Building Technology & Urban Systems Division
BERKELEY LAB

Beyond Widgets: Integrated Efficiency and IAQ Retrofit Package for K-12 Schools

Goal: Develop school retrofit packages capable of delivering significant energy savings and Indoor Air Quality (IAQ) benefits

Integrated system retrofit packages present opportunities for deep energy savings; however the added complexity of such retrofits requires more effort for design and energy savings assessments. This can create barriers for utility incentive programs that need to be able to easily evaluate such projects and estimate energy savings. The Beyond Widgets program addresses barriers to systems-based retrofits by developing, testing, and validating integrated packages of efficiency retrofits and creating streamlined approaches to implementation.

Motivation for IAQ – focused retrofit packages

Underinvestment in school facilities and mechanical equipment across the U.S means many systems operate inefficiently, are poorly maintained[1], and do not guarantee adequate ventilation. The need to improve ventilation and filtration to support better IAQ can be an opportunity for school districts to also upgrade their heating, ventilation, and air conditioning (HVAC) systems. Schools can achieve significant energy, cost, and emissions reductions from efficiency retrofits, and improved ventilation and IAQ supports a healthier and more productive learning environment[2], reducing exposure to outdoor and indoor-generated air pollutants and helping mitigate risks from airborne viruses.

Approach: Packaged retrofit solutions

Recognizing school needs for improved efficiency and IAQ, the Beyond Widgets team identified energy efficiency measures (EEMs) that can deliver significant energy savings and in many cases improved IAQ as well. EEMs included occupancy-based ventilation strategies, efficient lighting and controls, efficient supply air filtration, HVAC sequence improvements, retuning, and scheduling, and HVAC equipment upgrades. EEMs were combined into ten distinct system packages that improve cost-effectiveness and energy impact.

Validation through simulations and experiments

Whole building energy simulations were carried out for a typical existing school building reference model (single-story elementary). Modeling included baseline building performance and performance with the proposed retrofit package in order to predict annual savings (energy, utility cost, and CO_2). Retrofit performance was simulated for climate zones in CA and NC. Combining electricity and gas savings, site energy savings for the packages ranged from 14% to 36%. After simulation analysis, one of the retrofit packages (package 5: efficient lighting and controls, demand control ventilation (DCV), economizer retuning, outside air scheduling, MERV 14 supply air filters) was selected for further development, including validation through FLEXLAB testing. The graph on the following page shows packge 5 savings results for the NC climate zone simulation.

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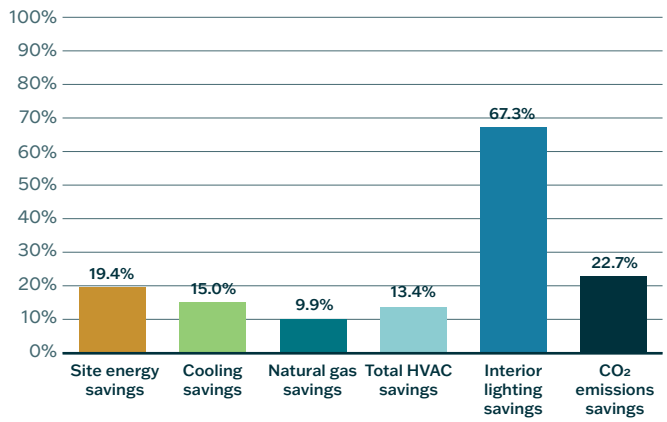
1 Pistochini, et al. (2020) Improving Ventilation and Indoor Environmental Quality in California K-12 Schools. California Energy Commission. www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-049.pdf

2 D. Vakalis, C. Lepine, H. L. MacLean & J. A. Siegel (2020): Can green schools influence academic performance?, Critical Reviews in Environmental Science and Technology, DOI: 10.1080/10643389.2020.1753631

Retrofit package validation in LBNL's FLEXLAB. Occupant emulators and programmable plug loads are shown at desks in a classroom configuration.

Simulated whole building savings (NC climate zone) for retrofit package 5



The ratio of $PM_{2.5}$ in the retrofit cell over the existing building cell, for three testing seasons

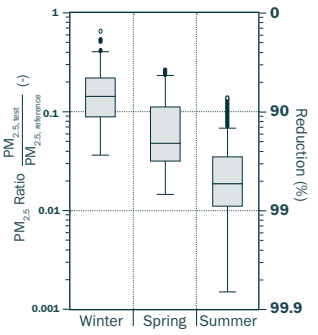
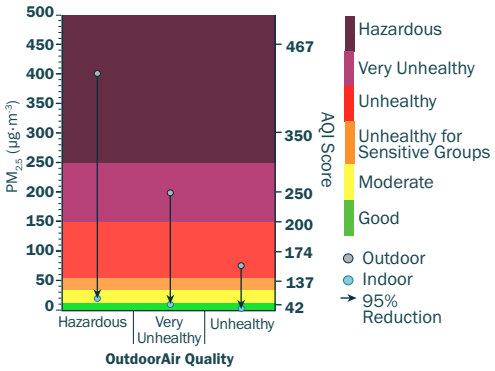


Illustration of what 95% reduction in $PM_{2.5}$ corresponds to in terms of EPA's air quality index



Retrofit Package EEMs

- LED lighting retrofit with advanced controls (including occupancy and daylight sensing)
- Demand Control Ventilation (DCV) with zonal CO_2 sensors, reduces supply air energy demands during unoccupied periods while ensuring that air quality meets defined limits
- Economizer retuning to fix faulty operation and ensure adequate ventilation and free cooling operation when outside air conditions allow
- Outside Air (OA) scheduling to ensure synchronization with occupancy schedules
- MERV 14 supply air filtration – improves removal of particulate matter ($PM_{2.5}$) from outdoor sources like vehicle exhaust and wildfire smoke and mitigation of airborne pathogens.

The system package was also tested in LBNL's FLEXLAB™ (flexlab.lbl.gov) under a range of seasonal conditions to evaluate the energy performance benefits and indoor environmental and air quality implications, compared against an existing building baseline. Lab validation included measurement of energy savings, environmental quality parameters like task illuminance, thermal comfort measurements, and the IAQ parameter of $PM_{2.5}$ concentrations.

For visual comfort, task illuminance levels were maintained above 500 lux in all locations of the test space during occupied hours. Thermal comfort was also maintained at very similar performance levels between the baseline and retrofit cases, under the indices of Predicted Percentage Dissatisfied (PPD) and Predicted Mean Vote (PMV). The difference in $PM_{2.5}$ concentrations between the cell with the retrofit package (including MERV 14 supply air filters) and the baseline cell with typical filtration conditions was dramatic. The ratios of the $PM_{2.5}$ levels in the test cell relative to the reference cell show 80% to over 99% reductions in $PM_{2.5}$ concentrations, with a mean value of around 95% improvement.

PUBLICATIONS

Shackelford, J., Robinson, A., Regnier, C., & Lee, S. (2023). Getting Beyond Widgets: Performance of Efficient Indoor Air Quality System Retrofit Packages for Schools - a report on the modeled energy, greenhouse gas, and cost savings of several multi-measure retrofit packages for energy efficiency and indoor air quality in primary schools. Lawrence Berkeley National Laboratory. https://eta.lbl.gov/publications/getting-beyond-widgets-performance

For a study of more retrofit packages developed for elementary and secondary rural and urban schools, with simulated package performance in 10 climate zones around the U.S., see: Shackelford, J., Dutton, S., Regnier, C., Chan, W., & Robinson, A. (2024). Modeled Retrofit Package Performance for Schools. Lawrence Berkeley National Laboratory. Modeled Retrofit Package Performance for Schools. A companion one-page summary is also available, Modeled Retrofit Package Performace for Schools Overview.