Efficient and Healthy Schools Recognition Program

Energy Efficiency + Health

March 14, 2023
EE+Health Recognition Webinar 3:
Building Assessment Tools for School Energy Retrofits
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)
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
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

- Engage Stakeholders
  - Find champions

- Assess Building Stock
  - Benchmark and track performance

- Set Goals
  - Incorporate goals into policy plans and practices

- Align With Building Lifecycle Events
  - Implement zero energy, all-electric and renewable energy projects

- Engage Occupants
  - Educate students

- Track and Report Progress
  - Stay informed

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Stakeholder Engagement and Visioning

Making the case for efficiency and health

Key Messages for Communicating Carbon Neutral Schools

- Public K-12 school buildings represent 7.6 billion square feet of building space, or 66% of all K-12 building space [source].
- 19% of the population in the United States is a student or school staff and spends their day connected to a school building [10, 11, 12].
- America’s K-12 schools currently spend $13.0 billion per year on energy [source].
- Schools in the United States produce emissions equivalent to 12 coal-fired power plants each year [source] [11, 12].
- The educational sector consumes over 2,000 trillion BTUs of energy for all purposes 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 EAT, 12,000 MJe in 2016, public schools in the U.S., the average school is approximately 65,000 square feet. The average school produces about 20-30 MTCOe of emissions and may spend $100,000 or more on electricity and gas costs each year.
- According to the 2013 Energy Information Agency’s Commercial Building Energy Consumption Survey (CECOS), a typical school uses energy for space heating (35%), cooling (20%), computing and office equipment (14%), ventilation (8%), lighting (8%), water heating (4%), kitchen (7%), and other (10%) leads. [source] [13, 14].

Fast Facts About Schools, Energy, and Emissions

- 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 MTCOe [source].
- School buses represent the largest fleet of public transportation with about 140,000, largely diesel, buses in need of electrification [source].

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

Sherry Malden, PhD, MPH, Asa K. Mayer, PhD, Stephanie Barri, MS, Henka Boshern, PhD, Brian Dierbak, MArch, Dale Manning, PhD, Stephen J. Reynolds, PhD, Joshua W. Schaffert, PhD, Jordan Suter, PhD, Jennifer E. Cross, PhD

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

Energy benchmarking and ventilation assessments

Assess Building Stock

Benchmark and track performance
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.

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 2016 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.

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.
Assessing Building Stock

Building Assessment Tools for School Energy Retrofits

TODAY!

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 its 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.
Building Efficiency Target Tool for Energy Retrofits (BETTER)
Carolyn Szum and Han Li
BETTER: A Tool to Achieve Cost-Saving Energy and Emissions Reductions in Public and Private Buildings and Portfolios

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

Energy Energy Technologies Area, Lawrence Berkeley National Laboratory

March 14, 2023

Acknowledgments:

- 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.
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.


## Problem: Audit Costs for Portfolios

<table>
<thead>
<tr>
<th>No. of Buildings</th>
<th>Square Footage$^1$</th>
<th>Total Level I Audit Cost$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>164,000</td>
<td>$13,120</td>
</tr>
<tr>
<td>100</td>
<td>1,640,000</td>
<td>$131,200</td>
</tr>
<tr>
<td>1,000</td>
<td>16,400,000</td>
<td>$1,312,000</td>
</tr>
<tr>
<td>10,000</td>
<td>164,000,000</td>
<td>$13,120,000</td>
</tr>
</tbody>
</table>

---


Building Efficiency Targeting Tool for Energy Retrofits (BETTER)

- Replaces level 1 audits.
- 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.

https://better.lbl.gov/

How BETTER Works

1. Simple Inputs
2. Fast Analysis
3. Actionable Portfolio and Building Insights

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**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 (MTCO2e):**

- 6,749
- 17.5%

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**Top Energy Efficiency Recommendations:**

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

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**Building Portfolio Analysis**
Advantages

Simple Data Inputs
- Building Type
- Building Address
- Gross Floor Area
- Electricity
- Fossil

Minimal Domain Expertise Required

Operational Energy, CO₂ Savings

Short Run Time

Portfolio Insights

Fast, no-/low-cost Interventions
Supports Multilevel Analysis on Buildings and Portfolios

**HIGH-LEVEL ANALYSIS**
- **Rate** actual operational energy performance against peers
- **Earn** the ENERGY STAR® plaque for superior operational energy performance

**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

**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 ft²
  - 60 hours/week*
  - 100% occupancy**
  - Vintages: 1927, 1951 – 2019

* 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 (m²): 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 (MTCO₂e): 250
3.9 %
GHG Emissions Intensity Reduction (MTCO₂e/m²): 0.0002
Identified Schools with High Energy and Cost Savings Potential

Energy Consumption and Savings Summary

- Annual Electricity EUI (kWh/m²)
- Fossil Fuel EUI (kWh/m²)
- Savings Potential (USD / $)

Schools with high energy and cost savings potential are indicated by red boxes.
Lake Ridge Elementary School BETTER Analysis

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

- **Energy Efficiency Opportunities:**

  **Electricity Change-point Model**

  **Electricity Consumption Benchmarking**
  - Baseload (Typical): 75%
  - Cooling Change-point (Poor): 15%
  - Cooling Sensitivity (Typical): 73%

  **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:**

<table>
<thead>
<tr>
<th></th>
<th>Electricity Usage and Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Kilowatt Hours (kWh)</td>
</tr>
<tr>
<td><strong>Baseline (08/2019 – 03/2019)</strong></td>
<td>491,760</td>
</tr>
<tr>
<td><strong>Post-upgrade (08/2020 – 03/2021)</strong></td>
<td>376,960</td>
</tr>
<tr>
<td><strong>Savings (non-weather normalized)</strong></td>
<td>114,800</td>
</tr>
<tr>
<td><strong>Savings (weather normalized)</strong></td>
<td>125,696 (19%)</td>
</tr>
</tbody>
</table>

* 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

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

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!”

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
Owners / Managers / Research
Market Transformation
Public Sector
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 tCO₂e

Equivalent to the CO₂ sequestered by planting 37,551 new trees annually

"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

**Method:** Custom spreadsheet of building size, location, type, and utility bill data.

**Use Case:** Have ENERGY STAR (ES) data and rating(s) (1-100) and then transfer data to BETTER to quantify savings potential(s) and EEMs to improve score(s).

**Method:** ES generates an Excel file with building and interval meter data for one or more buildings that BETTER can upload and analyze.

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**Use Case #1:** Have Audit Template (AT) data then use BETTER to validate results from audit.

**Use Case #2:** Have BETTER data then use it to populate AT.

**Method:** BuildingSync.

---

**Use Case #1:** Have Asset Score (AS) data and rating (1-10) and then use BETTER to optimize operating energy performance.

**Use Case #2:** Have BETTER data then transfer to AS to get a rating (1-10).

**Method:** BuildingSync.

---

**Use Case #1:** Have SEED data and then transfer data to BETTER to quantify savings potential(s) and to identify energy efficiency measures (EEM). Results displayed in SEED (and BETTER) as self-contained HTML.

**Use Case #2:** Have BETTER data then transfer to SEED for data management.

**Method:** Transfer via dynamic API call.
New Feature: Net Zero Energy Building (NZEB) Analysis at Scale

- Energy savings potentials (BETTER)
- Annual Electricity EUI after saving
- PV EUI
- PV EUI by assumption (lacking floor area/levels and roof space)

- Can achieve NZEB (14 bldg)
- Can achieve NZEB, estimated (6 bldg)
- May achieve NZEB after retrofit, BETTER (6 bldg)
- Difficult to achieve NZEB (4 bldg)
- Insufficient data (5 bldg)
California State Agency

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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.
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%)

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Environmental and Social Impact

- Contribute to the Biden Administration’s goal to retrofit 2 million commercial buildings and homes.¹

- Sequester CO₂ 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.

---

   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 cszum@lbl.gov at Berkeley Lab.

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

![Bar chart comparing CBECs 2012 against BETTER statistics for K-12 school size distribution.]
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 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.
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 m²
Medium: 1000 m² <= area < 10000 m²
Large: area >= 10000 m²
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

- **Start**
  - Building Data
  - Weather Data
  - Energy Consumption
- **Data pre-processing**
  - Enhanced ASHRAE IMT
- **Inverse Modeling**
  - Heating-sensitive consumption
  - Heating change-point
  - Cooling-sensitive Consumption
  - Cooling change-point
  - Baseload Consumption
- **Energy Use Intensity**
- **Benchmark Dataset**
  - Benchmarking
    - Good
    - Typical
    - Poor
    - Baseload
    - Cooling sensitivity
    - Cooling change-point
    - Heating sensitivity
    - Heating change-point
- **Assessment**
  - Identify energy efficiency measures
  - Quantify energy & cost savings
- **Generate benchmarking and retrofit targeting report**
- **End**
- **Retrofit Target Level**
Property Information

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
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.*

<table>
<thead>
<tr>
<th>Building ID*</th>
<th>Billing Start Dates*</th>
<th>Billing End Dates*</th>
<th>Energy Type*</th>
<th>Energy Unit*</th>
<th>Energy Consumption*</th>
<th>Energy Cost</th>
<th>Average Outdoor Air Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/1/2017</td>
<td>1/31/2017</td>
<td>Electric - Grid</td>
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* 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

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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*m²)* by month for at least 12 months.*

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

* BETTER uses kWh and m² as common units for calculations, but may display savings in output reports in kWh/m² or kBtu/ft², depending on the unit system selected in spreadsheet upload template.
## Change-Point Modeling

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<th>Schematic Plot</th>
<th>Model Coefficient</th>
<th>Interpretation</th>
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<td>1P Model</td>
<td><img src="image1" alt="Schematic" /></td>
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<td>(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.</td>
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<td>(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.</td>
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<td>(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.</td>
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<td>5P Model</td>
<td><img src="image4" alt="Schematic" /></td>
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<td>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.</td>
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Benchmark Coefficients

Model Coefficients → Electricity Base load

Benchmark Statistics → Electricity Base load Distribution

- Median
- Standard Deviation

Base load
Cooling Sensitivity
Cooling Change-point
Heating Sensitivity
Heating Change-point
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)
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

- Increase Cooling Setpoints
- Decrease Heating Setpoints
- Reduce Equipment Schedules
- Ensure Adequate Ventilation
- Use High Efficiency Heat Pump
- Decrease Infiltration (2 of 3)
- Reduce Lighting Load
- Reduce Plug Loads
- Add/Fix Economizers
- Increase Cooling System Efficiency
- Increase Heating System Efficiency
- Add Wall/Ceiling Insulation (2 of 3)
- Upgrade Windows (2 of 3)
- Upgrade to Sustainable Resources for Water Heating

- High Electric Baseload
- High Fossil Fuel Baseload
- High Cooling Sensitivity
- Low Cooling Change-point
- High Heating Sensitivity
- High Heating Change-point
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)
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:

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

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<th>Cost</th>
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<td>- Seal building envelope reducing air infiltration - Learn More</td>
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<td>- Add low flow faucets in block Block 1 - Learn More</td>
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#### 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, increased attention is needed to ensure adequate outside air ventilation rate 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 schools and offices, 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 remove 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
  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:

- **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.

- **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.

- **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.

Check the box for all equipment you see.
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

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

*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

<table>
<thead>
<tr>
<th>Cost Effective Upgrade Opportunities</th>
<th>Energy Savings $</th>
<th>Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Envelope</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Seal building envelope reducing air infiltration² - Learn More</td>
<td>Low</td>
<td>$5</td>
</tr>
<tr>
<td>• Upgrade roof insulation in block Block 1 for Roof 1 - Learn More</td>
<td>Low</td>
<td>$5-$5</td>
</tr>
<tr>
<td>• Upgrade wall insulation in block Block 1 for Wall 1 - Learn More</td>
<td>Low</td>
<td>$5-$5</td>
</tr>
<tr>
<td>• Upgrade to high efficiency windows in block Block 1 for Window 1 - Learn More</td>
<td>Medium</td>
<td>$5-$5</td>
</tr>
<tr>
<td><strong>Lighting Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Upgrade to LED fixtures in block Block 1 for Fixture 1 - Learn More</td>
<td>Medium</td>
<td>$</td>
</tr>
<tr>
<td>• Upgrade to LED fixtures in block Block 1 for Fixture 2 - Learn More</td>
<td>Medium</td>
<td>$</td>
</tr>
<tr>
<td>• Install occupancy sensors for interior lighting control in block Block 1 - Learn More</td>
<td>Low</td>
<td>$5</td>
</tr>
<tr>
<td><strong>HVAC Systems and Controls</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Implement demand controlled ventilation (DCV) in block Block 1 - Learn More</td>
<td>Medium</td>
<td>$5</td>
</tr>
<tr>
<td>• Add variable frequency drive to supply fans in block Block 1 - Learn More</td>
<td>Medium</td>
<td>$5</td>
</tr>
<tr>
<td><strong>Service Hot Water Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Add low flow faucets in block Block 1 - Learn More</td>
<td>Low</td>
<td>$5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health and Safety Impact of Upgrade Opportunities</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building Envelope</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Seal building envelope reducing air infiltration² - Learn More</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>• Upgrade roof insulation in block Block 1 for Roof 1 - Learn More</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>• Upgrade wall insulation in block Block 1 for Wall 1 - Learn More</td>
<td>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.</td>
<td></td>
</tr>
<tr>
<td>• Upgrade to high efficiency windows in block Block 1 for Window 1 - Learn More</td>
<td>Selecting windows with the appropriate heat gain and visible light transmittance can help maintain thermal comfort and improve occupant satisfaction with indoor lighting level.</td>
<td></td>
</tr>
<tr>
<td><strong>Lighting Systems</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Upgrade to LED fixtures in block Block 1 for Fixture 1 - Learn More</td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>
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.

### Building Parameters

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

<table>
<thead>
<tr>
<th>Building Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditioned Floor Area</td>
<td>10,000</td>
<td>ft²</td>
</tr>
<tr>
<td>Building Wall Area</td>
<td>4,800</td>
<td>ft²</td>
</tr>
<tr>
<td>Building Roof Area</td>
<td>10,000</td>
<td>ft²</td>
</tr>
<tr>
<td>Building Footprint</td>
<td>10,000</td>
<td>ft²</td>
</tr>
<tr>
<td>Window-to-wall ratio</td>
<td>50</td>
<td>%</td>
</tr>
<tr>
<td>Skylight area</td>
<td>0</td>
<td>ft²</td>
</tr>
<tr>
<td>Zip Code</td>
<td>20155</td>
<td></td>
</tr>
<tr>
<td>Building Use Type</td>
<td>School</td>
<td></td>
</tr>
</tbody>
</table>

### BUILDING ENVELOPE INFORMATION

- Total Gross Above Grade Wall Area: 4800.0 ft²
- Total Window Area: 2400.0 ft²
- Building Window to Wall Ratio: 50%
- Total Below Grade Wall Area: 0.0 ft²
- Total Gross Roof Area: 10000.0 ft²
- Total Skylight Area: 0.0 ft²
- Total Conditioned Floor Area: 100000.0 ft²
- Total Footprint Area: 100000.0 ft²

### Areas by Orientation

- NORTH
  - Gross Wall Area: 1200.0 ft²
  - Window Area: 600.0 ft²
- SOUTH
  - Gross Wall Area: 1200.0 ft²
  - Window Area: 600.0 ft²
- EAST
  - Gross Wall Area: 1200.0 ft²
  - Window Area: 600.0 ft²
- WEST
  - Gross Wall Area: 1200.0 ft²
  - Window Area: 600.0 ft²
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 CostEstimator spreadsheet has cost estimates for all measures provided by the AS recommendation engine
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.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Estimate ($)*</th>
<th>Cost Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upgrade roof insulation (R-20)</td>
<td>$240,000 to 392,000</td>
<td>New schools &amp; K-12 institutions</td>
</tr>
<tr>
<td>Upgrade to high efficiency windows</td>
<td>$734,000 to 955,000</td>
<td>Hostile, High Commercial Windows</td>
</tr>
<tr>
<td>Upgrade floor voids insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrade roof insulation (R-25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrade roof insulation (R-30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrade wall insulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Install a cat roof</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seal building envelope reducing air infiltration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upgrade to high efficiency skylights</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$675,000 to 5,147,000</td>
<td></td>
</tr>
</tbody>
</table>

### 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

<table>
<thead>
<tr>
<th>Selected Measure</th>
<th>Description and Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Install a cool roof</td>
<td>Install single-ply cool roof membrane. Cool roofs reduce solar heat gain during summer and work best in cooling dominating climates.</td>
</tr>
<tr>
<td>Add VFD to air handler supply fan</td>
<td>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.</td>
</tr>
<tr>
<td>Implement chilled water reset control strategy</td>
<td>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</td>
</tr>
</tbody>
</table>
Thank you
Next Steps: Develop Your Plan!
What could my plan look like?

Table of Contents

Executive Summary 08
Cross Cutting Theme 1: CLIMATE 10
Cross Cutting Theme 2: HEALTH 13

Focus Area 1: Education
GOAL 1: Provide professional learning opportunities to 100 percent of teachers to integrate the curriculum with a focus on social studies and science teachers.
GOAL 2: Create active and formalized Green Teams with specific goals for 100 percent of schools.
GOAL 3: Develop an interdisciplinary, formal green jobs training program for educators.
GOAL 4: Provide ongoing professional learning about green building and high performance building strategies.
GOAL 5: Leverage all of BVSD’s sustainability goals, both internally and externally, that tie multiple elements.
GOAL 6: Develop a sustainability literacy assessment and provide training for all schools.

Focus Area 2: Buildings
GOAL 1: With a balanced water management plan, 3 percent of existing buildings.
GOAL 2: Reduce annual 2006 baseline energy use and Thermal Index (Mbit/kwh) by square foot.
GOAL 3: Increase BVSD’s renewable electricity and recoverable energy.
GOAL 4: Design new buildings or additions to meet the 2020 ENERGY STAR (3.0) gold standard for schools, new construction, and major renovation.

Key pieces of a plan:
• Audience
• Team
• Assessment data
• Timelines
• Goals
Templates in the toolbox

Contents
- School District Commitment to Healthy, Energy Efficient, 
  District Overview and Goals
- District Energy and Carbon Emissions Goals
  Energy and Carbon
  Current Capital Funding Projects
  Facilities Efficiency Initiatives
  Other Initiatives
  Data Trends
  Other Sections to Consider
  Waste and Recycling
  Water
  Materials and Healthy School Buildings
  Transportation
  Gardens and Grounds
  Food and Nutrition
  Resources

District Overview and Goals

District serves number of students across grade levels
- building space across # of sites, campuses, 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

<table>
<thead>
<tr>
<th>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:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline EUI:</strong> 60</td>
</tr>
<tr>
<td><strong>2019</strong></td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>Average Portfolio Site EUI</td>
</tr>
<tr>
<td>Average Portfolio Site EUI</td>
</tr>
<tr>
<td>Total Portfolio Greenhouse Gas Emissions (Metric Tons CO2e/year)</td>
</tr>
</tbody>
</table>
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
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.
Webinar Series
Interested schools and districts will participate in a webinar series between January and March 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.

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