New U.S. Data Tools are Playing a Crucial Role in Decarbonizing Buildings at Speed, Scale, and Low Cost

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ABSTRACT

Preparing buildings for retrofits traditionally requires expensive on-site audits or time-intensive simulation models. As a result, the majority of buildings fail to pursue cost-saving retrofits. To address these barriers, the U.S. Department of Energy (DOE) has introduced the Building Efficiency Targeting Tool for Energy Retrofits (BETTER)—a new, free, on-line tool that utilizes a data-driven analytical engine and user-friendly web interface to automatically analyze a building's monthly energy usage in response to weather conditions. The tool benchmarks a building's electric and fossil energy usage against peers; estimates energy, cost, and emissions reductions at the building and portfolio levels; recommends energy efficiency measures; and prioritizes buildings for net-zero energy retrofits. Thanks to interoperability with the DOE's Standard Energy Efficiency Data (SEED) platform, BETTER is supporting U.S. jurisdictions to prepare buildings for retrofit at speed, scale, and low cost to comply with energy policies. This paper discusses the use of BETTER and SEED by one of the branches of the California state government to streamline a retrofit program across 455 public non-residential buildings to align with state goals to reduce greenhouse gas emissions. It describes the organization's challenge to reduce energy consumption across a geographically diverse, aging portfolio; explores how BETTER and SEED improved workflow efficiency; presents preliminary results, including avoiding audit costs of $3.28 million and developing the groundwork for retrofit projects estimated to prevent emission of 2,271 t CO_2e annually; and provides guidance for other jurisdictions seeking similar results.

Introduction

The California state government has state energy and environmental goals that include reducing greenhouse gas (GHG) emissions 40% by 2030 (against 1990 levels) (CARB 2024). A branch of the California state government[1] aligned with these goals also aimed to meet internal targets to reduce annual building portfolio energy costs through a combination of energy efficiency (EE) improvements and load shifting.

The core challenge was to reduce energy consumption and costs across the state government branch's large, geographically diverse and aging portfolio,[2] with a variety of

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[1] The California state government branch is intentionally omitted to protect confidentiality.

[2] 455 non-residential buildings covering 44 million square feet; 83% of these buildings were built before 2000.

equipment and systems. For instance, the heating, ventilation, and air-conditioning systems (HVAC) ranged from central plant configurations with cooling towers and chilled or hot water loops to basic split systems or packaged rooftop units (RTU). The building automation systems (BAS) also varied. Newer buildings combined central BAS with direct digital control technology for programmable and precise control of indoor temperature, humidity, lighting, and other functions. Older buildings utilized legacy pneumatic control systems, basic local thermostats, and local RTU controls. Buildings were occupied fully, operated roughly 60 hours per week, and utilized both electricity and natural gas.

To address this challenge, the state government branch partnered with Energy Resources Integration (ERI) LLC., an engineering firm headquartered in San Francisco, to implement a portfolio EE improvement strategy that involved: benchmarking the energy performance of buildings, prioritizing buildings for audits, conducting audits, implementing retrofit and retro-commissioning (RCx) projects, and applying utility rebates. As a first step, ERI decided to use DOE's BETTER tool to help benchmark and prioritize buildings for audits.

BETTER Overview

Launched in 2021, BETTER (https://better.lbl.gov/) is a free software toolkit of the U.S. DOE that is managed by Lawrence Berkeley National Laboratory (Berkeley Lab). BETTER was developed to provide actionable insights to improve energy and financial performance in commercial buildings and portfolios without requiring site visits and complex modeling. The tool identifies operational measures and technology upgrades to reduce energy consumption while prioritizing facilities for more in-depth audits and analysis. With minimal data entry (building type, gross floor area, city-level location, and 12 consecutive months of energy consumption), BETTER benchmarks a building's or portfolio's energy use against peers; quantifies energy, cost, and greenhouse gas (GHG) reduction potential; recommends energy efficiency measures (EEM) (technological and operational) for individual buildings or portfolios, targeting specific energy savings levels; and identifies the buildings in a portfolio that can most easily achieve net zero energy (NZE).

While there are a number of other widely used, public access energy benchmarking and retrofit analysis tools on the market, such as the U.S. Environmental Protection Agency's (EPA) ENERGY STAR® Portfolio Manager®, International Finance Corporation's (IFC) Excellence in Design for Greater Efficiency (EDGE), and New Building Institute's FirstView, BETTER offers several new capabilities. First, BETTER is computationally inexpensive. BETTER's core analysis is built upon a piecewise linear regression model which requires minimal computation and memory resources. The entire runtime for a single building analysis is 5 to 10 seconds. The lightweight computation also allows the toolkit to run multiple models in parallel to speed up large portfolio analyses. Second, BETTER is scalable, offering both portfolio and building analysis in a single analytical run. This includes providing EE recommendations for the portfolio, allowing users to identify equipment upgrades that might be implemented at scale and could potentially qualify for bulk purchase or financing discounts. Third, BETTER offers multiple savings target levels (conservative, nominal, or aggressive), providing users with multiple options for EE improvement based on the scale of energy savings desired. Users can gradually increase the level of desired savings from EE over time. Fourth, BETTER recommends dozens of no-cost/low-cost EEMs to facilitate energy savings for organizations without a large capital budget for upgrades.

At this time, BETTER does not provide estimated implementation costs for recommended EEMs nor does it incorporate factors such as occupancy or operating schedules when estimating savings. While these variables do impact energy consumption and can be used to create more sophisticated regression models and perform more in-depth analysis, BETTER is intended to serve as an EE improvement targeting tool that maximizes the amount of energy benchmarking and retrofit analysis that can be done with readily available monthly utility bills and building characteristics. More information on BETTER’s limitations and areas for further research can be found in the Limitations and Avenues for Further Research subsection of this paper.

How BETTER Works

To target buildings for retrofit, BETTER uses regression techniques to analyze a building's monthly energy use in response to weather conditions in order to determine how much energy is weather-sensitive (heating and cooling), and weather-independent (lighting, plug loads, etc.). Normalized energy use data is fit to temperature patterns to determine whether heating and cooling set points are appropriate and whether the equipment is performing optimally. BETTER’s analytical workflow can generally be described in four steps: data preparation, change-point model fitting, benchmarking, and assessment; Figure 1 shows the conceptual diagram of BETTER’s single-building analysis workflow.

Data preparation

The process begins with BETTER calendarizing the utility bills that have been entered by a user, where bills with arbitrary start and end dates are distributed into calendar months weighted by the number of days in each month. Following this, utility bills with different energy types (i.e., electricity and fossil fuel) are aggregated by BETTER, providing a clear breakdown of energy usage. Subsequently, BETTER normalizes the monthly energy consumption by the number of days and the building’s gross floor area to derive daily EUI for further modeling analysis. Monthly weather data from various sources, including the National Oceanic Atmospheric Administration (NOAA) (NCEI 2024) and OpenMeteo (Zippenfenig 2024) is curated for 8,152 NOAA weather stations globally. Finally, BETTER validates the sufficiency

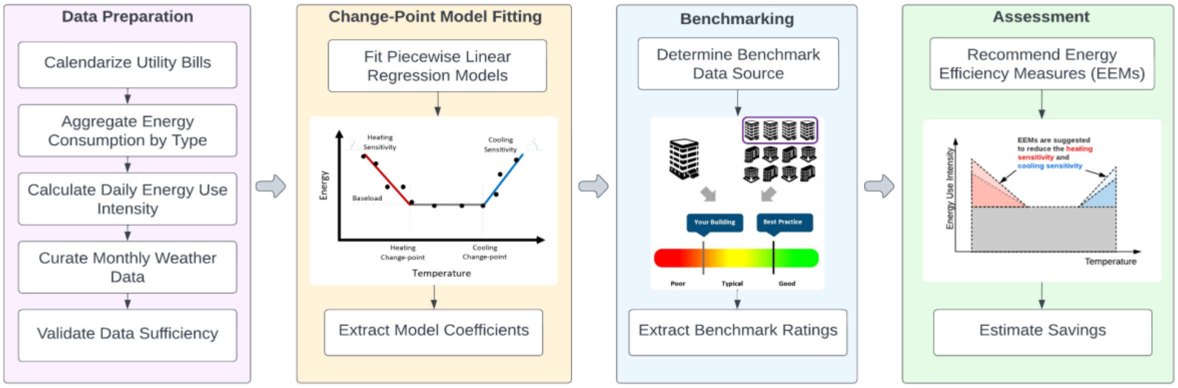

Figure 1. BETTER conceptual workflow for single building analysis.

of the gathered data to ensure reliable analysis in subsequent stages. Specifically, to ensure the analysis captures energy consumption patterns in all seasons, at least 12 consecutive months of utility bill data (which is automatically calendarized by BETTER) is required for electricity and/or fossil fuel. User-entered building location (e.g., city and state or postal code) is geocoded to find the closest NOAA weather station (usually at the nearest airport) to get the monthly weather data.

At this time, the tool does not automatically detect outliers in monthly utility bill data entered into BETTER. Instead, BETTER allows users to visually inspect monthly utility bills and decide whether to remove certain bills. BETTER also provides diagnosis when there is no model fit for the provided utility bills, which guides users to double-check their data before re-running the analyses.

Change-point model fitting

The core of BETTER's analysis capabilities is fitting piecewise linear regression models, which segment energy consumption into distinct operational modes. This technique identifies change-points whose coefficients delineate different energy usage patterns relative to outdoor air temperature, such as heating and cooling sensitivity, heating and cooling change-point temperature, as well as the non-weather-sensitive baseload. The change-point model algorithm originated from the American Society for Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Inverse Modeling Toolkit (Kissock et al. 2002). The physical implications of the extracted model coefficients are detailed in Table 1. The extracted model coefficients, which encapsulate the building's energy-weather-sensitivity, serve as a foundation for benchmarking its energy performance against peer buildings or national averages for the same primary space type.

Benchmarking

Benchmarking is a critical component of the BETTER analysis, allowing users to gauge the performance of their building against industry standards. Depending on data availability and the user’s selection, BETTER allows benchmarking a building against a normal distribution from buildings of the same primary space-type in a user-defined portfolio, or the national distribution. With regard to benchmarking against a user-defined portfolio, BETTER can be used to analyze the performance of any commercial building type for which a user can enter all required data (gross floor area, type, city location, and 12 consecutive months of energy use for all fuels) for at least 30 buildings. With regard to benchmarking against the national distribution, BETTER can analyze the performance of a single building, or a portfolio of less than 30 buildings, against U.S. national reference benchmark statistics for U.S. offices, U.S. K-12 schools, U.S. multifamily buildings, and U.S. public libraries.[3]

The benchmarking module compares the value of each extracted change-point model coefficient against the corresponding normal distribution. The comparisons provide quantitative information about where the building stands on a spectrum from “Poor” to “Good,” for different aspects of the building’s energy performance (i.e., weather-independent consistent load, weather-sensitive energy consumption). Specifically, a coefficient can be rated as “Poor” (at least one standard deviation worse than the median for the peer group), “Typical” (between one standard

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[3] The national statistics and their development process can be found at the “FAQ” page of BETTER under “Analytical Settings,” at https://better.lbl.gov/docs/faq/.

deviation worse and one standard deviation better than the median for the peer group), or "Good" (at least one standard deviation better than the median for the peer group).

Table 1. Change-point Model Coefficients and Their Implications.

Model Coefficient	Physical Implications
Baseload	Energy consumption of all non-weather-related equipment like computers and lighting. The lower the baseload, the less the energy consumed in plugs and permanently plugged equipment.
Cooling sensitivity	Cooling system energy consumption for each degree increase in outdoor temperature. Low cooling sensitivity indicates a less energy-consuming cooling system.
Cooling change-point	The temperature at which the building's energy consumption begins to increase as the temperature increases. The cooling change-point is also a proxy for the cooling setpoint temperature.
Heating sensitivity	Heating system energy consumption for each degree decrease in outdoor temperature. Low heating sensitivity indicates a less energy-consuming heating system.
Heating change-point	The outdoor air temperature at which the building's energy consumption begins to increase as the temperature decreases. The heating change-point is also a proxy for the heating setpoint temperature.

Assessment

The final step is the assessment phase, where BETTER recommends EEMs tailored to the building's specific energy consumption profile. These EEMs aim to address areas of inefficiency identified in the benchmarking stage, such as high heating or cooling sensitivity, or abnormal change-point temperatures and baseload. With these insights and engineering heuristics (Li et al. 2019), BETTER can also estimate potential energy, energy cost savings, and GHG emissions reductions from implementing the recommended EEMs, providing a compelling case for retrofit investments. BETTER estimates energy savings for a building by calculating the difference between the predicted current level energy consumption and the target level energy consumption. The corresponding cost savings and GHG reduction estimates are based on the energy savings and corresponding fuel price and marginal GHG emission factor, respectively. Proxy fuel prices and marginal GHG emission factors are automatically retrieved based on the building's location. Optionally, users can also provide their own utility cost so that BETTER can calculate the unit fuel prices for cost savings estimation.[4]

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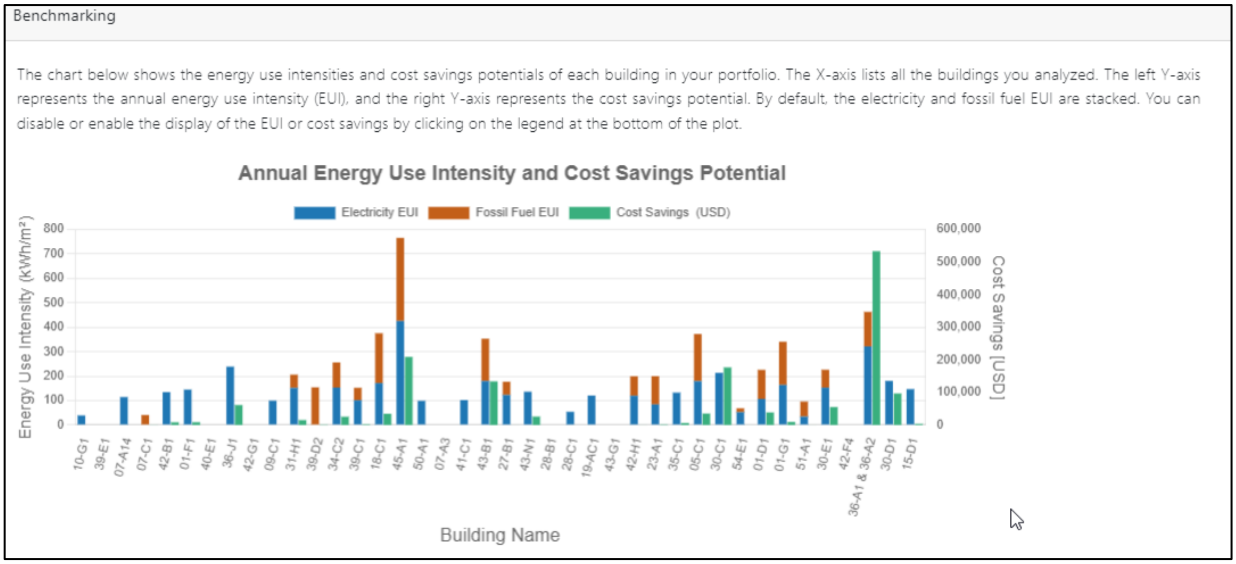
[4] For additional details, refer to the "Frequently Asked Questions (FAQ)" page of BETTER under "Output Reports" and "Weather, Fuel Price and Emissions Data" at https://better.lbl.gov/docs/faq/.

BETTER Analysis and Preliminary Results

As described above, BETTER allows a user to benchmark buildings within a user-defined portfolio for any space type or against U.S. national reference benchmark statistics for offices, K-12 schools, multifamily buildings, and public libraries. ERI decided to benchmark buildings within a user-defined portfolio. Specifically, ERI used BETTER to analyze each of the California state government branch's 455 non-residential buildings' monthly energy usage in response to weather conditions; benchmark each building's electric and fossil energy usage against similar buildings in the portfolio; quantify energy, cost and GHG emissions reduction potentials at the building and portfolio levels; and identify EE measures to decarbonize the state government branch's buildings and portfolio.

ERI benchmarked buildings in BETTER in batches of 50, grouping buildings with similar equipment or operating characteristics into the same batch for comparative analysis. Using BETTER, ERI produced detailed reports that identified the scope for retrofit and RCx projects in each of the 455 sites. An example of a BETTER portfolio analysis for 20 buildings in the state government branch portfolio is shown in Figure 2.


Benchmarking

The chart below shows the energy use intensities and cost savings potentials of each building in your portfolio. The X-axis lists all the buildings you analyzed. The left Y-axis represents the annual energy use intensity (EUI), and the right Y-axis represents the cost savings potential. By default, the electricity and fossil fuel EUI are stacked. You can disable or enable the display of the EUI or cost savings by clicking on the legend at the bottom of the plot.

Figure 2. Example BETTER portfolio analysis for buildings in the state government branch portfolio.

BETTER Analysis for Building 50-A1

BETTER's electricity change-point model and benchmark results for Building 50-A1 are shown in Figure 3. The model and benchmark indicated the building had typical to good electricity performance as compared to similar buildings in the state government branch portfolio. Moreover, it showed the mechanical cooling system efficiently cooled the building, and the occupied and unoccupied building cooling setpoints did not require adjustments. However, the benchmark showed there could be opportunities to reduce lighting and plug loads in the building.

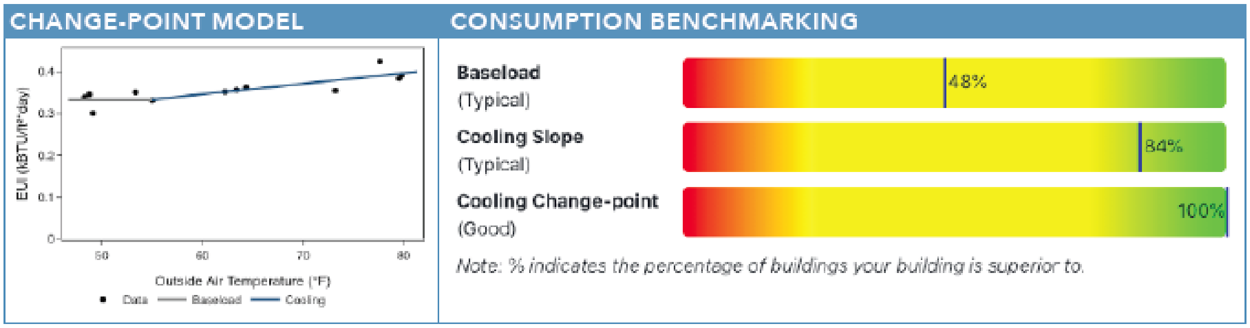


Figure 3. BETTER electricity change-point model and benchmark results for Building 50-A1.

BETTER's fossil fuel change-point model and benchmark results for Building 50-A1 is shown in Figure 4. BETTER determined that Building 50-A1 had poor fossil fuel performance as compared to similar buildings in the portfolio. The building's heating slope coefficient was worse than 87% of peer buildings, pointing to potential problems with the building envelope, infiltration/ventilation rates, and the overall efficiency of the mechanical heating system. Finally, analysis indicated that occupied and unoccupied heating setpoints in the building needed to be reduced.

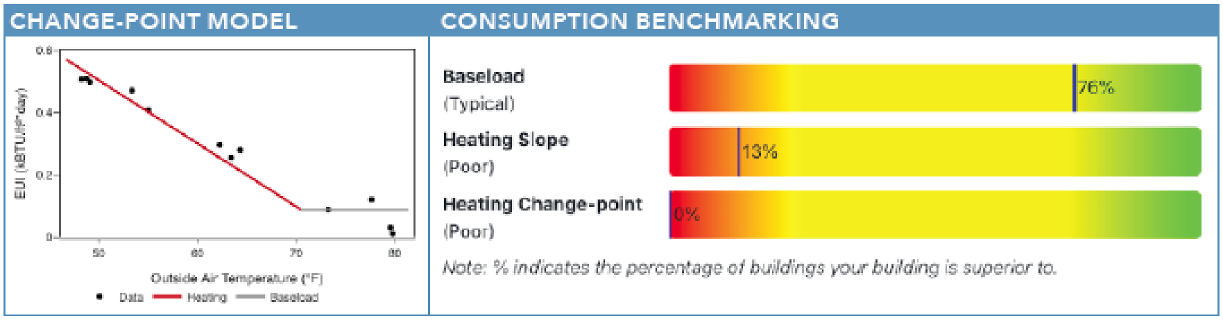


Figure 4. BETTER fossil fuel change-point model and benchmark results for Building 50-A1.

BETTER recommended the following EEMs to achieve energy, cost, and GHG emissions reductions in Building 50-A1: reduce lighting load, reduce plug load, ensure adequate ventilation rates, reduce equipment schedules, decrease heating set points, add wall / ceiling insulation, decrease infiltration, and increase heating system efficiency. BETTER estimated that making the EE improvements would reduce annual energy consumption by approximately 33.7%, cutting annual energy costs by roughly $66,687 and avoiding emission of 275.5 t CO_2e.[5] BETTER analysis further showed that the majority of cost savings would result from a reduction in fossil fuel used for heating and electricity for baseload functions.

Based on the BETTER analysis conducted for 455 sites (similar to that shown for Building 50-A1 in Figures 3 and 4), ERI determined the state government branch could save up to $6.6 million in annual energy costs, reduce annual electricity usage by 33 million kilowatt

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[5] See the Assessment subsection of this paper for information on how BETTER estimates energy, energy cost, and GHG emissions reductions.

hours (kWh), and natural gas usage by 900,000 therms through a variety of retrofit and RCx measures similar to the example described above.

Scaling the Solution

While BETTER assisted the state government branch initiate its EE improvement program by helping it to benchmark energy performance and prioritize buildings for audits, retrofits, and RCx projects, BETTER is not designed to help consolidate monthly energy performance data coming from numerous sources (e.g., spreadsheets, ENERGY STAR® Portfolio Manager®) and manage that data to scale its retrofit program and comply with future energy policies, such as the Building Energy Savings Act (Senate Bill 48), which will fund the development of a statewide building performance standard (BPS) (IMT 2023). Thus, the state government branch turned to the DOE SEED Platform to further manage and scale its retrofit program.

SEED Overview

The SEED Platform is an open-source software application designed to manage building performance data, such as building characteristics, energy consumption, and CO_2 emissions (as required by a benchmarking ordinance or BPS), which can be costly and time consuming for states, local governments, and organizations operating building portfolios to manage and track over time. SEED helps users combine data from multiple sources, clean and validate those data, and generate queries and reports. SEED can be used directly as a web platform or a backend to other solutions. The core functionality of SEED includes the ability to: handle the complicated nature of building data, such as the relationship between parcel and tax lot data and buildings; import data from many sources and map to standardized fields;[6] automate data quality checks; automate merging, matching and linking of data; provide a web-based platform with user access controls; and provide graphs and charts to evaluate the performance status of the buildings. As shown in Figure 5, it is also possible to integrate SEED data with other applications, such as BETTER, through API connections and data exchange protocols.

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[6] Spreadsheets of jurisdiction tax records or other property data; spatial data such as GeoJSON; building asset data from DOE tools such as Audit Template and BuildingSync™; or building energy performance data from ENERGY STAR® Portfolio Manager®.

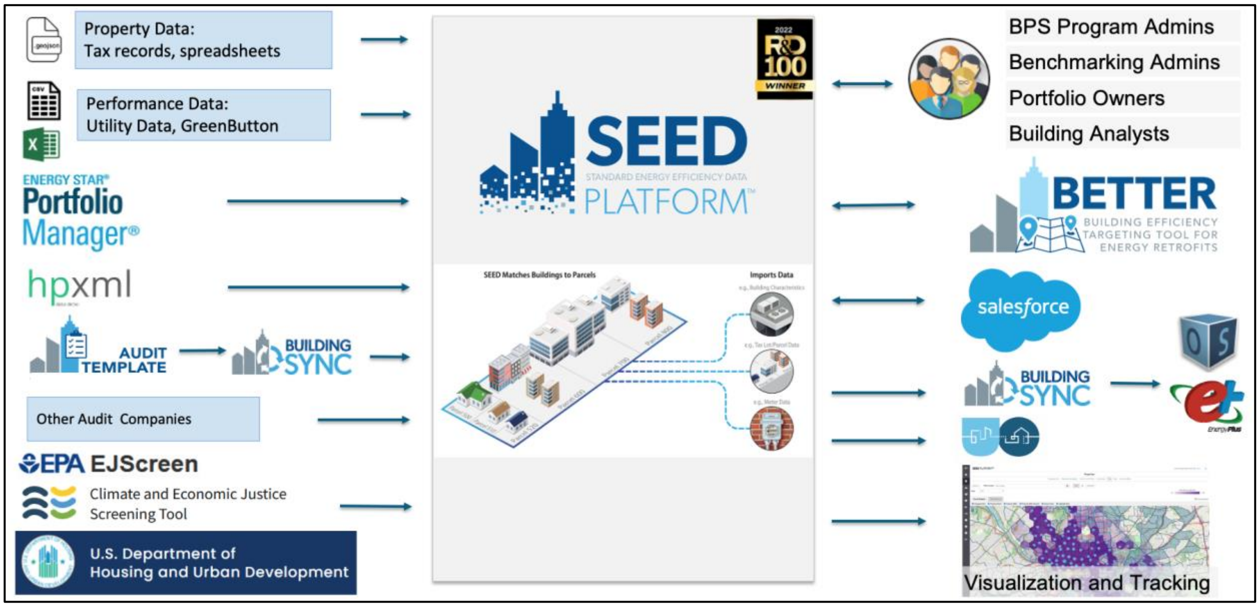


Figure 5. SEED interoperability with other data tools and platforms

In the case of the California state government branch, the SEED Platform was selected to complement the application of BETTER because the agency could easily import a large proportion of their portfolio's building performance data from ENERGY STAR® Portfolio Manager® into SEED and then run BETTER analyses on it directly from the SEED Platform through the API connection.

How the California State Government Branch Used SEED and BETTER Together

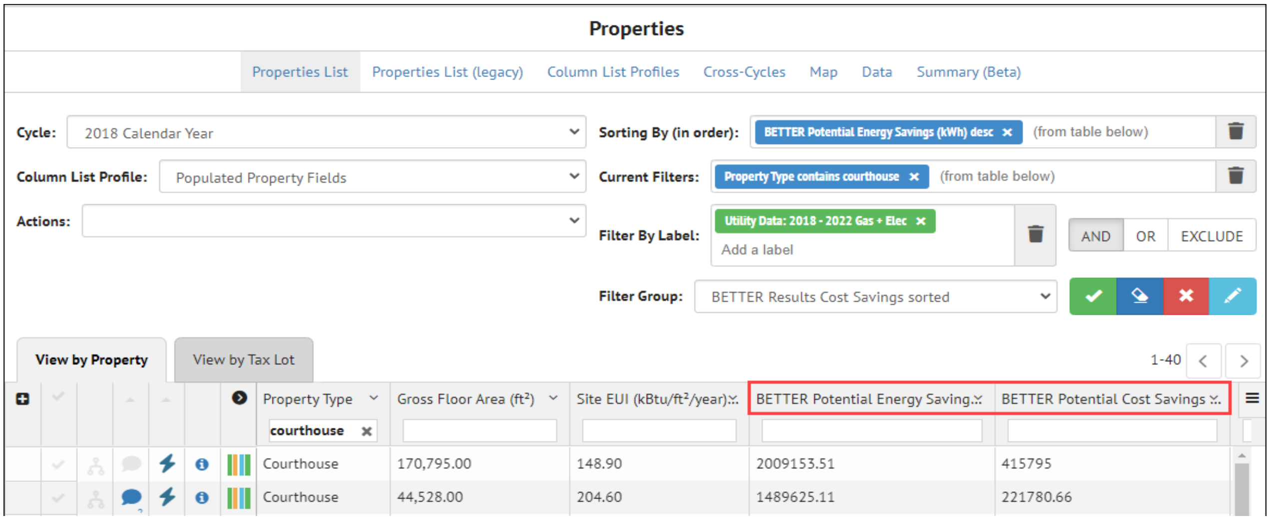
The SEED user support team at Berkeley Lab and NREL created an Organization account on a production instance of SEED. A SEED administrator added the required users from the State of California as "users" so that data could be uploaded by the respective user. In addition to creating the account, it was necessary to create a BETTER account, obtain a BETTER analysis API key for that account, and enter that API key into the SEED account. The SEED support team then assisted the California government branch in uploading into the SEED account the buildings that were in ENERGY STAR® Portfolio Manager®. Figure 6 shows the building energy data for the non-residential properties, including site EUI, in order to determine which buildings have the highest energy consumption. Data was then loaded into the SEED account across five years of ENERGY STAR® Portfolio Manager® records (2018–2022), and SEED showed "cross-cycle" comparisons for those years, showing the change, for example, in site EUI across those years. Once the building energy data was imported into SEED, the user support team assisted the California government branch to run BETTER analysis on a subset of the buildings. All data needed to run the BETTER analysis came directly from the ENERGY STAR® Portfolio Manager® account via SEED and no additional manual data entry was required. The workflow to evaluate the SEED records through BETTER involved the following steps.

Step 1. selection of buildings for BETTER analysis. In order to perform a BETTER analysis for a building in SEED, it is necessary to have 12 consecutive months of energy consumption data stored in SEED. It is also necessary for all the buildings in an analysis set to be of the same "Property Type." With those criteria, 40 buildings were selected to run BETTER through SEED.

Step 2. run BETTER from SEED. SEED then passed the needed information to BETTER for each building, using the API connection. As a result, the buildings were created in BETTER; monthly energy data was added to each building; each building was analyzed in BETTER; the BETTER results are communicated back to SEED via the API connection and added to the SEED database for each building. Technical details can be found at BETTER's API documentation.[7] The API connections all happen "behind-the-scenes" and the SEED / BETTER user does not need to know anything about how the API connection works. However, programmers can take advantage of the API connections in both platforms to perform analysis tasks if desired.

Step 3. view BETTER results in SEED. In the Analyses section of SEED, the high-level results for the 40 buildings were displayed, showing the settings for the analysis, as well as whether a change-point model could be developed for each building.

The main results for the BETTER analysis show the number of buildings, as well as the BETTER analysis settings and the date the analysis was created. A portfolio report is generated by BETTER and can be displayed in SEED. Figure 6 below shows some of the data that is reported in the Portfolio result. The BETTER results are also added as fields to the SEED database, and can be displayed in the Property List view. In the figure below, the field "BETTER Potential Energy Savings" is shown in descending order with the highest potential savings first.



Cycle: 2018 Calendar Year
Column List Profile: Populated Property Fields
Actions:
Sorting By (in order): BETTER Potential Energy Savings (kWh) desc (from table below)
Current Filters: Property Type contains courthouse (from table below)
Filter By Label: Utility Data: 2018 - 2022 Gas + Elec
Filter Group: BETTER Results Cost Savings sorted

Property Type	Gross Floor Area (ft²)	Site EUI (kBtu/ft²/year)	BETTER Potential Energy Saving	BETTER Potential Cost Savings
courthouse				
Courthouse	170,795.00	148.90	2009153.51	415795
Courthouse	44,528.00	204.60	1489625.11	221780.66

Figure 6. The BETTER results are added as fields to the SEED database and can be filtered and sorted as needed. In this screenshot, the "BETTER Potential Energy Savings" is sorted in descending order.

The Unique Value of Accessing BETTER from the SEED Platform

Running BETTER analysis from within SEED provided the California state government branch some important advantages over using BETTER alone with regard to scaling its retrofit

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[7] https://better.lbl.gov/docs/api/

program. First, it could combine building energy performance management data from spreadsheets as well as ENERGY STAR® Portfolio Manager® into a single platform and run BETTER without further data translation. Second, it could also view the BETTER analysis for an individual building in both SEED and BETTER (avoiding the need to duplicate data entries in BETTER). Third, it could sort, filter, and then label the buildings in SEED that should have a detailed audit performed for energy retrofit recommendations. Fourth, when buildings were identified as warranting further analysis, it could add audit information (from Audit Template or BuildingSync™) to the existing building data in SEED. Fifth, from within SEED it could easily view and analyze building energy performance changes over time. Finally, it could perform further analysis for BPS using the Insights feature of SEED, which allows SEED users to set energy and GHG emission targets for the future and to see how specific buildings, as well as the building portfolio, are meeting those targets over time.

Preliminary Results

As a result of implementing BETTER, the state government branch selected nine buildings for investment-grade audits based on the following criteria: energy and cost savings potential greater than 25%; energy use intensity greater than 50,000 kBtu/ft^2/year; and electricity demand greater than 300 kW. As a result of subsequent investment-grade audits and application of SEED, the state government branch has scoped retrofit projects in those nine buildings across its portfolio which are estimated to save approximately $834,350 in annual energy costs and avoid emissions of 2,271 t CO_2e per year. While the results of all nine audits were not assessed by the authors, in the case of Building 50-A1 described above, six of the seven EEMs identified by BETTER were also identified by the audit. Moreover, BETTER's estimated energy saving for Building 50-A1 of 5,093,770 kBtu/year was almost identical to the auditor's estimated energy saving of 5,097,736 kBtu annually.[8] The state government branch is also considering entering buildings prioritized by BETTER for retrofits into DOE's Building Energy Asset Score tool to further assess the costs and potential savings from large capital improvements recommended by BETTER (e.g., fenestration upgrades).

According to the sustainability supervisor for the California state government branch, the use of BETTER and SEED "improved our workflow efficiency by allowing us to consolidate building energy performance data from multiple sources across the state; conduct portfolio-level analysis; and prioritize buildings for investment-grade audits and retrofits." (Y. Roussev, sustainability supervisor, California government branch, pers. comm., February 21, 2024).

Limitations and Avenues for Further Research

Despite the success of this pilot project, limitations may exist for other jurisdictions to follow the California government branch's lead. First, the California government branch sustainability supervisor noted that training material isn't yet publicly available to guide jurisdictions to access BETTER from SEED, which may inhibit others from pursuing a similar approach. Moreover, the workflow hasn't yet been tested on portfolios larger than 500 buildings, and it would be important to ensure the BETTER-SEED API connection is equipped to handle

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[8] While the cost of the retrofit of Building 50-A1 was estimated during the investment grade audit, that information was not collected as part of this study comparing BETTER results to audit results because BETTER does not estimate retrofit costs at this time. See the Limitations section for more details.

the analysis of thousands of buildings in a single analytical run to support compliance with BPS programs or other large-scale energy and decarbonization policy implementation.

Second, objective studies comparing BETTER's remote analysis results to investment grade audit results are limited to the single building comparison in this paper. To address this limitation, there are forthcoming studies planned to evaluate BETTER results against audit results, including a study by PowerOptions, a non-profit energy consortium, to compare the results of American Society for American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Level 2 audits against BETTER results for 15 multifamily buildings. In the meantime, there is some anecdotal evidence of the tool's efficacy. For instance, the Energy Education Coordinator for Prince William County Public Schools (the second largest school division in Virginia) used BETTER to reduce annual energy costs by 17% in eight schools. Additionally, the Energy Sustainability and Analytics Program Manager at PowerOptions reported that their organization used BETTER to analyze over fifty buildings across a dozen portfolios for its members' Building Decarbonization Roadmaps. As part of this initiative, PowerOptions verified with their members' facility management teams that for every 10 EEMs recommended by BETTER in the Building Decarbonization Roadmaps, nine of them had not been implemented in the past 10 or more years in the facility and were a needed improvement (BETTER 2024).

A third limitation is that although building energy consumption is impacted by various factors (e.g., climate, insulation, occupancy, operation schedules), BETTER only breaks down building energy consumption into weather-sensitive and non-weather-sensitive components. To quantify the impacts of non-weather factors (e.g., occupancy, operating hours), users will need to collect more data and conduct deeper analysis outside of BETTER.[9]

Another limitation of BETTER is that, at this time, it does not provide estimated implementation costs for recommended EEMs, and therefore, does not take into account local incentives nor provide cost-effectiveness metrics, such as the net present value (NPV), payback period, or internal rate of return (IRR), to help prioritize and plan retrofit projects. To address this limitation, the Berkeley Lab team that manages BETTER is exploring options to incorporate the aforementioned cost-effectiveness metrics into the tool. In the case of the California government branch, they overcame this potential limitation by utilizing BETTER to select buildings for investment grade audits based on criteria unrelated to cost. The investment grade audits themselves provided the cost-effectiveness metrics associated with the RCx and retrofit projects.

Finally, as described in the Benchmarking subsection above, while BETTER allows users to compare the energy performance of a building against a normal distribution from peer buildings of the same primary space type in a user-defined portfolio, or against the national distribution for the primary space type, there are only four primary space types for which a national distribution and U.S. reference benchmark statistics are embedded into the tool. Currently, U.S. reference benchmark statistics exist for U.S. offices, U.S. K-12 schools, U.S. multifamily buildings, and U.S. public libraries. To address this, DOE is continuing to identify primary space types for which Berkeley Lab will add the national distribution and embed reference benchmark statistics. Approximately one to two space types have been added each year since BETTER's inception, and that pace is anticipated to continue.

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[9] See the BETTER Overview subsection for more on how BETTER's data requirements and analytical methodology support its specific role in the market as an EE improvement targeting tool.

Guidance for Other Jurisdictions

Despite these potential limitations, the California state government branch plans to continue to use both BETTER and SEED to implement its portfolio EE improvement strategy to meet state energy and GHG emissions reduction goals. The following are recommendations for other jurisdictions and supporting organizations to get started. Begin by setting up an account in BETTER. Setting up a BETTER account requires minimal time and effort and will allow a jurisdiction to familiarize itself with the tool and ensure that it provides the type of analysis needed. Pilot BETTER with a portfolio of 30 buildings of the same type, and, to the extent possible, utilize the data transfer capabilities between ENERGY STAR® Portfolio Manager® and BETTER to streamline the data entry process into BETTER. Once the jurisdiction has determined BETTER provides valuable analysis, then contact the SEED user support team at Berkeley Lab and NREL to set up a SEED instance, and use SEED to manage a jurisdiction's building performance data and unique organizational capacities unavailable in BETTER, as described in the subsection How the California State Government Branch Used SEED and BETTER Together. From within SEED, run BETTER analysis on either the entire portfolio or sub-divide into smaller portfolios (50 buildings or less) that have similar characteristics in terms of building type, building vintage, occupancy levels, operating hours, and/or climate zone for more of an "apples to apples" comparison. Scan the portfolio analytics (e.g., Figure 2) to identify which buildings are good candidates for operations and maintenance tune-ups due to mid-range energy and financial performance; which buildings are already high performers and for which design, technology, and operational best-practices can be shared across the portfolio; and which buildings may require audits and/or capital investments due to high energy and cost savings potential. Finally, be prepared with internal or external capital to finance audits and retrofits. The initial set of nine audits that were executed by the state government branch were immediately funded with internal capital. Consider options to set aside cost savings in a revolving fund that can be used to finance future retrofits across a large public portfolio.

Conclusions

In conclusion, while limitations exist for both BETTER and the BETTER-SEED workflow, together, these tools, both free and open-source,[10] represent important advancements in data-driven, remote building energy management and analysis that are increasing the speed and scale of retrofits and RCx projects in the United States. Together, these platforms can be utilized, and built upon, to scale the impact of both market distribution technologies and to overcome four major barriers to preparing buildings for retrofit. The first barrier is the high cost of energy audits. BETTER can be utilized in place of an entry-level (Level 1) audit, where the purpose is to identify the rough potential for energy savings in a building and recommend EEMs (Kelsey 2021). As shown in the case presented here, BETTER helped to avoid Level 1 audit costs of $3.28 million and identified nine buildings for Level 2 investment grade audits based on the specific goals of the California state government branch. The second barrier is the need for collection of detailed data on building equipment and systems, which is often required to develop and calibrate robust building energy models. SEED facilitates data collection from multiple readily available sources (e.g., tax records, utility bills), cleans, and validates it. Once entered

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[10] BETTER's analytical engine source code is available on GitHub and can be adopted, redeveloped, and redistributed freely under an open-source license. The BETTER web application and API are not open source.

into SEED, BETTER requires only building type, location, gross floor area, and 12 consecutive months of energy consumption to generate a retrofit analysis. The use of easily-obtained building and energy data significantly simplifies and expedites the retrofit process for the U.S. market. The third barrier is the need for domain expertise to perform audits and building energy modeling. BETTER and SEED are user-friendly tools with simple user interfaces. The tools require no specific building domain expertise, unlike audits and use of most physics-based models (Lee et al. 2015). The fourth barrier is the high cost of retrofits themselves. Where budgets for EE retrofit may be limited, BETTER recommends approximately 20 no-cost or low-cost operational interventions (such as thermostat temperature setback for cooling) that can immediately save energy and costs across a portfolio. Similarly, BETTER's ability to recommend EEMs for the portfolio also enable users to identify system or equipment upgrades might be implemented at scale and could potentially qualify for bulk purchase or financing discounts. While audit costs, data requirements, and domain expertise are not a major deterrent for carrying out retrofits in a single building, these factors can prevent building owners and operators from taking action at scale.

However, to maximize the impact of these tools, additional work is needed to support deployment through training and technical assistance (TA) programs. In particular, these efforts should focus on deployment in U.S. small commercial buildings and public school districts. According to the U.S. Energy Information Administration (IEA) 2018 Commercial Buildings Energy Consumption Survey (CBECS), U.S. small commercial buildings have natural gas intensities almost double that of U.S. large commercial buildings (IEA 2018), and a June 2020 Government Accountability Office (GAO) report found that about 50% of public school districts are struggling to upgrade and maintain key building systems that ensure facilities are free of health hazards (U.S. DOE EERE 2023). By providing training to these groups, underserved markets will have the tools and capacity to take readily available building and energy data and implement no-cost operational upgrades, thereby reducing EUI in some of the most energy-intensive sectors in the United States (e.g., food service and sales) and helping to address school facility deterioration, which has negative impacts on both student and teacher health and performance.

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