NZE) through a combination of EE and solar PV.

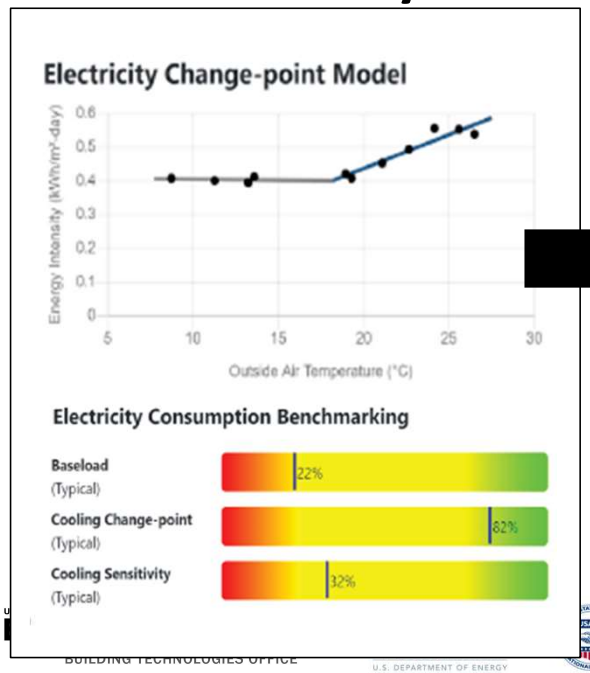
1. Pendray, J. (2020, July 28). *Johnson Controls Declares War on In-Person Audits*. Retrieved from Propmodo: https://www.propmodo.com/johnson-controls-declares-war-on-in-person-audits/

How BETTER Works

1. Simple Inputs



2. Fast Analysis



3. Actionable Portfolio and Building Insights

Annual Savings Potential

Number of Office Buildings:

26

Cost Savings (USD / $):

2,506,975

21.4 %

Electricity Energy/Cost Savings:

21.4 %

GHG Emissions Reduction ($MTCO_2e$)

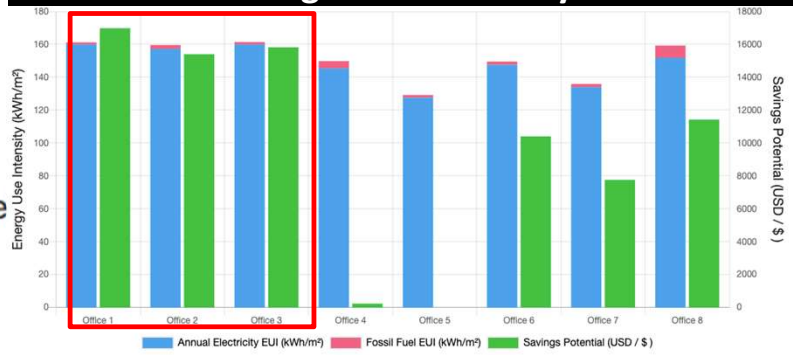
6,749

17.5%

Top Energy Efficiency Recommendations

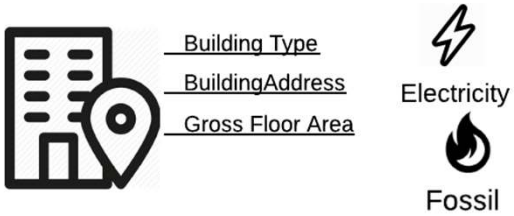
- Reduce Equipment Schedules
- Reduce Lighting Load
- Reduce Plug Loads
- Decrease Heating Setpoints
- Increase Cooling System Efficiency

Building Portfolio Analysis



Advantages

Simple Data Inputs



Short Run Time

Portfolio Insights

Minimal Domain Expertise Required

Operational Energy, CO_2 Savings

Fast, no-/low-cost Interventions

Supports Multilevel Analysis on Buildings and Portfolios

ENERGY STAR® PortfolioManager®

HIGH-LEVEL ANALYSIS

Rate actual operational energy performance against peers

Earn the ENERGY STAR® plaque for superior operational energy performance

BETTER — BUILDING EFFICIENCY TARGETING TOOL FOR ENERGY RETROFITS — U.S. DEPARTMENT OF ENERGY

MID-LEVEL ANALYSIS

Quantify actual operational energy, cost, and emissions reduction potential

Identify efficiency measures to improve operational energy performance

Target buildings for detailed analysis of potential structural improvements using Asset Score

BUILDING ENERGY ASSET SCORE — U.S. DEPARTMENT OF ENERGY

DEEP-LEVEL ANALYSIS

Assess physical and structural energy performance using whole-building simulation

Select cost-effective physical and structural improvements for implementation

LIVE DEMO

CASE STUDY

Prince William County Public Schools (PWCS)

- **2nd Largest School Division in Virginia**
  - 89,000 students, 96 schools

- **1st School Division to Pilot BETTER**
  - 62 elementary schools analyzed
  - 5 million ft^2
  - 60 hours/week*
  - 100% occupancy**
  - Vintages: 1927, 1951 – 2019

Lake Ridge Elementary School, Woodbridge, Virginia

* All of portfolio has a School Age Child Care program (SACC). This runs M-F 6-18:30. Equates to 100% occupancy for 40 hours and 25% occupancy for 20 hours. All sites also have fully operational kitchens to include cooking, serving, cleaning. 100% of occupied square footage is conditioned. Operating hours decreased to M-F 9-10 hours between April 2020 and April 2021 due to pandemic.
** Occupancy levels were 10-30% between April 2020 and April 2021 due to pandemic.

Motivation, Strategy, and Tools

- **Motivation: June 2020 Sustainability Initiative**
  - Net zero energy buildings
  - Renewable energy integration
  - Reduce energy use 20-25% against 2012 levels
- **Strategy and Tools:**
  - EnergyCAP for monthly utility bill tracking
  - ENERGY STAR® Portfolio Manager® for rating and certification
  - BETTER for remote energy analysis and basic auditing
- **How BETTER is Used:**
  - Analyze school portfolio
  - Identify schools with high energy/cost savings for site visits
  - Zero-in on underperforming equipment and systems
  - Conduct 8 site visits
  - Write and implement work orders for 8 schools (mostly RCx)
  - Track energy and cost savings

Set Analysis Parameters

4. Settings

Savings Target

- ○ Conservative
- ○ Nominal
- ◉ Aggressive

Aggressive: The savings goal will be one half standard deviation better than the median savings of the benchmarking peer group.

Benchmark Statistics

- ◉ Default
- ○ Generate

Default: BETTER will automatically use built-in benchmark statistics that match the property type selected in Step 2.

Minimum Model R^2

0.6

Portfolio Savings Analysis

Annual Savings Potential

Number of K-12 School Buildings:

20

Total Floor Area (m^2):

1,592,214

Cost Savings (USD / $):

76,631

3.6 %

Energy Savings (kWh):

737,075

3.8 %

Electricity Energy/Cost Savings:

3.6 %

Fossil Fuel Energy/Cost Savings:

N.A.

GHG Emissions Reduction ($MTCO_2e$):

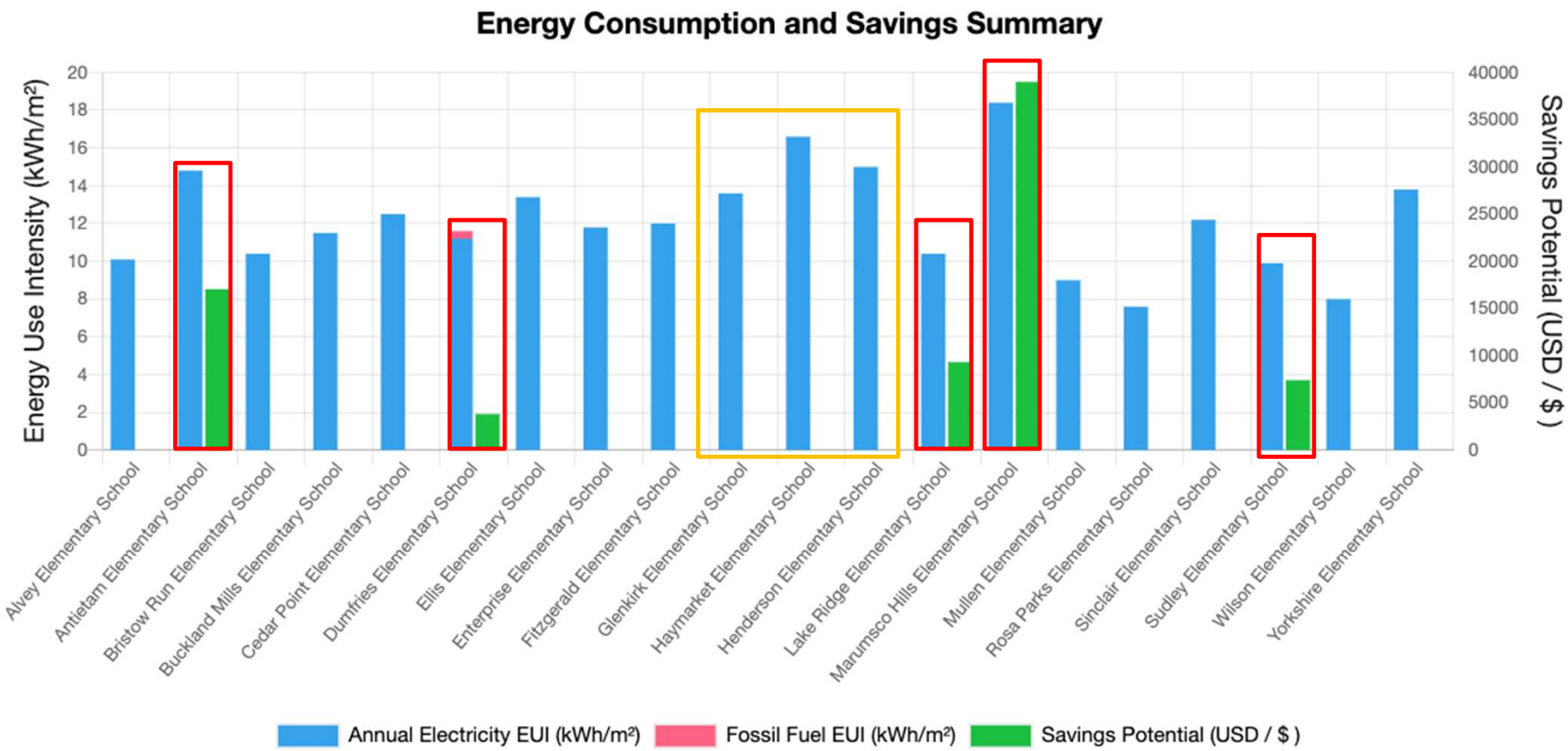
250

3.9%

GHG Emissions Intensity Reduction ($MTCO_2e/m^2$):

0.0002

Identified Schools with High Energy and Cost Savings Potential



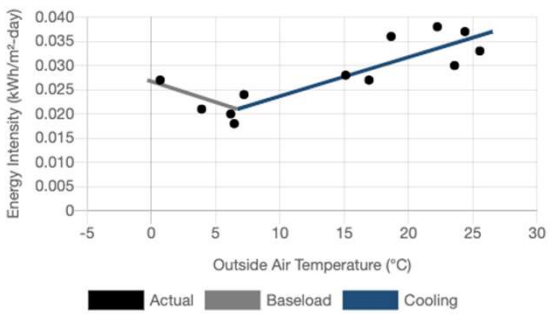
Lake Ridge Elementary School BETTER Analysis

- **Savings Potential:**

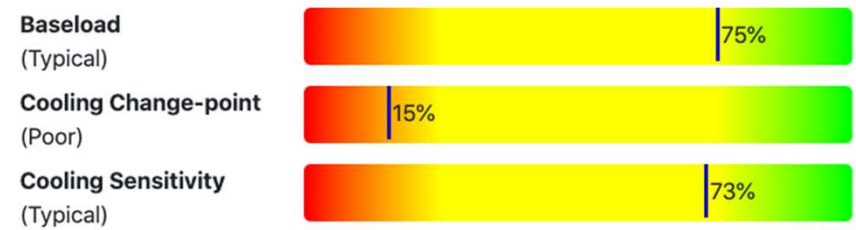
Potential Cost Savings (USD / $):	Potential Energy Savings (kWh):
9,332	81,714
12%	12%

- **Energy Efficiency Opportunities:**

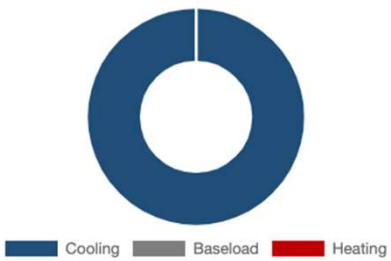
Electricity Change-point Model



Electricity Consumption Benchmarking



Cost Savings Breakdown (USD / $)



Energy Efficiency Recommendations

- Increase Cooling Setpoints
- Reduce Equipment Schedules
- Add/Fix Economizers

Actions Taken and Preliminary Savings

Performed Site Visit and Implemented Work Order in July 2020:

- Increase Cooling Setpoints
  - Increased chilled water supply temperature (and set alarms if the temperature was too low).
- Add/Fix Economizer
  - Fixed two failed energy recovery/outdoor air unit (OAU)
  - Decreased relative humidity in classrooms (which had risen to over 70%).
- Reduce Equipment Schedules
  - Shut off an energy recovery/OAU which was "on" but should have been "off."
- Other*
  - Fixed failed rooftop unit (RTU) air conditioner.
- **Preliminary Savings:**

	Electricity Usage and Costs	
	Kilowatt Hours (kWh)	**U.S. Dollars ($)**
Baseline (08/2019 – 03/2019)	491,760	$49,308
Post-upgrade (08/2020 – 03/2021)	376,960	$36,244
Savings (non-weather normalized)	114,800	$13,064
Savings (weather normalized)	**125,696 (19%)**	**$12,117 (20%)**

* BETTER is a targeting tool and may not identify all potential energy efficiency opportunities. LBNL researchers are continuing to validate BETTER in the field and determine if the logic for identifying energy efficiency measures needs further enhancements.
Operating Hours: Lake Ridge Elementary School ran its HVAC 9-10 hours M-F during pre-and post-upgrade periods.
Occupancy: While occupancy did vary during the pre- and post-upgrade periods, a statistically significant correlation between occupancy and energy could not be identified using regression analysis. Going forward, LBNL will continue to work with PWCS to collect and analyze monthly occupancy data during pre-and post-upgrade periods, along with energy usage data, to normalize savings for occupancy.

Weather Normalized Portfolio Electricity Savings

Elementary School	Electricity Savings	
	Kilowatt hours (kWh)	U.S. Dollars ($)
▪ Antietam Elementary School	55,192	$5,434
▪ Dumfries Elementary School	11,781	$1,151
▪ Glenkirk Elementary School	178,347	$19,223
▪ Haymarket Elementary School	324,553	$33,003
▪ Henderson Elementary School	2,261	$1,180
▪ Lake Ridge Elementary School	125,696	$12,117
▪ Marumsco Hills Elementary School	28,342	$2,849
▪ Sudley Elementary School	20,308	$2,191
Total Savings	**746,480**	**$77,148**
% Savings	**17%**	**17%**

Operating Hours: Schools ran their HVAC systems 9-10 hours M-F during pre-and post-upgrade periods.
Occupancy: While occupancy did vary during the pre- and post-upgrade periods, a statistically significant correlation between occupancy and energy could not be identified using regression analysis. Going forward, LBNL will continue to work with PWCS to collect and analyze monthly occupancy data during pre-and post-upgrade periods, along with energy usage data, to normalize savings for occupancy.

Testimonials and Awards

- "Doing individual analysis and assessment of the monthly and annual energy data for 62 schools is much too time-consuming. We can use BETTER to point to the 10-12 buildings that might have temperature setpoint/scheduling issues so they can be fixed."

- "I wanted to share with you an award we just received for our school division and say thank you for helping us realize our goals and push the envelope in sustainability, energy, and O&M. I look forward to our continued relationship, there is still much more to accomplish!"

  - *Bryan Conrad, Existing Building Commissioning Professional, Energy Education Coordinator, Energy Management, Office of Facilities Services, PWCS, April 2020*

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GreenRibbonSchools

Thank You!

- For Technical Assistance using BETTER, please contact David Landman, EHSC@lbl.gov.

Additional Resources

- BETTER URL: https://better.lbl.gov/
- Analytical engine source code: github.com/LBNL-ETA/BETTER_analytical_engine
- Articles, reports, and training videos: https://better.lbl.gov/news/ and https://better.lbl.gov/how_it_works/

EXTRA SLIDES

Stakeholder Working Group

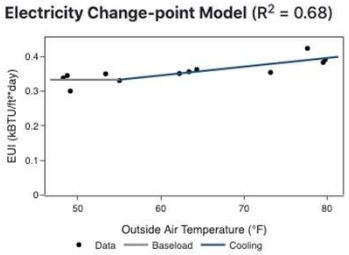
ESCO / Finance	Johnson Controls, esg energy systems group, citi, ERI, EIS
Owners / Managers / Research	Blackstone, amazon, Florida Gulf Coast University, kodelabs, ASHRAE
Market Transformation	IMT Institute for Market Transformation, World Resources Institute, C40 Cities Climate Leadership Group, arc, PowerOptions, NYC Climate Action Alliance
Public Sector	NASA, Judicial Council of California 1926, Prince William County Public Schools Providing A World-Class Education, Department of Energy & Environment Government of the District of Columbia, Cambridge CDD@344 Community Development Department 344 Broadway, City of Berkeley

California State Agency

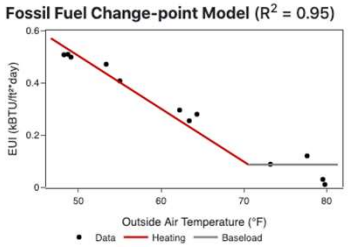
Audit Savings in 450 Buildings
▪ Avoided Level 1 audit costs of $3.28 million. ▪ Streamlined Level 2 audits in 9 sites (saved 6 hours on-site). ▪ Initiated retrofit and RCx projects in 9 public buildings.

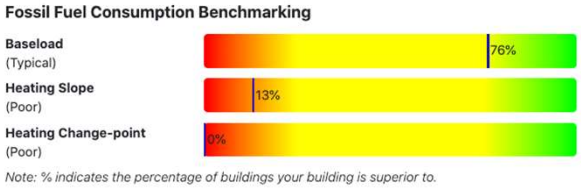
Retrofit and RCx Savings in 9 Buildings	
Annual Electricity Savings	4,236,860 kWh
Annual Natural Gas Savings	68,700 therms
Annual Cost Savings	$834,350
Payback Period	3.4 years
Annual Emissions Reductions	2,271 tCO_2e
Equivalent to the CO_2 sequestered by planting 37,551 new trees annually	

Building 50-A1 Electricity Change-point Models and Benchmarks



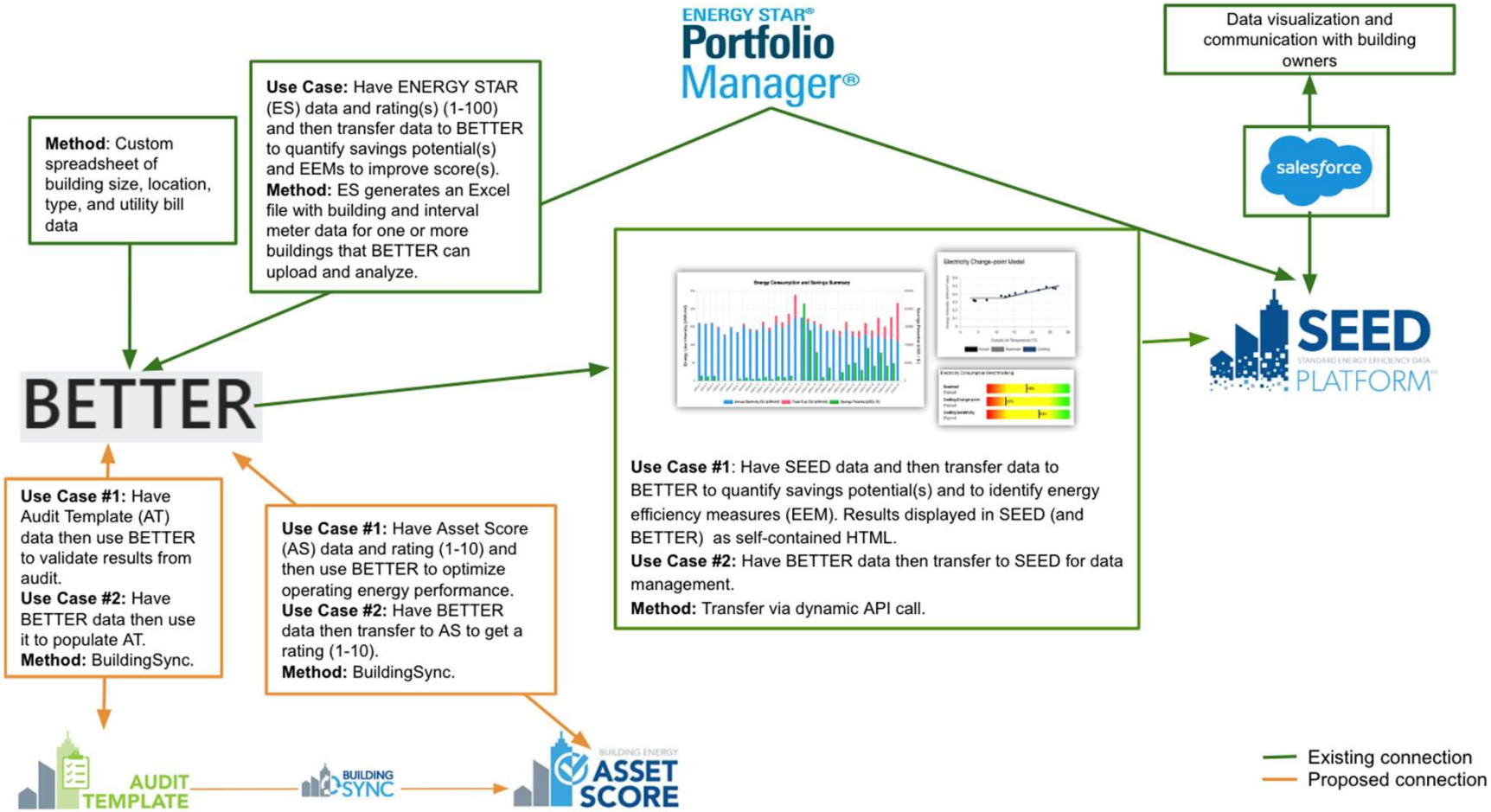
Building 50-A1 Fossil Fuel Change-point Models and Benchmarks



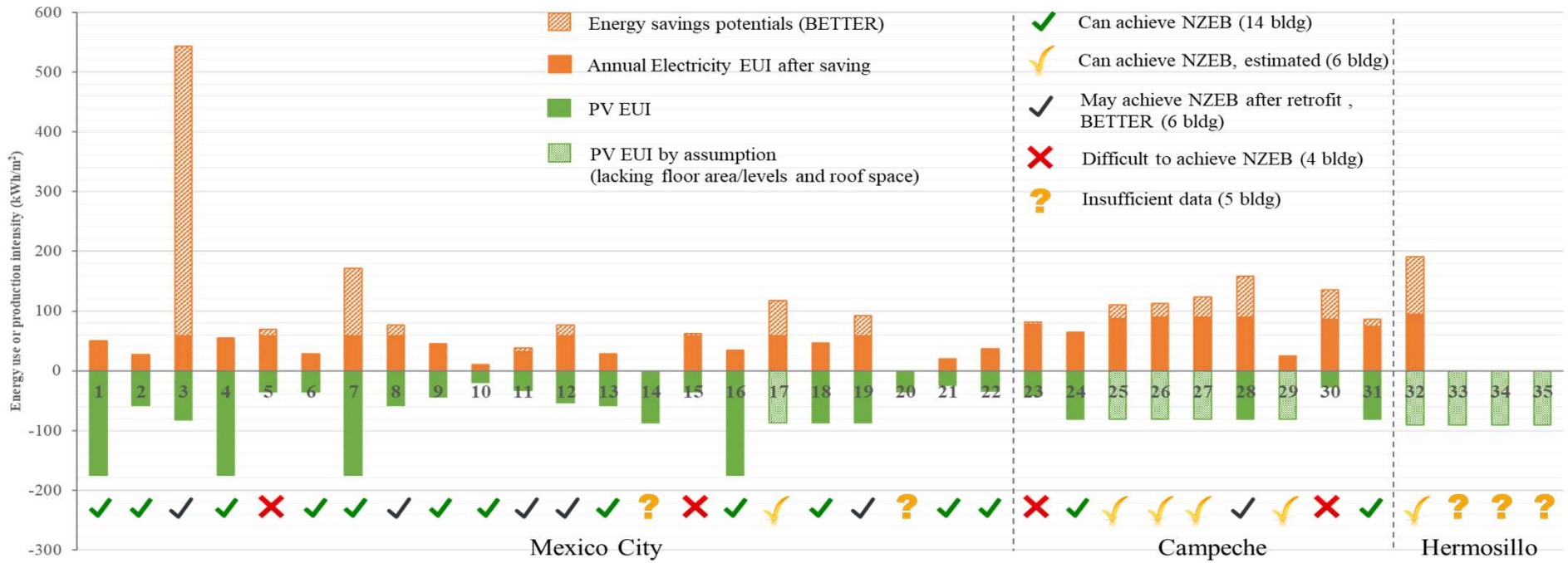


"BETTER improved our workflow efficiency, in relation to both time and cost of analysis, by giving visibility of likely energy saving opportunities prior to visiting geographically remote locations across the State of California." *Sustainability Supervisor for California State Agency*

Equipped for Data and Analytics Transfer Among U.S. DOE Tools



New Feature: Net Zero Energy Building (NZEB) Analysis at Scale



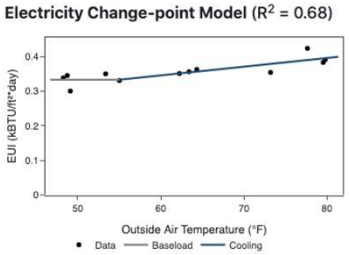
1	2	3	4	5	6	7	8	9	10	11	12
J. BOTANICO	BEA - SEDUVI - CDMX	PPMA	A. IZTACALCO - DGOP	BEA - Edificio Nuevo - CDMX	SEDECO 298	SOBSE DGOP	A. GAM	SAF - OFICINAS	SEDECO 299	A. CUAUHTEMOC	A. VENUSTIANO CARRANZA
13	14	15	16	17	18	19	20	21	22	23	24
A. IZTACALCO - CIVICO	A. IZTAPALAPA - OFICINAS	SAF - GOBIERNO	JARDIN 3RA EDAD	BEA - Proyecto Metro - CDMX	BEA - Finanzas - CDMX	SIBISO	VALLEJO 5	SEDEMA T.8	ILIFE CDMX	BEA - SAIG - CP	BEA - SEDESYH - CP
25	26	27	28	29	30	31	32	33	34	35	
BEA - SDS - CP	BEA - FISCAM - CP	BEA - SEP - CP	BEA - SEDUOPI - CP	BEA - SDE - CP	BEA - Palacio de Gobierno - CP	BEA - Seguridad - CP	BEA - Conservation of CEDES - HM	BEA - Aquarium of CEDES - HM	BEA - Garden of CEDES - HM	BEA - Central Offices CEDES - HM	

California State Agency

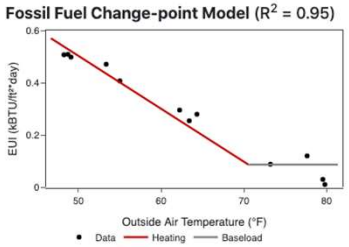
Audit Savings in 450 Buildings
▪ Avoided Level 1 audit costs of $3.28 million. ▪ Streamlined Level 2 audits in 9 sites (saved 6 hours on-site). ▪ Initiated retrofit and RCx projects in 9 public buildings.

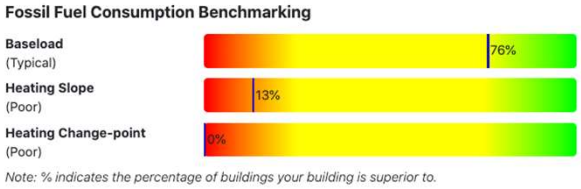
Retrofit and RCx Savings in 9 Buildings	
Annual Electricity Savings	4,236,860 kWh
Annual Natural Gas Savings	68,700 therms
Annual Cost Savings	$834,350
Payback Period	3.4 years
Annual Emissions Reductions	2,271 tCO_2e
Equivalent to the CO_2 sequestered by planting 37,551 new trees annually	

Building 50-A1 Electricity Change-point Models and Benchmarks



Building 50-A1 Fossil Fuel Change-point Models and Benchmarks





"BETTER improved our workflow efficiency, in relation to both time and cost of analysis, by giving visibility of likely energy saving opportunities prior to visiting geographically remote locations across the State of California." *Sustainability Supervisor for California State Agency*

Delivering Efficiency Retrofits to Underserviced Neighborhoods

"BETTER offers a possibility of delivering efficiency retrofits in underserved markets faster and cheaper by orders of magnitude."

Tom Strumolo, Founder, CEO, Energy General LLC

- Making a list of priority buildings that need retrofits.
- Starting with older buildings with oil and gas heating systems.
- Focusing on underserviced neighborhoods in New England.
- Working from the grass roots level up, not from the top down.
- Can register for a free BETTER assessment at https://rapidretrofits.tumblr.com.

Estimated Market Size

U.S. Commercial Buildings

97B ft^2
6M Buildings

Total Available Market

75% Built Before 2000

73B ft^2
4.5M Buildings

Serviceable Available Market

Use BETTER 2022 – 2026

7B ft^2
450,000 Buildings

Market Share (10%)

1. U.S. Energy Information Administration (EIA). (2021, May 3). *Commercial Building Energy Consumption Survey (CBECS)*. Retrieved from 2018 CBECS Survey Data: Preliminary Building Characteristics Information: https://www.eia.gov/consumption/commercial/data/2018/index.php?view=characteristics.

Environmental and Social Impact

- Contribute to the Biden Administration's goal to **retrofit 2 million commercial buildings and homes**.[1]
- Sequester CO_2 emissions equivalent to **planting ~300 million new trees** by 2026.[2]
- Avoid **50-75% of embodied GHG** emissions.[3]
- Help **preserve energy efficiency jobs** and accelerate the **post-COVID-19 economic recovery**.

1. NAHB Now. (2021, March 31). *Biden's $2 Trillion Infrastructure Plan Proposed More than $200 Billion for Housing, Commercial Buildings.* Retrieved from https://nahbnow.com/2021/03/bidens-2-trillion-infrastructure-plan-proposes-more-than-200-billion-for-housing-commercial-buildings/
2. U.S. commercial buildings consume approximately 6.963 quads of total site energy and emit 685 MtCO2e annually from electricity and natural gas [7-9]. Approximately 75% of U.S. commercial buildings were built before 2000 and are in need of a retrofit [7]. By 2026, BETTER will be used by approximately 10% of the U.S. commercial building floorspace requiring retrofit (or 430,000 buildings), achieving 15% energy savings per square foot annually. Using those assumptions, estimates yield 0.19 quads of site energy savings and projected emissions reductions of 18.5 MtCO2e by 2026 in the United States. [7-9]. For full calculations, contact Carolyn Szum ccszum@lbl.gov at Berkeley Lab.
3. New Buildings Institute. (2021, May 8). *Should I Stay or Should I Go: The Embodied Carbon of Buildings.* Retrieved from https://www.imt.org/should-i-stay-or-should-i-go-the-embodied-carbon-of-new-and-existing-buildings/

Testimonials

"Having a remote tool like BETTER that works at the portfolio level is unique in the marketplace." *Don Anderson, Chief Sustainability Officer, Operating Partner*

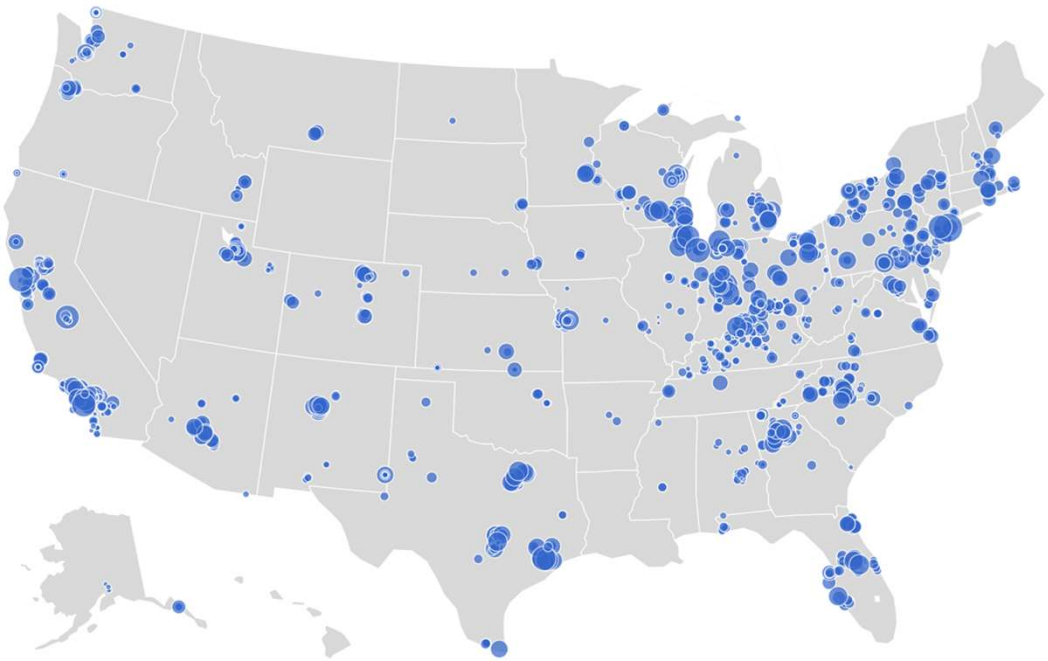
"Really impressive tool. BETTER goes a lot deeper than what we do with remote analytics." *David Bonn, Vice President, Client Services Energy and Sustainability*

"I'm convinced that BETTER is an important evolutionary step for the U.S. Department of Energy and the broader market." *Chris Pyke, Senior Vice President, Product*

K-12 SCHOOL STATISTICS

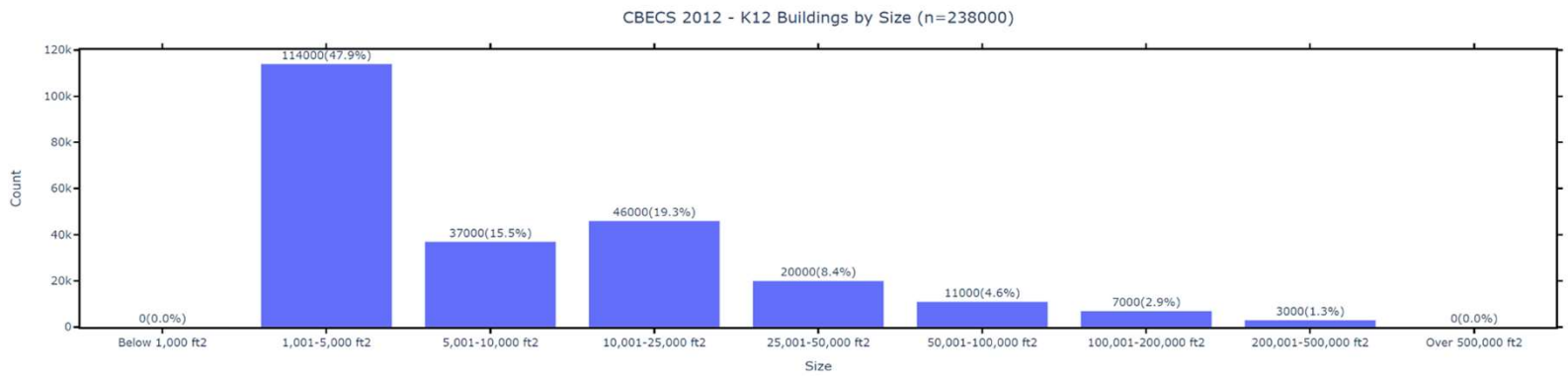
1a. K-12 School Database Summary

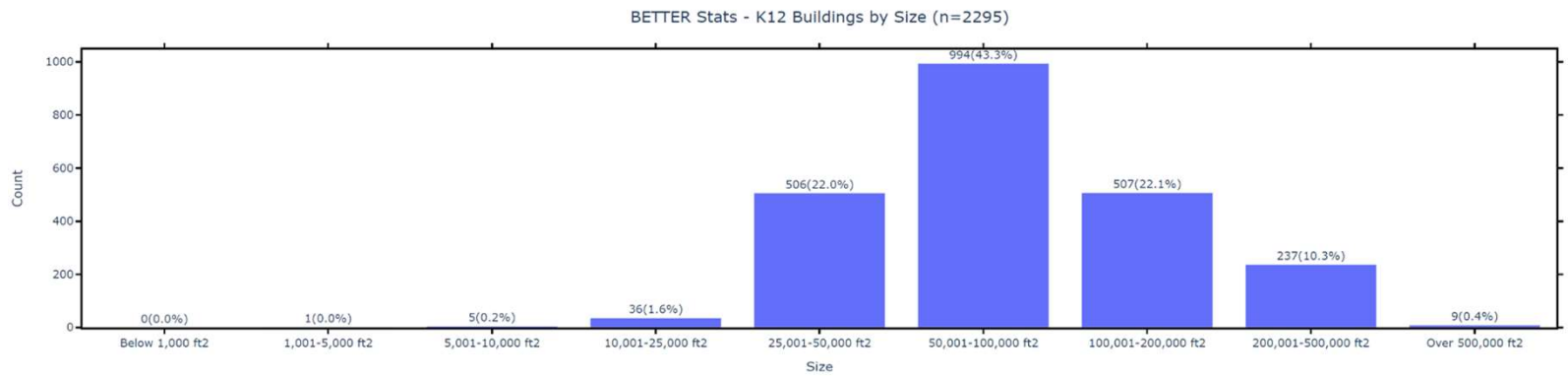
- # of K-12 schools: 2295
- Total square footage (ft^2) of K-12 schools: 238,218,099



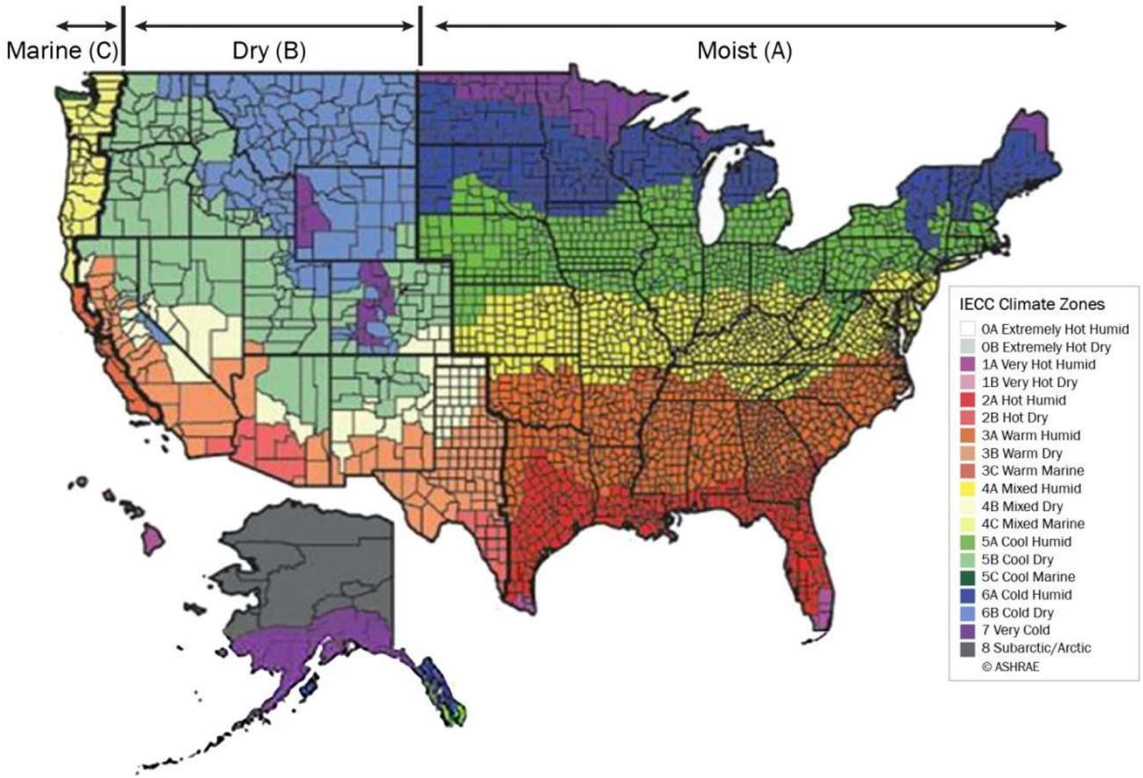
1b. K-12 School Database: Size Distribution

- K-12 School Size Distribution (ft^2)
  - CBECS 2012 vs BETTER Statistics





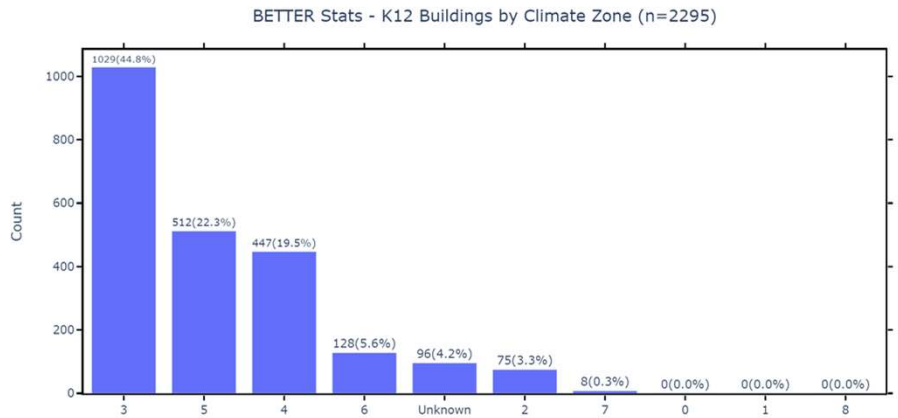
Climate Zone Map from IECC 2021

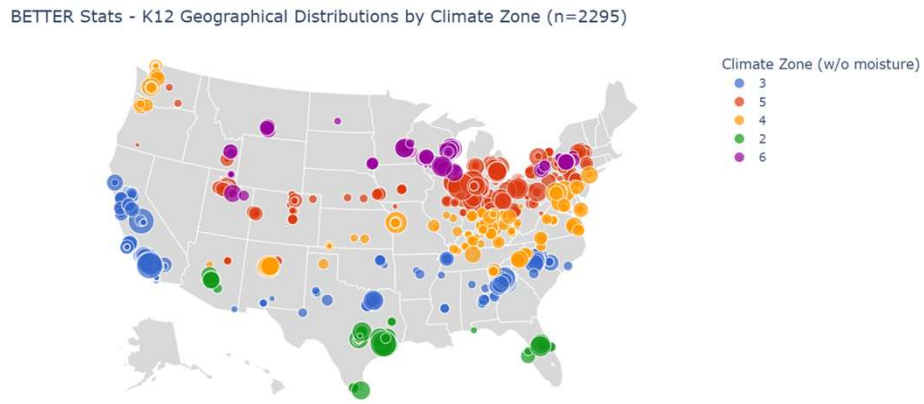


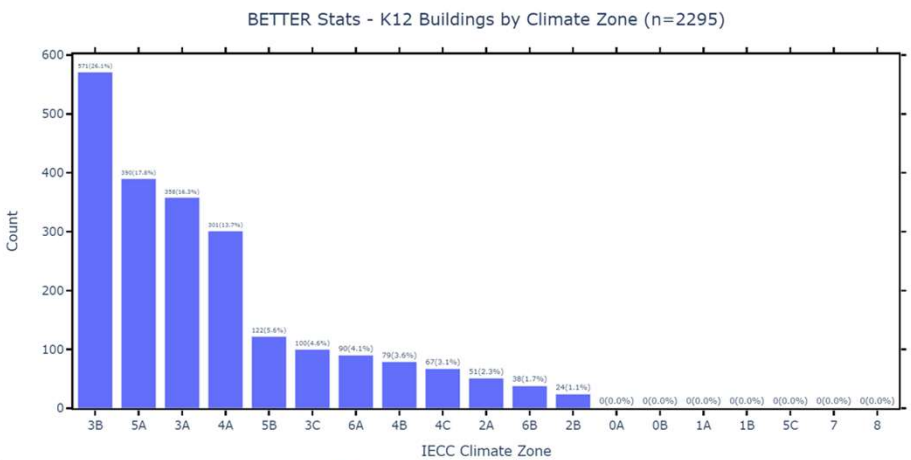
https://basc.pnnl.gov/images/climate-zone-map-iecc-2021

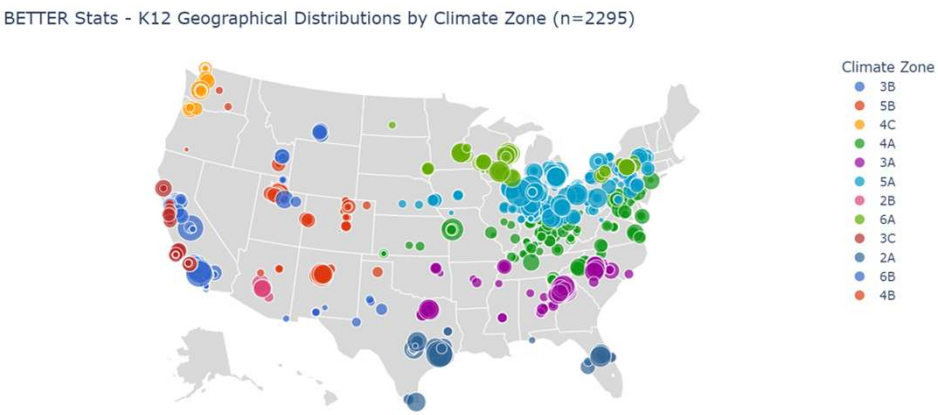
1b. K-12 School Database: Climate Zone Distribution

- K-12 School: Climate Zone Distribution







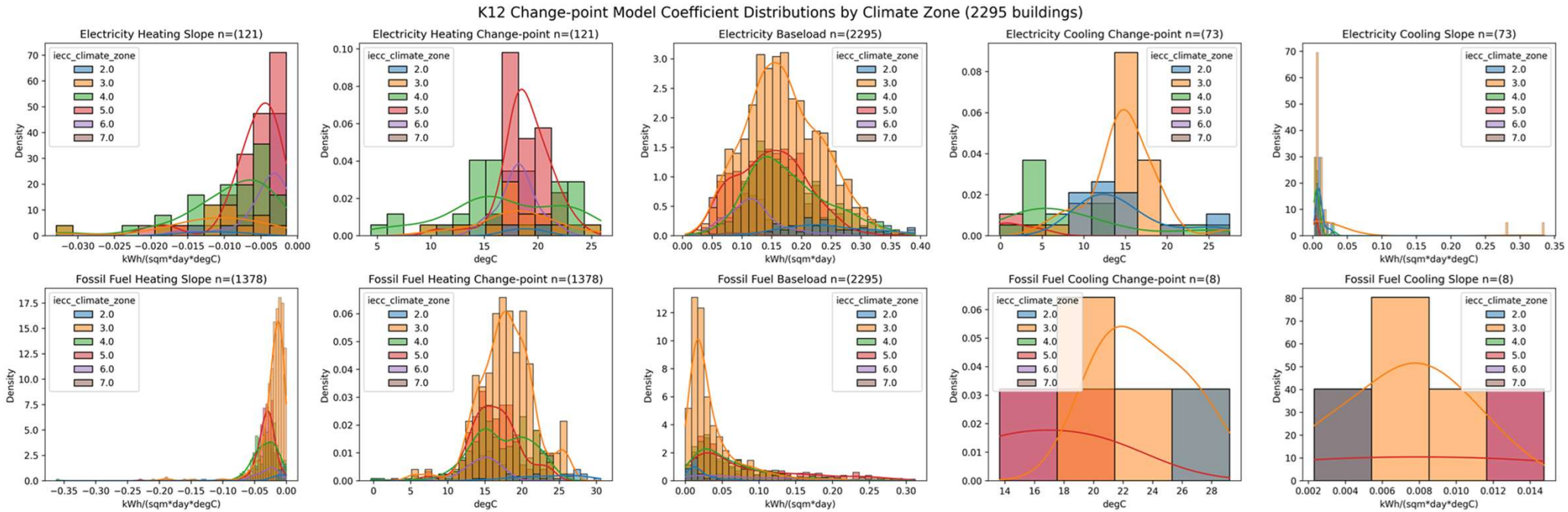


K-12 Schools distribution by IECC 2021 climate zone

K-12 Schools: U.S. Reference Benchmark Statistics Development

Change-point model coefficients distribution breakdown by climate zone:

- Sample size is relatively small to break down the distributions by climates zones (there are less than 30 data points for some coefficients in some climate zones).
- As additional data becomes available, the team will assess different distributions by climate zones and potentially identify unique U.S. reference benchmark statistics by climate zones.

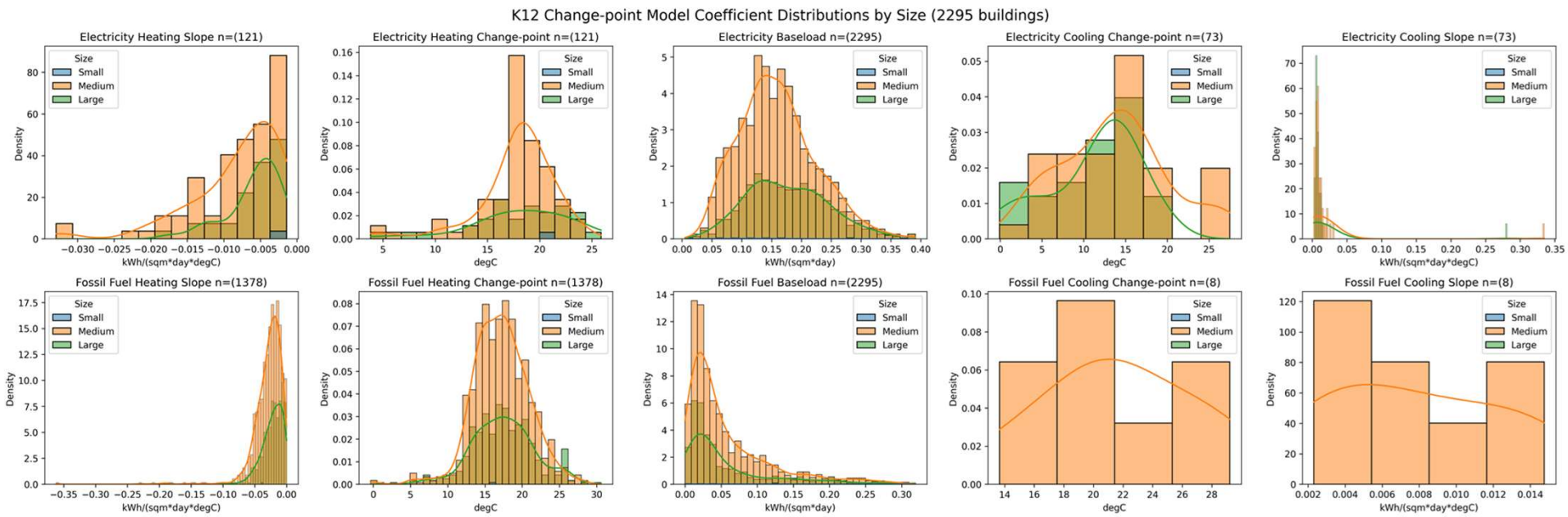


K-12 Schools: U.S. Reference Benchmark Statistics Development

Change-point model coefficients distribution breakdown by building size

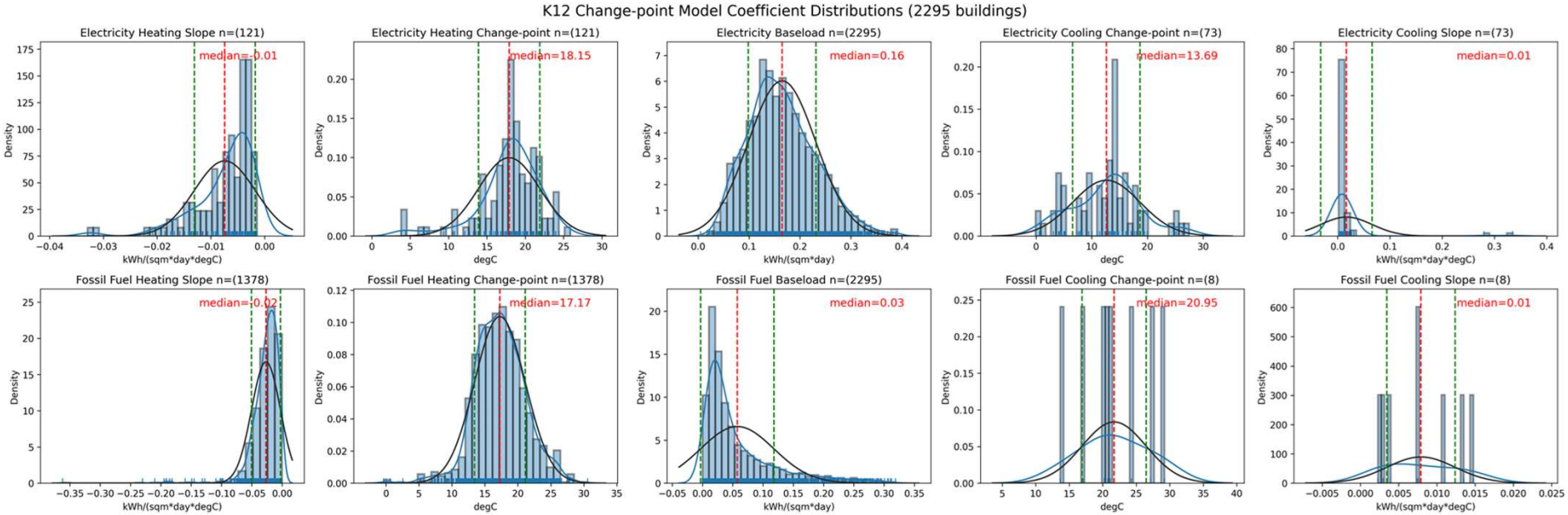
- Sample size is relatively small to break down the distributions by building sizes (there are less than 30 data points for some coefficients)
- As additional data becomes available, the team will assess different distributions by climate zones and potentially identify unique U.S. reference benchmark statistics by sizes.

Building size cutoffs:
Small: area < 1000 m^2
Medium: 1000 m^2 <= area < 10000 m^2
Large: area >= 10000 m^2



K-12 Schools: Change-point Model Coefficient Distributions and Final U.S. Reference Benchmarks Statistics

The following figures show the change-point model coefficient distributions used by BETTER



real data

normal distributions fitted from data

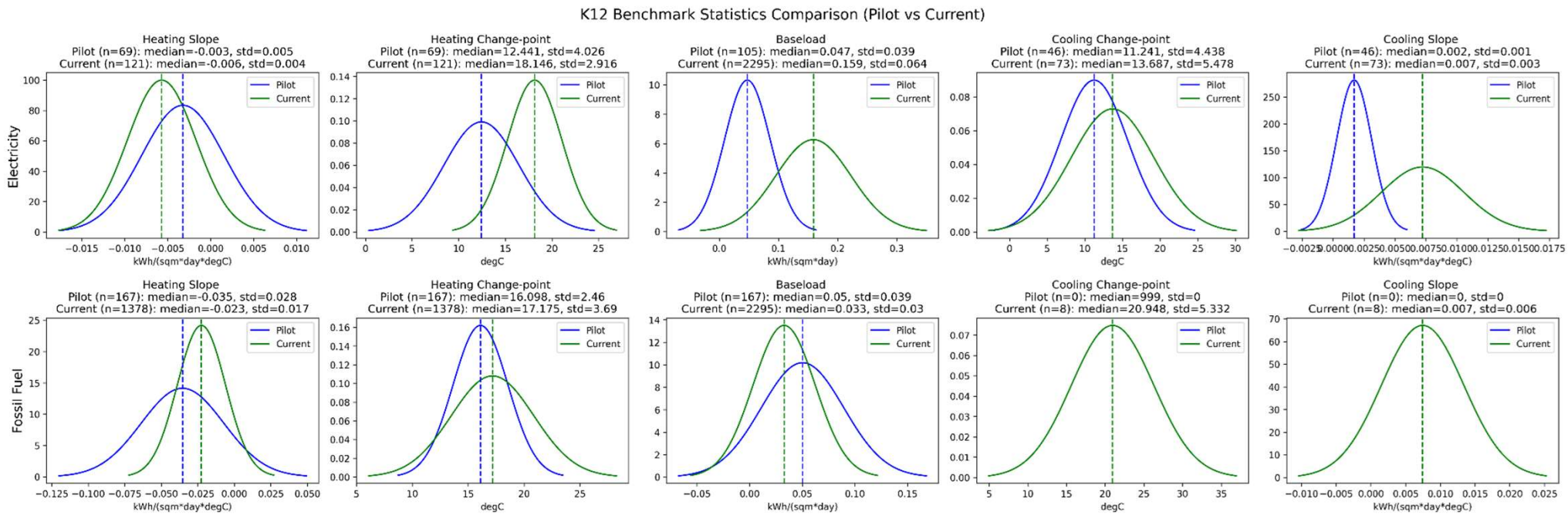
Sample median

One standard deviation from median

Note: For fossil fuel cooling change-point and slope, the sample size is less than 30, which suggests fossil fuel is not typically used for cooling in U.S. K-12 schools. However, the team will continue to add data to these distributions, after available, to increase the representativeness of the statistics.

K-12 Schools: Pilot Phase Compared to Current U.S. Reference Benchmarks Statistics

The following figures show the change-point model coefficient distribution comparison between the BETTER pilot phase and the current phase (Starting March 2022).

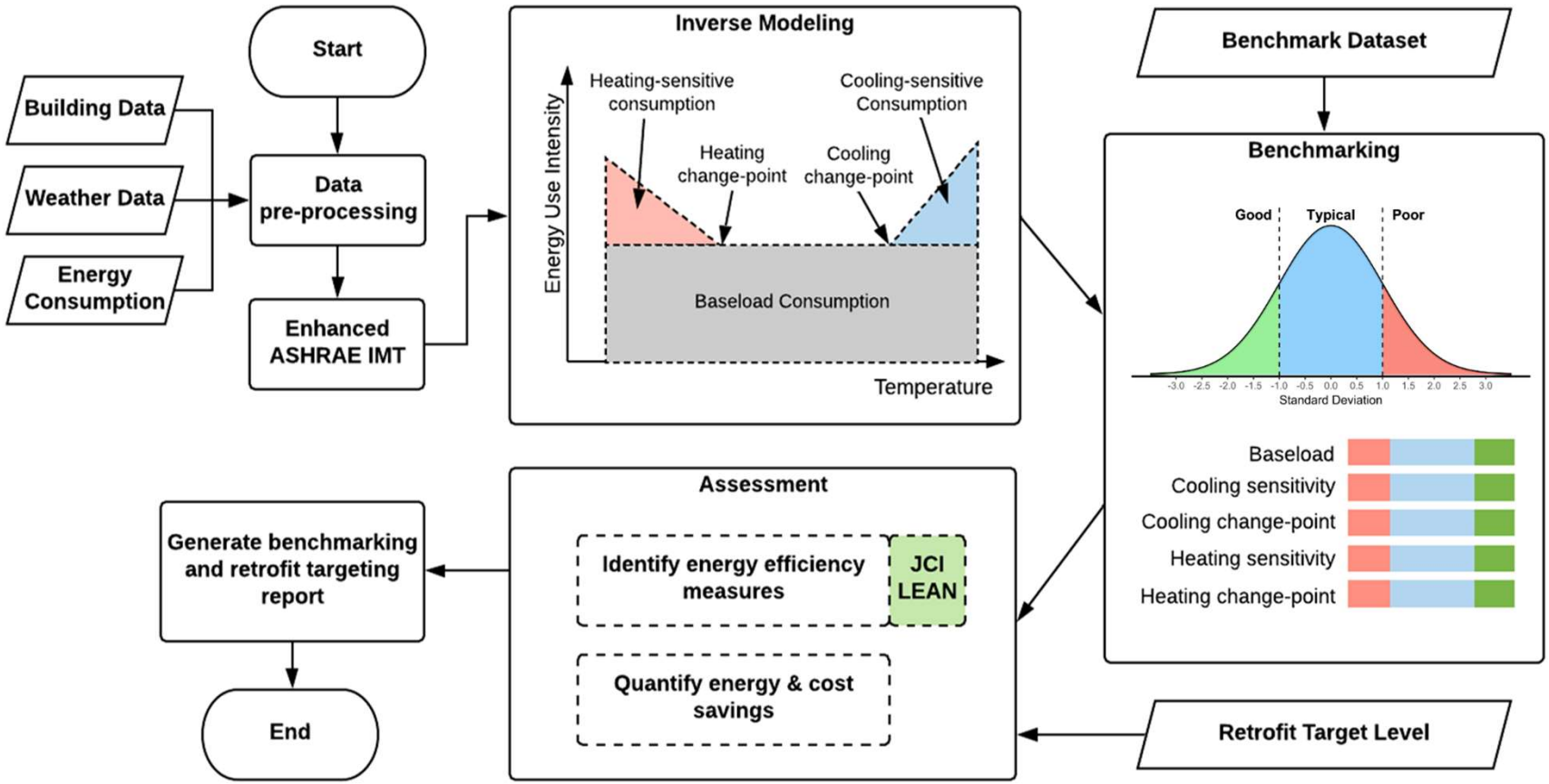


Note: the current statistics were derived in March 2022

APPENDIX

DATA FRAMEWORK AND ANALYSIS METHODOLOGY

Overall Workflow



Property Information

SI Units (meters, kWh, °C)

Select Currency * : US dollar (USD / $)

Gross Floor Area Unit: sq. meters

Building ID*	Building Name*	Location*	Gross Floor Area (Excluding Parking)*	Primary Building Space Type*
1	Office 1	Miami, FL	4982	Office
2	Office 2	Houston, TX	4982	Office
3	Office 3	Atlanta, GA	4982	Office
4	Office 4	Los Angeles, CA	4982	Office
5	Office 5	Las Vegas, NV	4982	Office
6	Office 6	San Francisco, CA	4982	Office
7	Office 7	Baltimore, MD	4982	Office

1. Unit System
   - Select Imperial Units (feet, kBtu, °F) or SI Units (meters, kWh, °C)
2. Building Location (City, State/Province, Zip, Country)
   - Used to find weather data
3. Gross Floor Area (Exclude Parking)
   - Used to normalize consumption
4. Primary Building Space Type
   - Used for benchmarking

Monthly Energy Consumption and Cost Data

- Minimum of 12 consecutive months of energy consumption data is required.
- Gather all electricity and fossil fuel consumption data from utility bills for each billing period.
- Energy cost is optional. If no energy cost is entered, BETTER will use a default cost per unit.
- Average outdoor air temperature is optional. If no weather data is entered, BETTER will use National Oceanic and Atmospheric Administration (NOAA) data.*

Building ID*	Billing Start Dates*	Billing End Dates*	Energy Type*	Energy Unit*	Energy Consumption*	Energy Cost	Average Outdoor Air Temperature
1	1/1/2017	1/31/2017	Electric - Grid	kWh (thousand Watt-hours)	66338		
1	2/1/2017	2/28/2017	Electric - Grid	kWh (thousand Watt-hours)	55528		
1	3/1/2017	3/31/2017	Electric - Grid	kWh (thousand Watt-hours)	64180		
1	4/1/2017	4/30/2017	Electric - Grid	kWh (thousand Watt-hours)	62067		
1	5/1/2017	5/31/2017	Electric - Grid	kWh (thousand Watt-hours)	69730		

* NOAA weather data may not be available for all locations. An error message will show on the BETTER analysis reports to prompt a user to enter average outdoor air temperature data for a given location and/or billing period as appropriate.

Weather Data

- **Data Source:** National Oceanic and Atmospheric Administration (NOAA)
- **Time interval:** Sub-hourly
- **Input:** Address, billing periods start and end dates

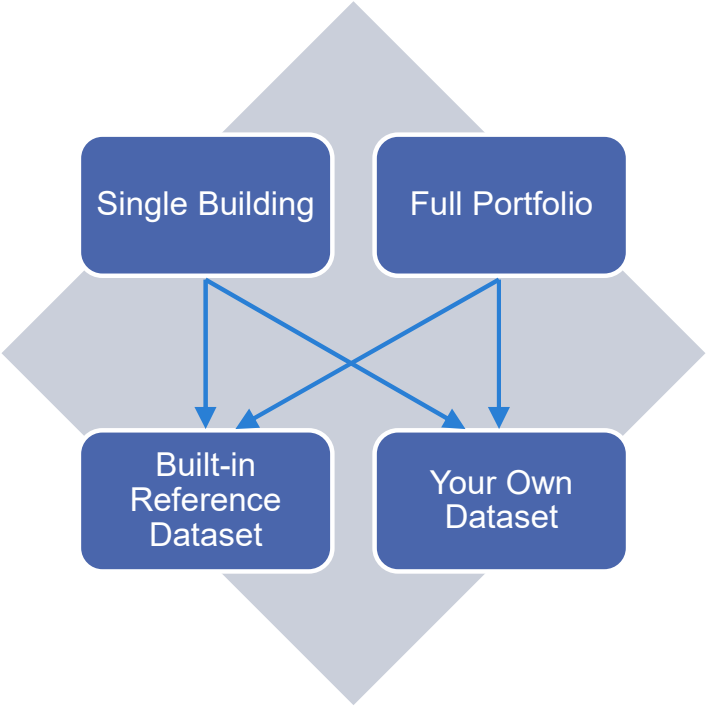
USAF	WBAN	StationID	STATIONNAME	CTRY	STATE	ICAO	LAT	LON	ELEV_M	BEGIN	END	EndYear
450320	99999	450320-99999	TA KWU LING	CH			22.533	114.15	13	19921204	20171117	2017
450350	99999	450350-99999	LAU FAU SHAN	CH			22.467	113.983	35	20040713	20171117	2017
450390	99999	450390-99999	SHA TIN	CH			22.4	114.2	8	20040713	20171117	2017
450440	99999	450440-99999	CHEUNG CHAU	CH			22.2	114.017	79	20020313	20171117	2017
450450	99999	450450-99999	WAGLAN ISLAND	CH			22.183	114.3	60	20040122	20171117	2017
470311	99999	470311-99999	MEILAN	CH		ZJHK	19.935	110.459	22.9	20040706	20171117	2017
470312	99999	470312-99999	ZHENGDING	CH		ZBSJ	38.281	114.697	71	20040706	20171117	2017
501360	99999	501360-99999	MOHE	CH			52.967	122.533	438	19730101	20171117	2017
503530	99999	503530-99999	HUMA	CH			51.733	126.633	175.6	19560820	20171117	2017
504340	99999	504340-99999	TULIHE	CH			50.45	121.7	733	19570531	20171117	2017
504680	99999	504680-99999	AIHUI	CH			50.25	127.45	166	19610801	20171117	2017
505270	99999	505270-99999	HAILAR	CH			49.25	119.7	650	19560820	20171117	2017
505480	99999	505480-99999	XIAO'ERGOU	CH			49.2	123.717	288	19570531	20171117	2017
505570	99999	505570-99999	NENJIANG	CH			49.167	125.233	243	19560820	20171117	2017
505640	99999	505640-99999	SUNWU	CH			49.433	127.35	235	19560820	20171117	2017
506030	99999	506030-99999	XIN BARAG YOUQI	CH			48.683	116.817	556.7	19600101	20171117	2017
506320	99999	506320-99999	BUGT	CH			48.767	121.917	739	19560820	20171117	2017
506560	99999	506560-99999	LONG-ZHEN	CH			48.65	126.667	305	19610801	20130120	2013
506580	99999	506580-99999	KESHAN	CH			48.05	125.883	237	19570601	20171117	2017
507270	99999	507270-99999	ARXAN	CH			47.167	119.933	997	19560820	20171117	2017
507450	99999	507450-99999	SANJIAZI	CH		ZYQQ	47.24	123.918	145.4	19560820	20171117	2017
507560	99999	507560-99999	HAILUN	CH			47.45	126.867	248	19560820	20171117	2017
507740	99999	507740-99999	YICHUN	CH			47.7	128.833	259.1	19570601	20171117	2017
507880	99999	507880-99999	FUJIN	CH			47.233	131.983	65	19560820	20171117	2017
508440	99999	508440-99999	TAILAI	CH			46.4	123.45	150	19610801	20171117	2017
508540	99999	508540-99999	ANDA	CH			46.383	125.317	150	19560820	20171117	2017
508880	99999	508880-99999	BAOQING	CH			46.317	132.183	83	19570602	20171117	2017

Dataset and Property Types

- Benchmark a single building or your full portfolio.

- Two modes of use:
  - Benchmark against a built-in reference dataset.*
  - Benchmark against your own portfolio.

- U.S. built-in benchmarking datasets are for:
  - U.S. Offices, U.S. K-12 schools *(current)*
  - U.S multifamily residential *(forthcoming)*



*At this time, the "reference" benchmark statistics for U.S. offices and K-12 schools are not perfectly representative of the U.S. national stock because the statistics were *not* developed from the U.S. Energy Administration (EIA) Commercial Building Energy Consumption Survey (CBECS) dataset (which is representative of the U.S. national stock) but rather from *training datasets developed based on voluntary contributions from U.S. industry* that are not fully representative of the U.S. national stock in terms of characteristics such as size and climate zone distribution. We are working to expand these training datasets, and hence improve associated "reference" benchmark statistics, so they are more representative of the U.S. national stock. This includes expanding the training data sets to include: *at least 30 data points for each of the 10 BETTER model coefficients for each of the eight CBECS size categories in each of the eight International Energy Conservation Code (IECC) climate zones in the United States (and possibly for each of the relevant subtypes A, B, and C in these zones). To contribute anonymous data to this effort, please email support@better.lbl.gov.*

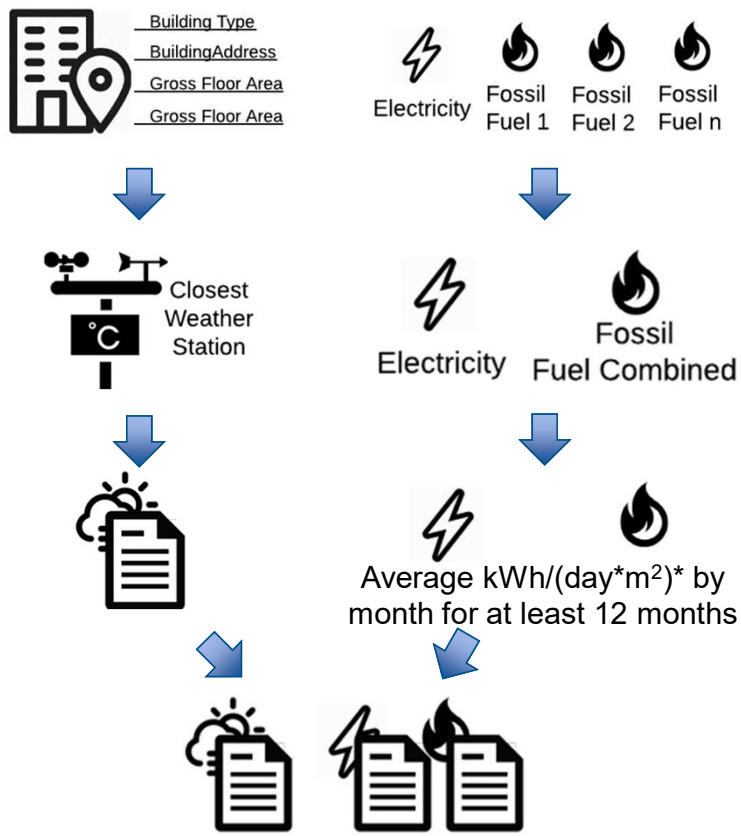
Automatic Data Pre-Processing

- Read building information (address, space type, gross floor area, etc.) and monthly energy usage and cost data

- Search for closest weather station.
- Combine different types of fossil fuel consumptions, and convert energy consumption unit to kWh.*

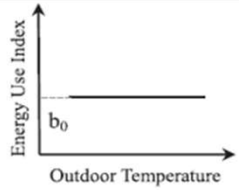
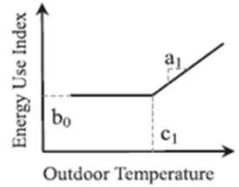
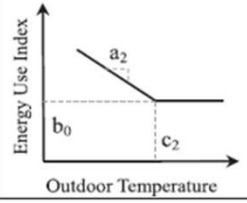
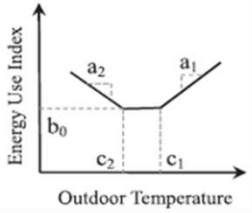
- Download sub-hourly weather file from NOAA ftp.
- Normalize energy consumption to show average kWh/(day*m^2)* by month for at least 12 months.*

- Align and aggregate weather data with energy consumption data (arbitrary billing periods).

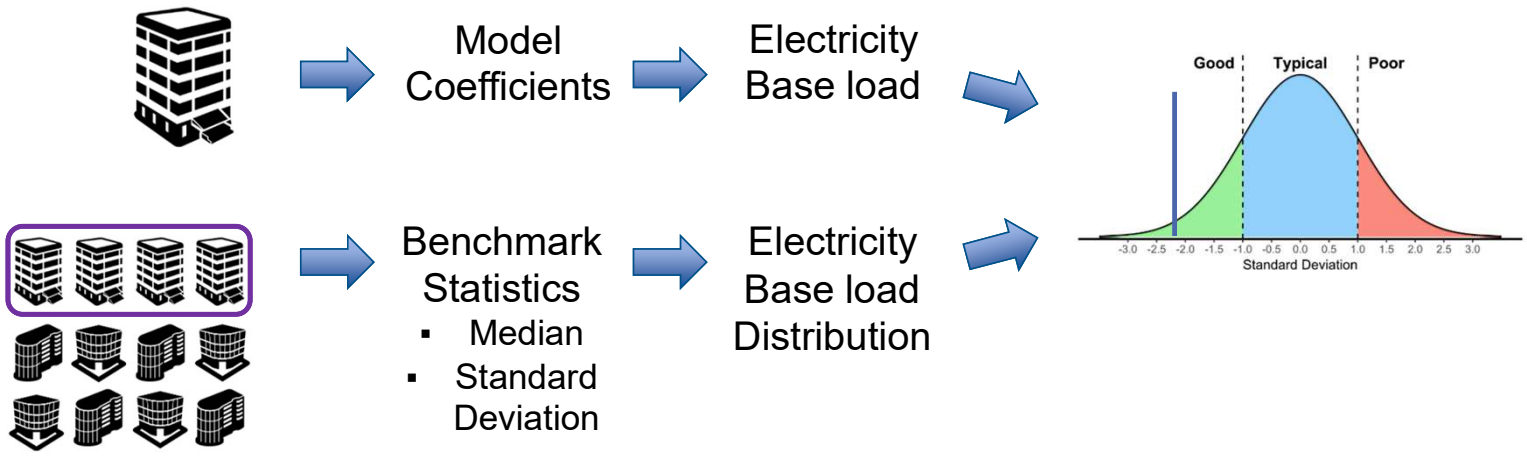


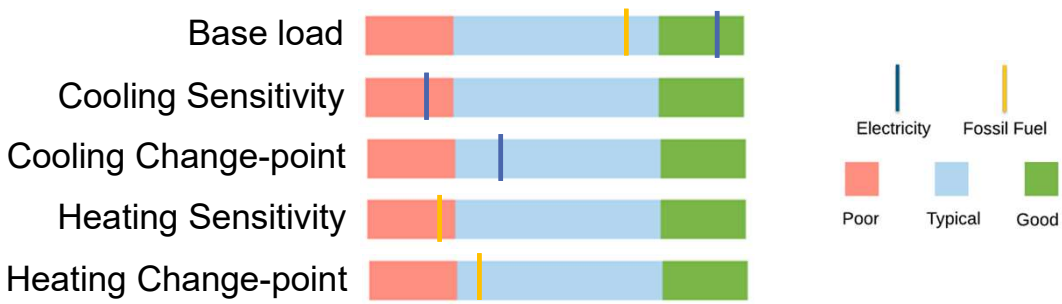
* BETTER uses kWh and m^2 as common units for calculations, but may display savings in output reports in kWh/m^2 or kBtu/ft^2, depending on the unit system selected in spreadsheet upload template.

Change-Point Modeling

Model Type	Schematic Plot	Model Coefficient					Interpretation
		Baseload (b0)	Cooling Sensitivity (a1)	Cooling Change-point (c1)	Heating Sensitivity (a2)	Heating Change-point (c2)	
1P Model		X					(1). The building is not heated or cooled. (2). The heating and cooling system of the building only consumes a very small amount of the total energy.
3P Cooling Model		X	X	X			(1). The cooling system of the building starts to operate when the outdoor air temperature goes beyond the change-point. (2). The steeper the slope, the higher energy consumption growth as outdoor air temperature rises.
3P Heating Model		X			X	X	(1). The heating system of the building starts to operate when the outdoor air temperature drops below the change-point. (2). The steeper the slope, the higher energy consumption growth as outdoor air temperature drops.
5P Model		X	X	X	X	X	The building's cooling and heating systems are driven by the same fuel type. As the outdoor air temperature drops below a certain point, the heating system starts to operate. As the outdoor air temperature rises above a certain point, the cooling system starts to operate.

Benchmark Coefficients



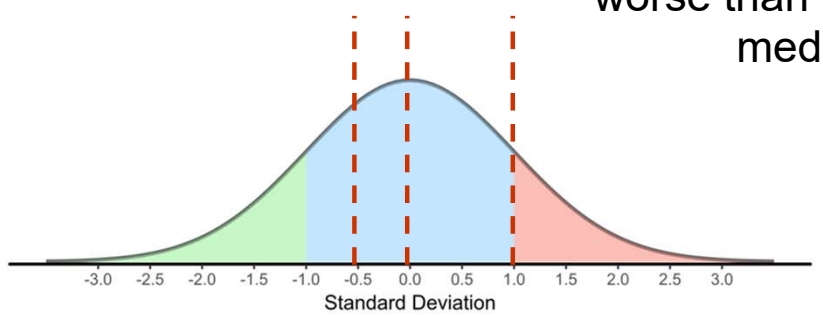


Energy Efficiency Targeting

Step 1. Specify energy efficiency target

Aggressive (½ a standard deviation better than the dataset median)

Conservative (1 standard deviation worse than the dataset median)

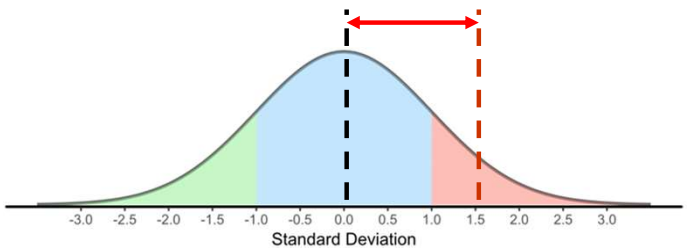


Nominal (equal to the dataset median)

Energy Efficiency Targeting

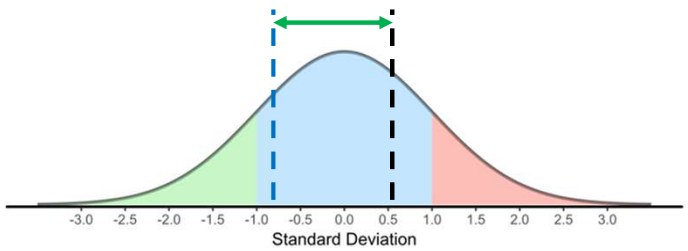
Step 2. Determine Facility Improvement Measures (FIM)

Example A.



- Current model coefficient: Poor
- Target： Nominal
- Target is better than current, need to pick FIMs

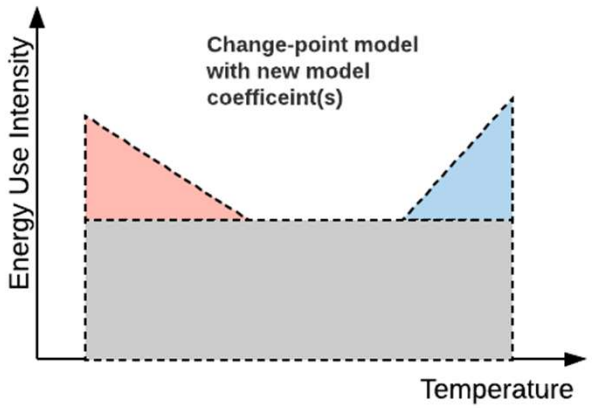
Example B.



- Current model coefficient: Typical
- Target： Conservative
- Target is worse than current, no need to pick FIMs

Energy Savings Estimation

Step 3. Calculate potential energy and cost savings

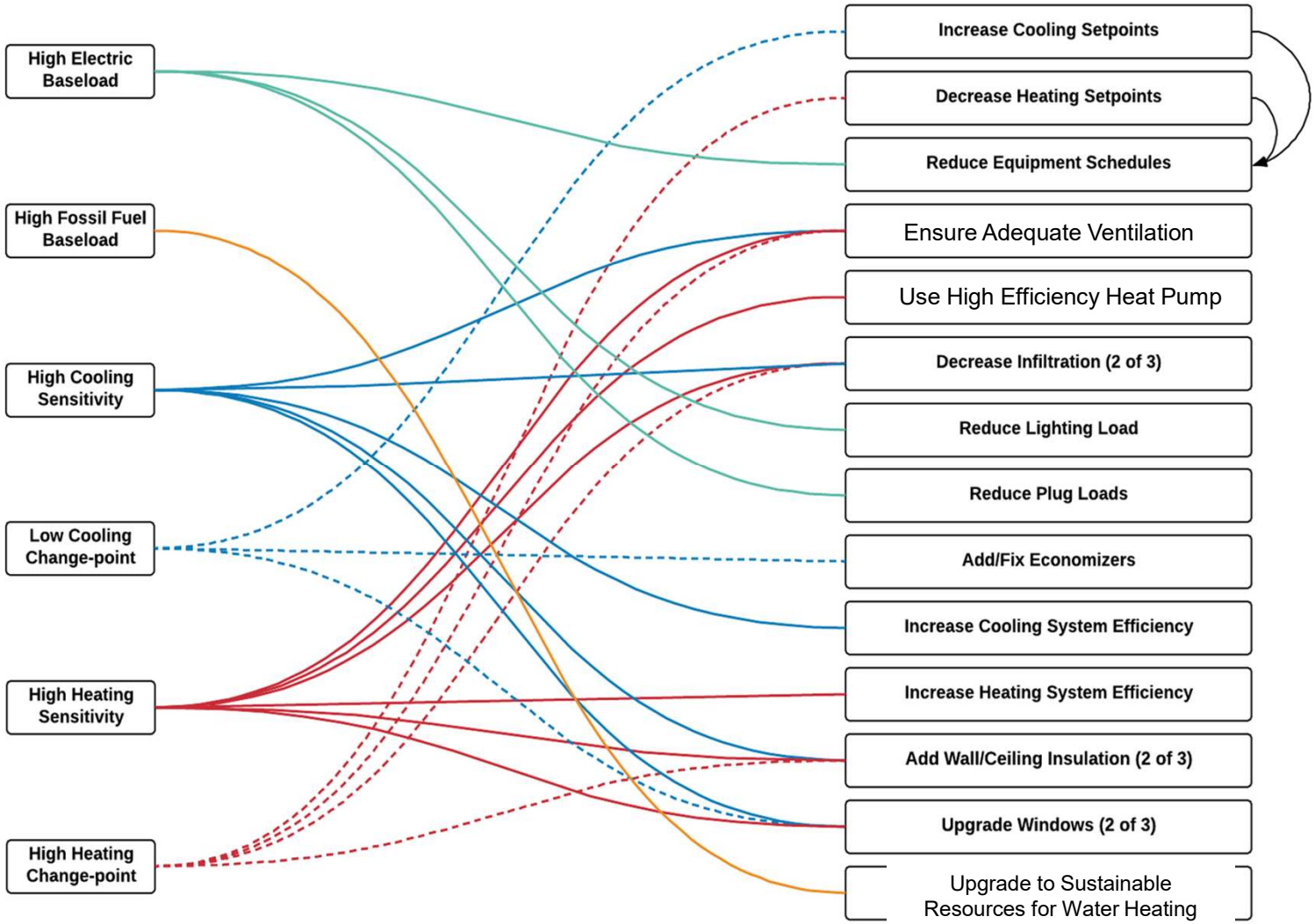


Re-run the model to get:

Current energy consumption − Estimated energy consumption with suggested FIMs = Estimated energy savings

Calculate associated cost

BETTER's Energy Efficiency Measures



OTHER

U.S. Reference Benchmark Statistics Development Process

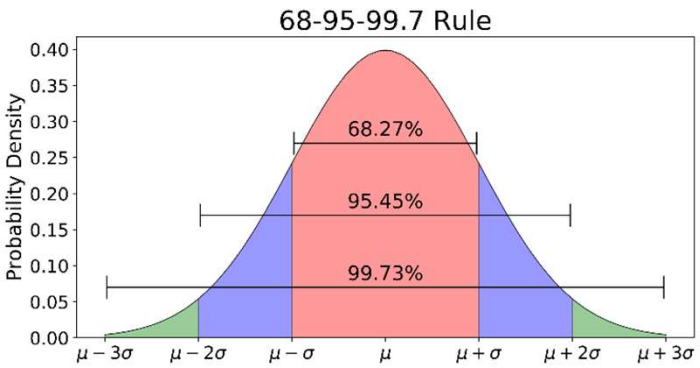
We take the following steps to develop "U.S. reference" benchmark statistics for building space types:

1. Assemble a clean and robust building dataset for a space type that is:
   - (a) composed of building size, location, and 12 consecutive months of energy consumption (all fuels);
   - (b) representative of the U.S. national stock (in terms of climate zone and size distribution) according to the most recent U.S. Commercial Building Energy Consumption Survey (CBECS); and
   - (c) provides at least 30 data points for each of the 10 BETTER model coefficients.
   - *Note: In the future, for more robust statistics, we aim to have at least 30 data points for each of the 10 BETTER model coefficients for each of eight CBECS size categories in each of the eight International Energy Conservation Code (IECC) climate zones in the United States (and possibly for each of the relevant subtypes A, B, and C in these zones). To contribute anonymous data to this effort, please email support@better.lbl.gov.*
2. Develop two change-point models for each building in the dataset (i.e., one for electricity and one for fossil energy).
3. Extract change-point model coefficients (i.e., electric and fossil baseloads, heating and cooling change-points, and heating and cooling slopes).
4. Fit normal distributions to extracted change-point model coefficients.
5. Evaluate the quality of the distributions of change-point model coefficients utilizing statistical tests (e.g., Kolmogorov–Smirnov (KS) test, which measures how well the normal distribution fits to the change-point model coefficient data points).
6. Repeat steps 1 to 6 until each distribution is sufficiently robust.
7. Once the distributions are sufficiently robust, we integrate the U.S. reference benchmark statistics (i.e., the median and standard deviation for each inverse model coefficient distribution) into BETTER for field validation.

K-12 Schools: U.S. Reference Benchmark Statistics Development

- Criteria for including change-point models and coefficients in U.S. reference benchmark statistics creation:

1. At least 12 months' of consecutive utility bills is required for each change-point model.
2. The R^2 of a change-point model should be at least 0.4.
3. A coefficient is discarded if it's more than three standard deviations away from the median.



Note: the criteria apply to both K-12 schools and office buildings

Quick Building Assessment Tool (QBAT)

Juan Gonzalez

Quick Building Assessment Tool for School Needs Assessments

March 15, 2023

Juan Gonzalez Matamoros
Pacific Northwest National Laboratory (PNNL)

PNNL is operated by Battelle for the U.S. Department of Energy

Learning Objectives and Roadmap

Learning Objectives:

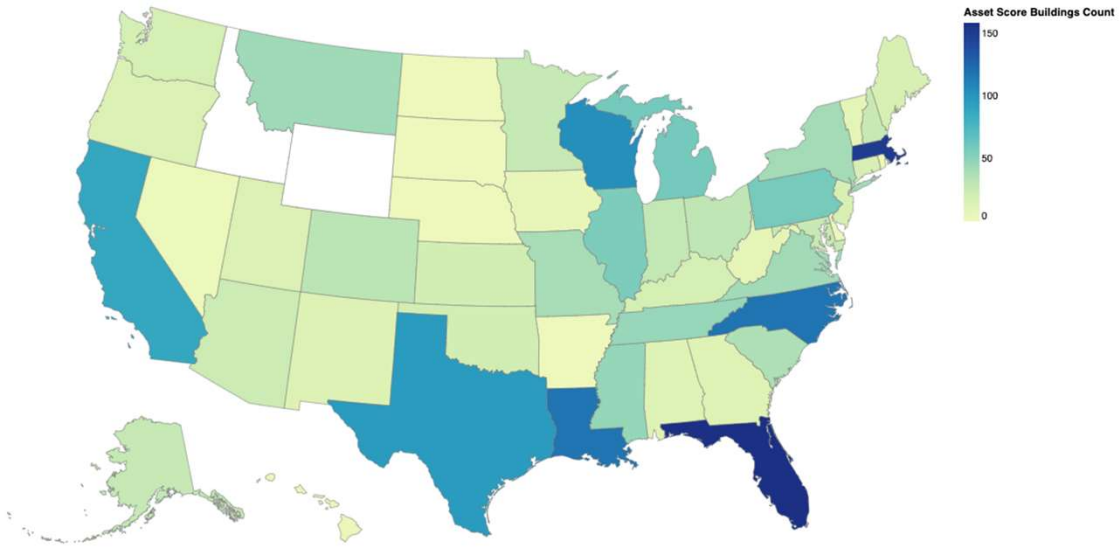
- Goals of Quick Building Assessment Tool (QBAT)
- Understand basics of data collection, tool navigation, data entry, and score reports
- Insight into how QBAT was used for the Bipartisan Infrastructure Law (BIL) to Renew America's Schools FOA
- Know where to go for help and additional resources

Road Map:

- Introduction to QBAT, Asset Score, and Cost Estimator
- Demo:
  - SEA form Data Collection for QBAT Module
  - Generating and Understanding QBAT Report
  - Cost Estimation Spreadsheet

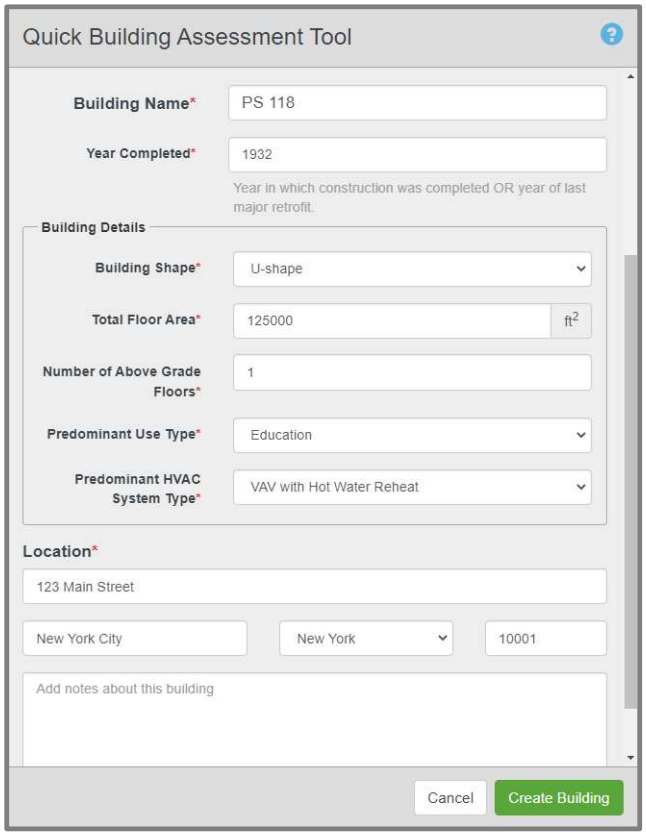
QBAT Application and Impact

- QBAT's design helps users generate **baseline energy need assessments**
- Over 2,000 schools in 48 states completed QBAT buildings between October 2022 and February 2023
- Many FOA applicants for the **Bipartisan Infrastructure Law (BIL) to Renew America's Schools** used their QBAT building records to apply for funding opportunities



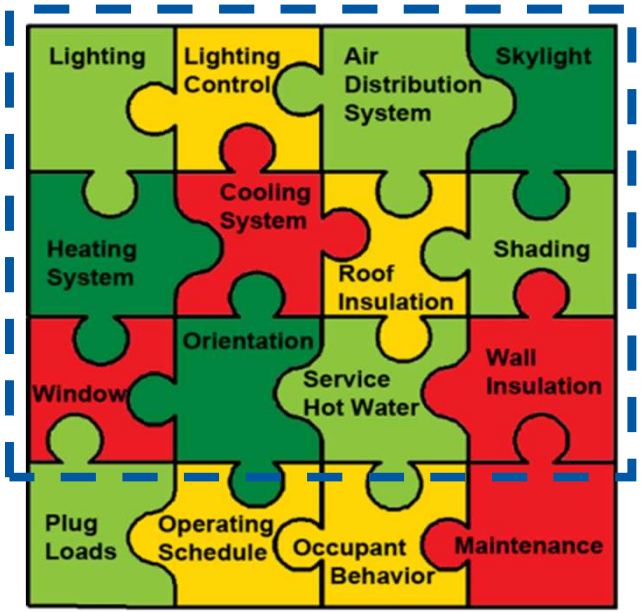
What is the Quick Building Assessment Tool (QBAT)

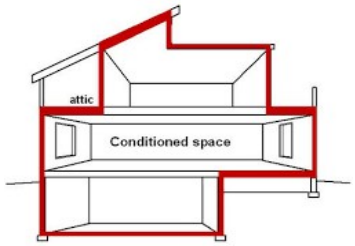
- The **Quick Building Assessment Tool (QBAT**) is a module built on **Building Energy Asset Score (Asset Score)**
- Accelerates the process of generating an **Asset Score Report** by requiring fewer inputs
- QBAT only requires **high-level, easily identifiable inputs** to simulate characteristic buildings for a given climate zone, HVAC system, and vintage
- Designed for **users of all backgrounds** to identify energy efficiency, health, and safety opportunities for their buildings



What is Asset Score?

- Free web-based tool for assessing the physical and structural energy efficiency of commercial and multifamily residential buildings
- Evaluates building energy “assets”: envelope and major energy-related systems and equipment
- Identifies opportunities to invest in energy efficiency upgrades





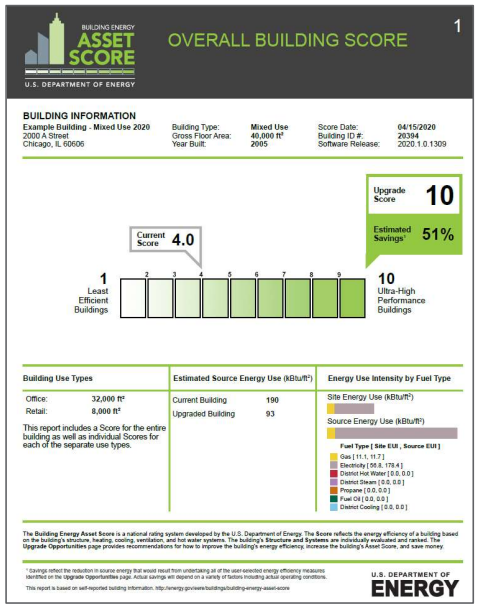
Available as part of the suite of analysis tools for commercial buildings sponsored by the U.S. Department of Energy Building Technologies Office:

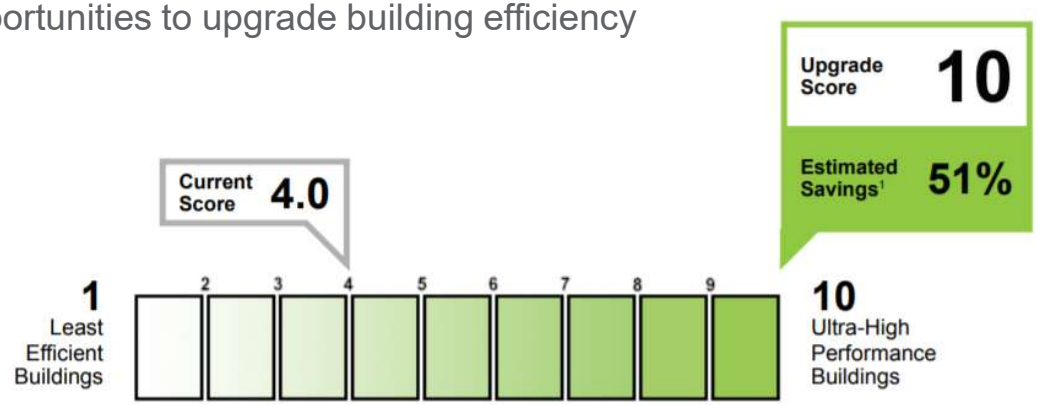
https://www.energy.gov/eere/buildings/building-technologies-office

What Does the Asset Score Tool Do?

- Generates an energy **asset score** - a simple energy efficiency rating that enables comparison among buildings

- Produces an **Asset Score Report** which includes:
  - Total estimated building energy usage and energy use by end use under standard operating conditions
  - An energy efficiency assessment of the building's individual systems
  - Opportunities to upgrade building efficiency





QBAT: Example Asset Score Report Output

- Energy efficiency retrofits, health, and safety recommendations

Cost Effective Upgrade Opportunities	Energy Savings [3]	Cost[4]
Building Envelope		
• Seal building envelope reducing air infiltration† - *Learn More*	Low	$$
• Upgrade roof insulation in block Block 1 for Roof 1.† - *Learn More*	Low	$-$$
• Upgrade wall insulation in block Block 1 for Wall 1.† - *Learn More*	Low	$$-$$$
• Upgrade to high efficiency windows in block Block 1 for Window 1.† - *Learn More*	Medium	$$-$$$
Lighting Systems		
• Upgrade to LED fixtures in block Block 1 for Fixture 1.† - *Learn More*	Medium	$
• Upgrade to LED fixtures in block Block 1 for Fixture 2.† - *Learn More*	Medium	$
• Install occupancy sensors for interior lighting control in block Block 1 - *Learn More*	Low	$-$$
HVAC Systems and Controls		
• Implement demand controlled ventilation (DCV) in block Block 1 - *Learn More*	Medium	$$
• Add variable frequency drive to supply fans in block Block 1 - *Learn More*	Medium	$$
Service Hot Water Systems		
• Add low flow faucets in block Block 1 - *Learn More*	Low	$$

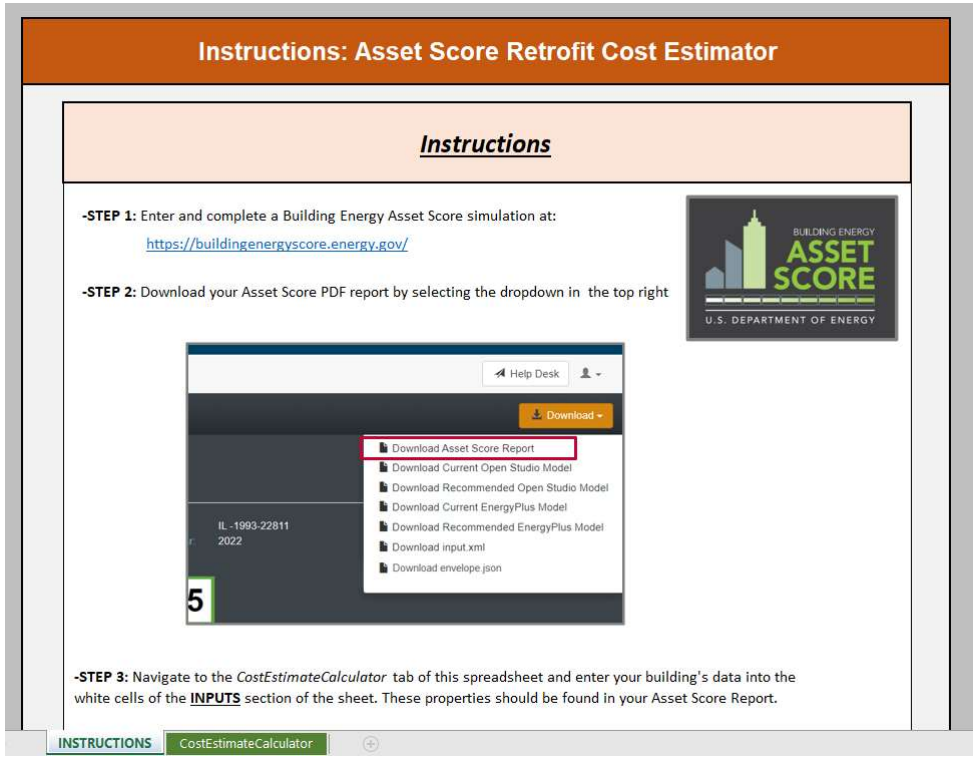
Building Name: **PS 118** Gross Floor Area: **125,000 ft²**

Health and Safety Impact of Upgrade Opportunities

• Lower VAV box minimum flow setpoints in block Block 1	Lowering VAV box minimum flow setpoints can improve thermal comfort by avoiding overcooling in summer and overheating during the winter. However, this may impact the outside air ventilation rate. Therefore, increase attention is needed to make sure that adequate outside air ventilation rate is provided to maintain indoor air quality.
• Add air-side economizer in block Block 1	Adding an economizer will increase outside air and can improve indoor air quality. In offices and schools, studies found that more outside air can reduce building-related symptoms and improves work performance and learning. Increasing ventilation can also mean more outdoor air pollutants may be brought indoors, such as vehicle exhausts if the outside air intake is near an area with significant traffic. It is therefore even more important to use high efficiency air filters, such as MERV 13 or better, to removal particulate matter (PM).
• Add variable frequency drive to condenser pumps in block Block 1	This measure is not expected to directly impact occupant health and safety. Follow commissioning, operation and maintenance, and performance monitoring best practices to enable efficient operation.
• Implement chilled water temperature reset in block Block 1	Adjustment of HVAC system control can affect thermal comfort by impacting zone or room level relative humidity. Monitor indoor temperature, relative humidity, and supply air flow, or conduct occupancy survey, to check for potential impact.
• Upgrade cooling plant pumping system to constant primary -variable secondary pumping system in block Block 1	This measure can affect thermal comfort as the pumping system upgrade may improve chilled water flow compared to current condition. Monitor indoor temperature, relative humidity, and supply air flow, or conduct occupancy survey, to check for potential impact.
• Implement demand controlled ventilation (DCV) in block Block 1	For DCV with zone level CO2 sensors, the control system can reduce the risk of having insufficient outside air ventilation when the space is occupied. Adequate ventilation is important for occupant health, work performance and learning. Adequate ventilation is also important for reducing building-related symptoms and mitigating infectious disease airborne transmission risks. For proper functioning of DCV, it is

Asset Score Retrofit Cost Estimator

- The **Asset Score Retrofit Cost Estimator (Cost Estimator)** is an excel spreadsheet that provides high level measure cost estimation
- Energy conservation measure (ECM) cost estimates help users decide which measures make sense for their facilities
- When applicable, cost estimates have sources listed to provide context for ECM cost estimations



DEMO

Detailed instructions can be found at:
https://www.energy.gov/scep/school-needs-and-benefits-assessment-resources

User Experience: School Energy Assessment Form

- To start, users will want to fill out a **School Energy Assessment (SEA) Form**
- **School Energy Assessment (SEA) Form:** An excel sheet designed for users of all backgrounds to identify key building characteristics needed for QBAT
- Example characteristics:
  - Building name
  - Location
  - Size
  - Shape
  - Vintage
  - HVAC equipment

Location 1: First look in the mechanical room (if you have one) to determine if you have central plant equipment. You will see one or more of the following:		**Check the box for all equipment you see**
Chiller • You will see a long cylinder tube or something that looks like a reciprocating engine in a car, depending on the type of chiller. • Larger chillers will be connected by piping to a cooling tower (water-cooled) outside of the building or vertical fans (air-cooled) outside the building.		2
Boiler • A boiler will provide heat in the mechanical room when on, increasing the temperature in the room. You will see an exhaust duct from the boiler. • The burner will be in front of the boiler, with a flame if it is on. • You will see wires and pipes on the exterior.		1
Warm Air Furnace • THis is usually vertical, with a distribution duct and exhaust duct coming out of it. • You'll see a vent on the side or the front.		

SEA Form to QBAT

- A populated SEA form distills spreadsheet inputs into fields required by the QBAT webtool

1) Form Summary for the Quick Building Assessment Tool

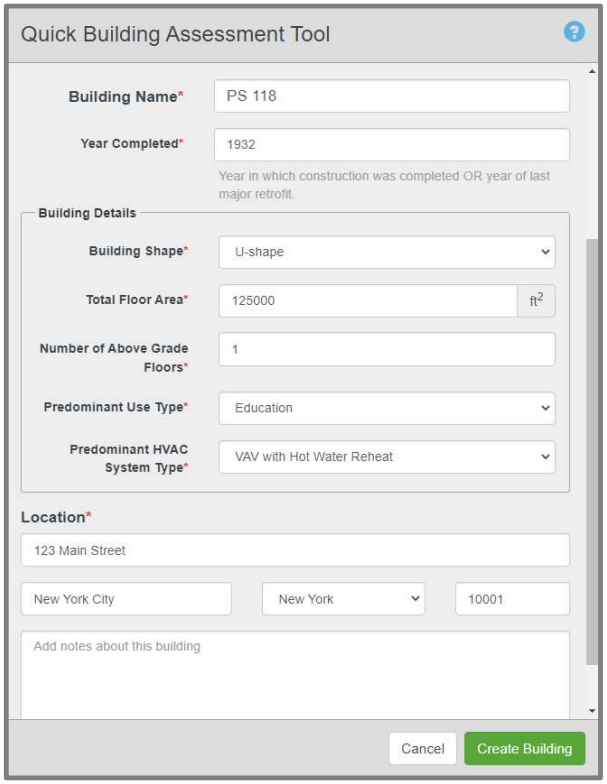
a.	Building/School name	Public School 118
b.	Street address	123 Main Street
c.	City	New York City
d.	State	NY
e.	Zip code	10001
g.	Year completed	1932
h.	Building shape	U-Shape
i.	Building size	125,000 ft2
j.	Total gross floor area above grade	125,000 ft2
k.	Total number of floors above grade	1

* Note that these fields will populate with correct values after the prior Tabs have been completed, and may show "0" or other text prior to completion of other Tabs.

2) Building System

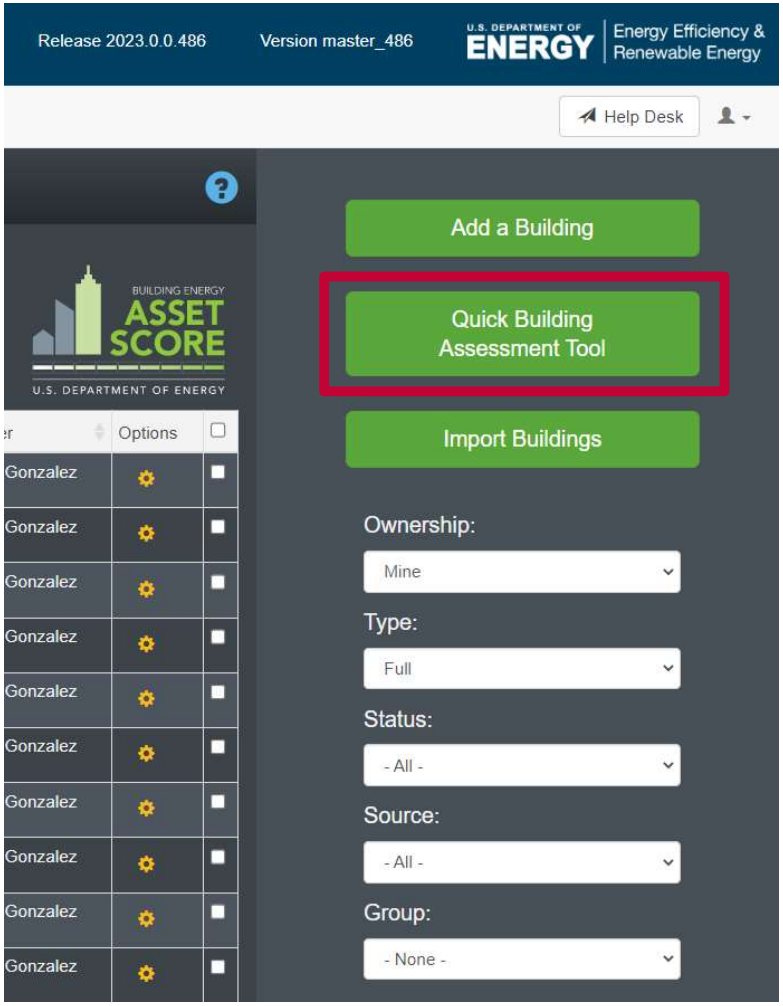
VAV with Hot Water Reheat

* Note that the system listed here is the QBAT building system option that most closely matches that of your facility, based on the system you identified in Tab IV.



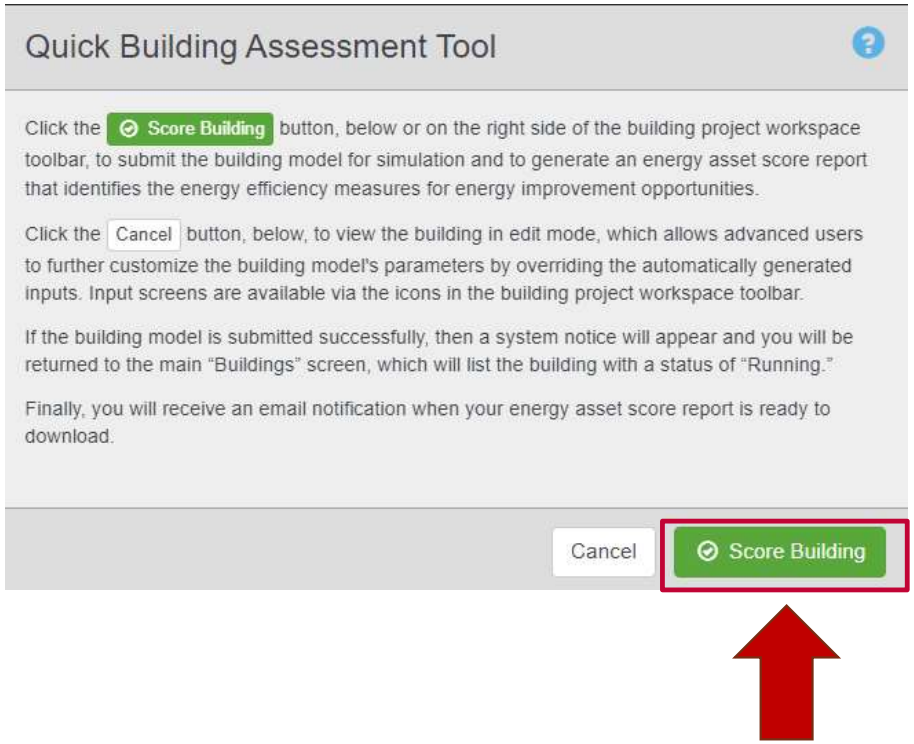
User Experience: QBAT

- Create a login at [DOE Asset Score tool]
- Select the green **"Quick Building Assessment Tool"** button in the upper right hand corner of the dashboard.
- Follow tool steps and input estimates generated from the SEA form, as applicable.



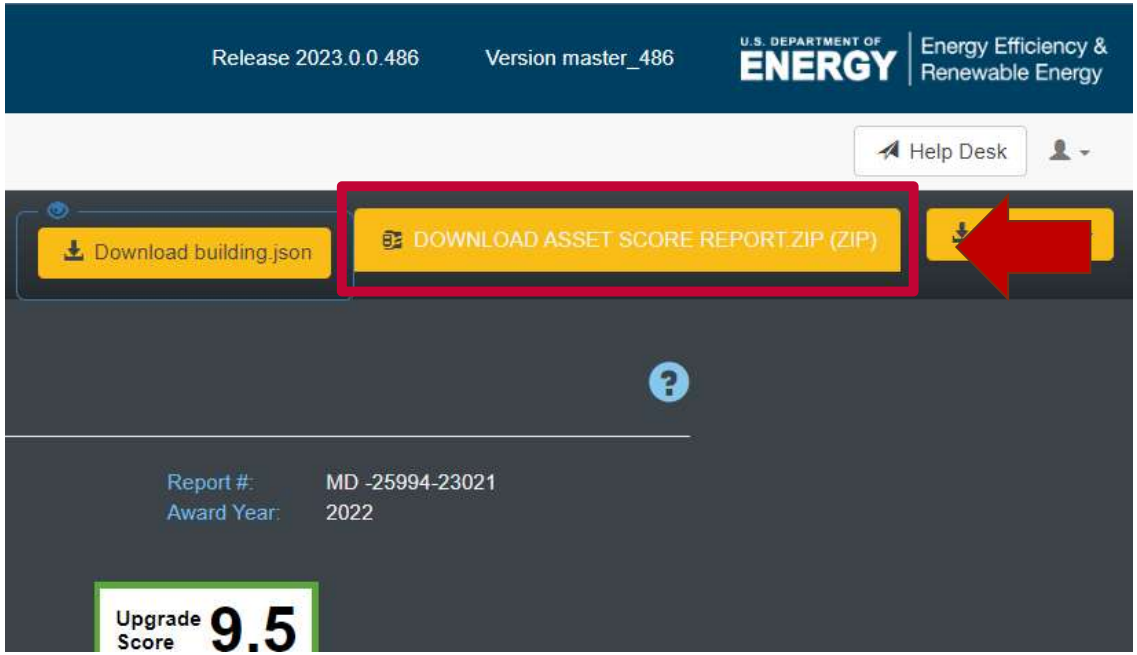
Generating Recommendation into an Asset Score PDF Report

- Clicking the green “Score Building” button on the bottom-right side of the pop-up begins simulation
- Alternatively, advanced users can “Cancel” and review the building’s inferred energy efficiency parameters
- Once simulated, users receive an email notification to download their building’s Asset Score PDF Report



Download Asset Score Report Files

- The Asset Score report files generated from QBAT can be downloaded from the “Download Asset Score Report.ZIP” button



QBAT: Example Asset Score Report Output

- Energy efficiency retrofits, health, and safety recommendations

Cost Effective Upgrade Opportunities	Energy Savings [3]	Cost[4]
Building Envelope		
• Seal building envelope reducing air infiltration† - *Learn More*	Low	$$
• Upgrade roof insulation in block Block 1 for Roof 1.† - *Learn More*	Low	$-$$
• Upgrade wall insulation in block Block 1 for Wall 1.† - *Learn More*	Low	$$-$$$
• Upgrade to high efficiency windows in block Block 1 for Window 1.† - *Learn More*	Medium	$$-$$$
Lighting Systems		
• Upgrade to LED fixtures in block Block 1 for Fixture 1.† - *Learn More*	Medium	$
• Upgrade to LED fixtures in block Block 1 for Fixture 2.† - *Learn More*	Medium	$
• Install occupancy sensors for interior lighting control in block Block 1 - *Learn More*	Low	$-$$
HVAC Systems and Controls		
• Implement demand controlled ventilation (DCV) in block Block 1 - *Learn More*	Medium	$$
• Add variable frequency drive to supply fans in block Block 1 - *Learn More*	Medium	$$
Service Hot Water Systems		
• Add low flow faucets in block Block 1 - *Learn More*	Low	$$

Health and Safety Impact of Upgrade Opportunities	
Building Envelope	**Health and Safety Impact**
• Seal building envelope reducing air infiltration†	Air sealing can improve thermal comfort by reducing cold drafts, and reduce occupant exposure to outdoor air pollutants, such as vehicle exhaust. It may also help with moisture and pest control by eliminating entry points. But with less outside air being provided by air infiltration, it is important to make sure that the building has sufficient ventilation after air sealing, such as by HVAC commissioning, otherwise indoor air quality may deteriorate.
• Upgrade roof insulation in block Block 1 for Roof 1.†	Better insulation may improve thermal comfort. However, adding insulation can disturb existing building materials that may contain asbestos. Consult an accredited asbestos professional to determine if this is a concern.
• Upgrade wall insulation in block Block 1 for Wall 1.†	Better insulation may improve thermal comfort. But note that adding insulation can disturb existing building materials that may contain asbestos. Consult an accredited asbestos professional to determine if this is a concern.
• Upgrade to high efficiency windows in block Block 1 for Window 1.†	Selecting windows with the appropriate heat gain and visible light transmittance can help maintain thermal comfort and improve occupant satisfaction with indoor lighting level.
Lighting Systems	
• Upgrade to LED fixtures in block Block 1 for Fixture 1.†	Indoor lighting retrofit has the potential to improve lighting quality and occupant satisfaction. Retrofits that also allow occupants to have more lighting control can provide greater flexibility to adapt and respond to changing needs.

Asset Score Retrofit Cost Estimator

- The **Cost Estimator** spreadsheet asks users to populate a handful of fields related to their building's geometry and location
- A user can reference the *Asset Score PDF* if they're unsure about their building's particular envelope geometry

Cost Estimator Spreadsheet

Building Parameters

Instructions: Enter your building's parameters in the 'Value' column below. Many of these inputs
INSTRUCTIONS tab for more details

User Inputs		
Building Parameter	**Value**	**Units**
Conditioned Floor Area	10,000	ft2
Building Wall Area	4,800	ft2
Building Roof Area	10,000	ft2
Building Footprint	10,000	ft2
Window-to-wall ratio	50	%
Skylight area	0	ft2
Zip Code	20155	
Building Use Type	***School***	

AS PDF Report

BUILDING ENVELOPE INFORMATION

Total Gross Above Grade Wall Area [1]	4800.0 ft^2
Total Window Area [2]	2400.0 ft^2
Building Window to Wall Ratio	50%
Total Below Grade Wall Area	0.0 ft^2
Total Gross Roof Area [3]	10000.0 ft^2
Total Skylight Area	0.0 ft^2
Total Conditioned Floor Area	10000.0 ft^2
Total Footprint Area	10000.0 ft^2

Areas by Orientation

NORTH	
Gross Wall Area	1200.0 ft^2
Window Area	600.0 ft^2
SOUTH	
Gross Wall Area	1200.0 ft^2
Window Area	600.0 ft^2
EAST	
Gross Wall Area	1200.0 ft^2
Window Area	600.0 ft^2
WEST	
Gross Wall Area	1200.0 ft^2
Window Area	600.0 ft^2

Select ECMs

- Asset Score recommendations can be found in the **Asset Score Report**
- Users can click on the “Learn more” buttons to get additional context for considerations for each ECM
- The **Cost Estimator** spreadsheet has cost estimates for all measures provided by the AS recommendation engine

AS PDF Report

Cost Effective Upgrade Opportunities

Building Envelope

- Add air barrier to reduce building air leakage.† - *Learn More*
- Add insulation to roof Roof 1 in Blk1, Blk2, and Block 3.† - *Learn More*
- Upgrade the window Window 1 in Blk1, Blk2, and Block 3.† - *Learn More*

Lighting Systems

- Replace existing lighting for Fixture 1 to LED lighting in Blk2 and Block 3.† - *Learn More*
- Replace existing lighting for Fixture 2 to LED lighting in Blk1 and Blk2.† - *Learn More*
- Install occupancy sensors for interior lighting control in Block 3, Blk2 - *Learn More*

HVAC Systems and Controls

- Upgrade cooling system in Blk1 with high efficiency electric chiller - *Learn More*
- Lower VAV box minimum flow setpoints in Blk2, Blk1 - *Learn More*
- Add air-side economizer in Blk1, Blk2 - *Learn More*
- Add variable frequency drive to condenser pumps in Blk1 - *Learn More*
- Implement demand controlled ventilation (DCV) in Blk1, Blk2 - *Learn More*
- Add variable frequency drive to supply fans in Block 3 - *Learn More*
- Implement fan static pressure reset in Blk1, Blk2 - *Learn More*
- Implement supply air temperature reset in Blk1, Blk2 - *Learn More*

Select ECMs (cont.)

- Users can pick relevant ECMs from drop downs
- The tool provides both cost estimates and the source for the estimate
- An additional miscellaneous cost section adds considerations for project management costs

Energy Conservation Measure (ECM) Cost Estimations

INSTRUCTIONS: Select energy conservation measures (ECMs) from the **Measure** columns below once you've completed the ***Building Parameters*** section above. Estimates are made using a combination of the building parameters you've provided and the data source linked in the **Cost Source** column to the right.

Envelope Measures		
Measure	**Estimate ($)***	**Cost Source**
Upgrade roof insulation (R-20)	*$141,000 to $182,000*	AERG schools ($/ft2 of roof area)
Upgrade to high efficiency windows	*$734,000 to $965,000*	Scout - Best Commercial Windows
Total	*$875,000 to $1,147,000*	

Upgrade floor cavity insulation
Upgrade roof insulation (R-20)
Upgrade roof insulation (R-30)
Upgrade wall insulation
Install a cool roof
Seal building envelope reducing air infiltration
Upgrade to high efficiency skylights
Upgrade to high efficiency windows

Miscellaneous Costs

Instructions: Enter costs related to project management and other miscellaneous costs. These costs are unrelated to the capital and installation cost of ECMs.

Project Management	$ 10,000.00

Overall Cost Estimate and Disclaimer

- Once all sections are completed, users can see the aggregated total cost of their selections at the bottom

- A disclaimer informs users about the limitations of these calculations and a brief recommendation to consider using a fully accredited professional

OVERALL COST*,**	*$733,000 to $1,199,000*

**DISCLAIMER - All installed cost estimates provided by this tool are based on high level approximations based upon literature review, subject matter expertise, and industry approximations. Every facility improvement project is unique, with various considerations for inflation, regional material costs, and regional labor costs. These estimates are NOT a guarantee for pricing. Developers of this tool accept no liability for these estimates and recommend users rely on independent quotations from accredited professionals.*

***DISCLAIMER - This calculator does not include the cost of complete system replacement measures that fell outside the scope of this study as indicated by an "n/a" above.*

Guidance and Assumptions

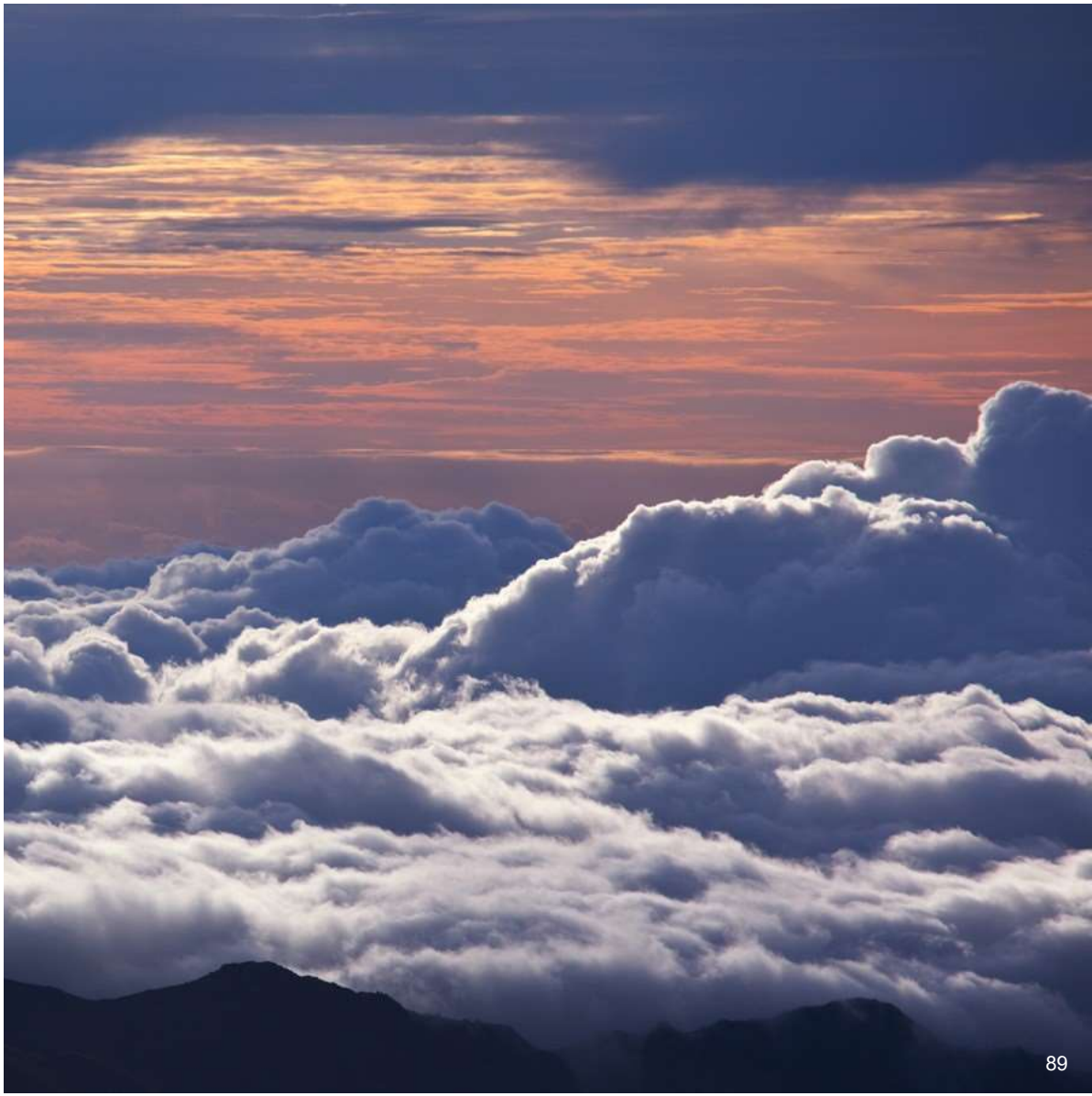
- Finally, any selected measures will have additional guidance below the cost estimates with information about when measures apply, and assumptions made in the calculations

Additional Guidance

Selected Measure	
Measure	**Description and Guidance**
Install a cool roof	*Install single-ply cool roof membrane. Cool roofs reduce solar heat gain during summer and work best in cooling dominating climates.*
Add VFD to air handler supply fan	*Based on ASHRAE 90.1 2010, Section 6.4.3.10, air-conditioning equipment with DX cooling greater than 110,000 Btu/hr should have supply fans controlled by two-speed motors or VFD. In addition to installing VFD or multi-speed control, it is recommended that fan motors be upgraded to premium efficiency models. Consider replacing existing VFDs with higher efficiency versions or install VFDs in fan motors without them.*
Implement chilled water reset control strategy	*Chillers are more efficient at higher leaving water temperatures; therefore, in general, optimum efficiency is achieved when the chilled water supply temperature setpoint is as high as possible to meet the load. This estimate assumes an existing direct digital controls or BAS and is the cost of labor to implement the strategy*

Pacific Northwest
NATIONAL LABORATORY

Thank you



Next Steps: Develop Your Plan!

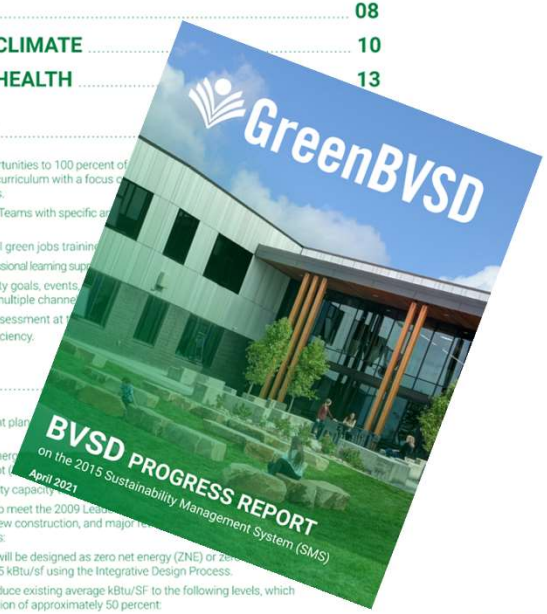
EFFICIENT AND HEALTHY SCHOOLS

What could my plan look like?

Key pieces of a plan:

- Audience
- Team
- Assessment data
- Timelines
- Goals

Table of Contents

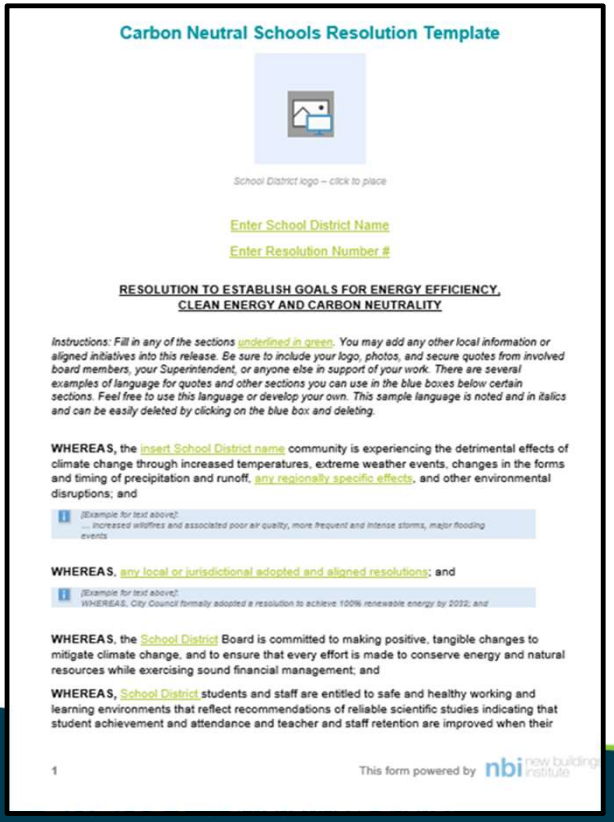


Guiding Standards for Lake Tahoe Unified School Construction Projects

SCOPE *See further details below*	MODERNIZATION	
	Mandatory	Case-by-case
Envelope air sealing, insulating walls and openings	✓	
Roofs insulation, rainwater collection		✓
Glazing & Shading heat minimization, high performance windows		✓
Lighting LED lighting & controls	✓	
Electrical energy monitoring	✓	
Metering submetering		✓
Kitchen electrification & Energy Star energy-efficient equipment	✓	
Heating electrification & maintainability		✓
Ventilation heat recovery & filtration		✓
Controls set points & operating hours	✓	
Domestic Hot Water recirculation pumps & pipe insulation	✓	
Plug Loads are measured & controlled	✓	
Water backflow device & high-efficiency fixtures	✓	
Schoolyard green schoolyards, stormwater mgmt. & rainwater collection		✓
Materials CalGreen, CA Section 01350 & CA Buy Clean	✓	
Renewables Onsite solar PV, storage		✓
Zero Net Energy Capable roof solar readiness	✓	

EFFICIENT AND HEALTHY SCHOOLS

Templates in the toolbox



Carbon Neutral Schools Resolution Template

School District logo – click to place

Enter School District Name

Enter Resolution Number #

RESOLUTION TO ESTABLISH GOALS FOR ENERGY EFFICIENCY, CLEAN ENERGY AND CARBON NEUTRALITY

Instructions: Fill in any of the sections underlined in green. You may add any other local information or aligned initiatives into this release. Be sure to include your logo, photos, and secure quotes from involved board members, your Superintendent, or anyone else in support of your work. There are several examples of language for quotes and other sections you can use in the blue boxes below certain sections. Feel free to use this language or develop your own. This sample language is noted and in italics and can be easily deleted by clicking on the blue box and deleting.

WHEREAS, the insert School District name community is experiencing the detrimental effects of climate change through increased temperatures, extreme weather events, changes in the forms and timing of precipitation and runoff, any regionally specific effects, and other environmental disruptions; and

[Example for text above]: ... increased wildfires and associated poor air quality, more frequent and intense storms, major flooding events

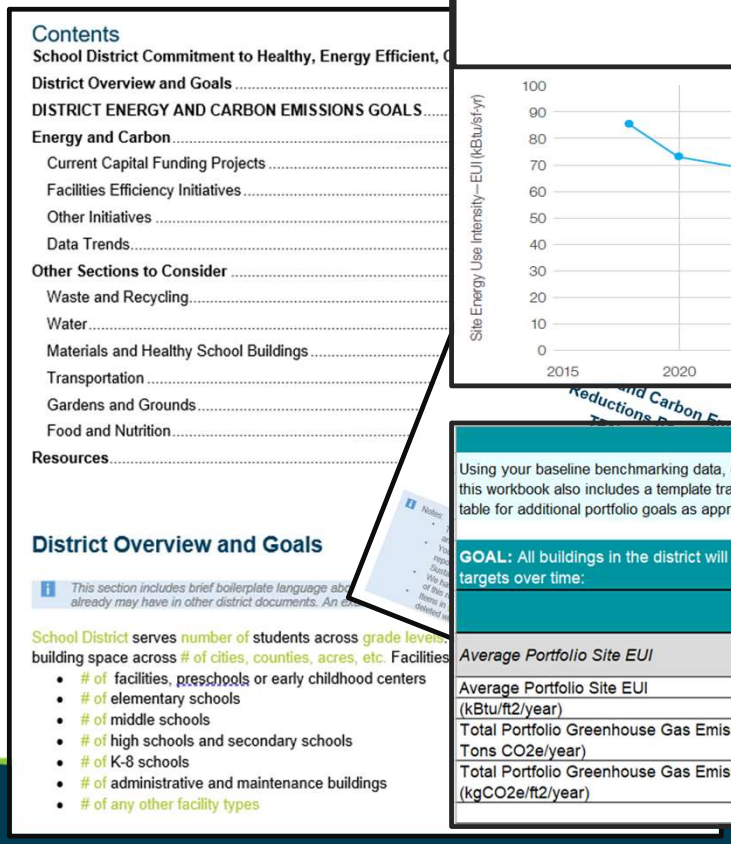
WHEREAS, any local or jurisdictional adopted and aligned resolutions; and

[Example for text above]: WHEREAS, City Council formally adopted a resolution to achieve 100% renewable energy by 2032; and

WHEREAS, the School District Board is committed to making positive, tangible changes to mitigate climate change, and to ensure that every effort is made to conserve energy and natural resources while exercising sound financial management; and

WHEREAS, School District students and staff are entitled to safe and healthy working and learning environments that reflect recommendations of reliable scientific studies indicating that student achievement and attendance and teacher and staff retention are improved when their

1 This form powered by nbi new building institute



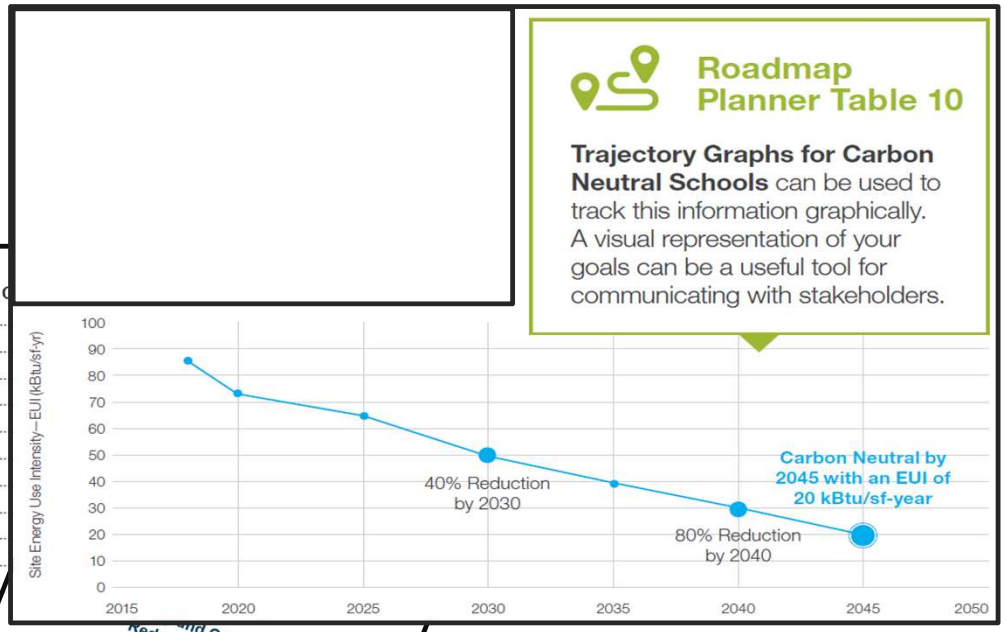
Contents

District Overview and Goals

This section includes brief boilerplate language abo already may have in other district documents. An ex

School District serves number of students across grade levels building space across # of cities, counties, acres, etc. Facilities

- # of facilities, preschools or early childhood centers
- # of elementary schools
- # of middle schools
- # of high schools and secondary schools
- # of K-8 schools
- # of administrative and maintenance buildings
- # of any other facility types



Roadmap Planner Table 10

Trajectory Graphs for Carbon Neutral Schools can be used to track this information graphically. A visual representation of your goals can be a useful tool for communicating with stakeholders.

Table 9: School District Portfolio Roadmap Goals

Using your baseline benchmarking data, customize the table below to note the district's portfolio goals and how they change over time. Table 14 in this workbook also includes a template track this graphically as a useful tool for communicating with stakeholders. Additional rows are included in this table for additional portfolio goals as appropriate for your portfolio.

GOAL: All buildings in the district will be carbon neutral by **[target year]** and the average portfolio site EUI will adhere to the following targets over time:

	Baseline [YEAR]	2025	2030	2035	2040	2045
Average Portfolio Site EUI	*[2019] EUI: 60*	*52*	*44*	*36*	*28*	*20*
Average Portfolio Site EUI (kBtu/ft2/year)	80	68	56	44	32	20
Total Portfolio Greenhouse Gas Emissions (Metric Tons CO2e/year)						
Total Portfolio Greenhouse Gas Emissions (kgCO2e/ft2/year)						

EFFICIENT AND HEALTHY SCHOOLS

What could be in my plan?

Plans might include:

- Key messaging and stakeholder documentation
- List of relevant goals and plans
- List of documents to be developed (resolutions, tech specs, etc.)
- Benchmarking and assessment data – Energy and IEQ
- Project and portfolio level goals
- Planning timelines and project list

EFFICIENT AND HEALTHY SCHOOLS

Submitting for Planning Recognition

Plans will be tailored to school district needs and may evolve over the course of this series.

Goal: an actionable plan that is not extra busywork for your district.

Plans can be:

- Focused on a particular topic (energy, IAQ, IEQ, etc.)
- Focused on a particular action (ex. building assessment)
- Be part of an existing plan or a larger plan focused on whole district sustainability
- In any format! PPT, word doc, one pager, infographic, etc.

EFFICIENT AND HEALTHY SCHOOLS

Webinar Series

Interested schools and districts will participate in a webinar series between January and March 2023.

Winter 2023

Spring 2023

Preparation

Schools and districts will prepare their materials for the final submission.

Final Submission

Schools and districts will complete a final submission by **May 1, 2023** to summarize key learnings and describe how tools or approaches can be applied in their school facilities.

May 2023

June 2023

Announcement

Schools and districts receiving recognition will be invited to attend an in-person celebration in June 2023.

Office Hours