California K-12 and Community College Zero Net Energy Retrofit Readiness Study

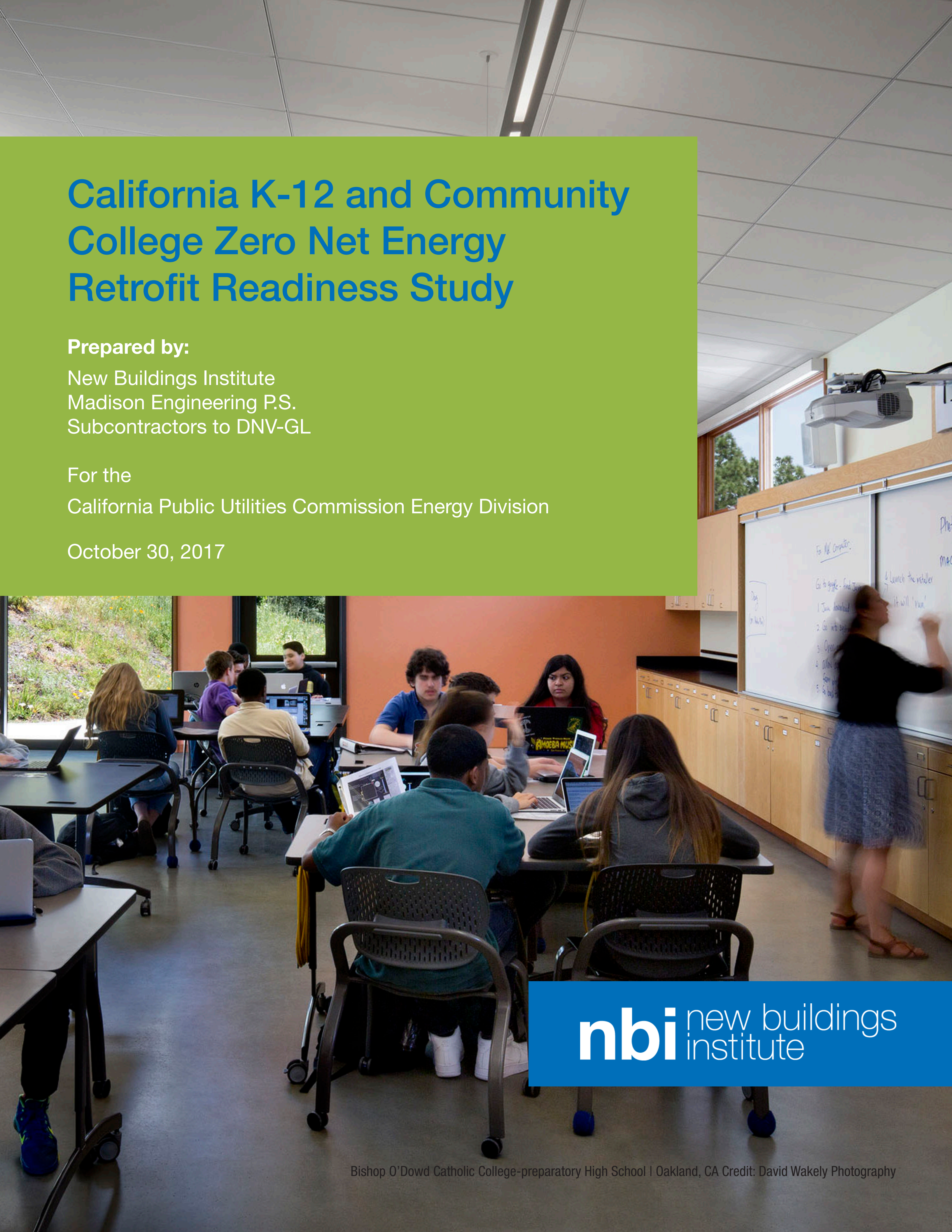
Prepared by:

New Buildings Institute
Madison Engineering P.S.
Subcontractors to DNV-GL

For the

California Public Utilities Commission Energy Division

October 30, 2017



Bishop O'Dowd Catholic College-preparatory High School | Oakland, CA Credit: David Wakely Photography

nbi new buildings institute

This page is was intentionally left blank.

TABLE OF CONTENTS

TABLES

FIGURES

GLOSSARY

ADA	Americans with Disabilities Act
BOC	Building Operator Certification
CASBO	California Association of School Business Officials
CASH	Coalition for Adequate School Housing
CCC	California Conservation Corps
CDE	California Department of Education
CEC	California Energy Commission
CEUS	California Commercial End-Use Survey
CHPS	Collaborative for High Performance Schools
CMAS	California Multiple Award Schedules
CPUC-ED	California Public Utility Commission – Energy Division
CSS	Commercial Saturation Survey
DEER	Database for Energy Efficiency Resources
DOE	Department of Energy
DGS	Department of General Services
DSA	Division of the State Architect
ED-GRS	U.S. Department of Education Green Ribbon Schools
EEP	Energy Expenditure Plan
EMS	Energy Monitoring System
EPA	Environmental Protection Agency
ESCO	Energy Service Company
EUI	Energy Use Intensity
FPU	Facilities Planning Utilization
FUSION	Facility Utilization Space Inventory Options Net
HVAC	Heating, Ventilating, and Air Conditioning
IgCC	International Green Construction Code
IOU	Investor Owned Utilities
IPD	Integrated Project Delivery
kWh	Kilowatt Hour

LCFF	Local Control Funding Formula
LEA	Local Education Agency
LED	Light Emitting Diode
LEED	Leadership in Energy and Environmental Design
LPD	Lighting Power Density
NBI	New Buildings Institute
O&M	Operation and Maintenance
OPR	Owners Project Requirements
OPSC	Office of Public School Construction
PA	Program Administrator
PG&E	Pacific Gas and Electric
PPA	Power Purchase Agreements
RECs	Renewable Energy Credits
SAB	State Allocation Board
SBD	Savings by Design
SCE	Southern California Edison
SCG	Southern California Gas
SDG&E	San Diego Gas and Electric
SDUSD	San Diego Unified School District
SEC	School Energy Coalition
SEEP	School Energy Efficiency Program
SFP	School Facility Program
SFUSD	San Francisco Unified School District
SIR	Savings to Investment Ratio
SFMP	School Facility Modernization Program
SSPI	State Superintendent of Public Instruction
USGBC CGS	U.S. Green Building Council Center for Green Schools
WE&T	Workforce Education and Training
ZESA	Zero Energy School Accelerator Program
ZNE	Zero Net Energy

CONTACT INFORMATION

CPUC Contract 12PS5095 between DNV-GL and the CPUC covers *The California K-12 and Community College Zero Net Energy (ZNE) Retrofit Readiness Study*. New Buildings Institute (NBI) and Madison Engineering are each separately subcontracted to DNV-GL for this work. The evaluation effort occurred under work order ED_D_ZNE_1, Task Order 04.

Table 1 below presents the various individuals involved in this effort.

Table 1: Individuals Involved in Research

Firm/Agency	Name	Role	Email	Phone
CPUC Energy Division	Robert Hansen	Study Manager at the California Public Utility Commission – Energy Division (CPUC-ED)	Robert.Hansen@cpuc.ca.gov	415-703-1794
CPUC Energy Division Advisor	Ralph Prahl	Oversight and Advisory	ralph.prahl@gmail.com	608-334-9942
CPUC Energy Division Advisor	Nikhil Gandhi	Oversight and Advisory	nikhilvgandhi@gmail.com	978-264-0511
CPUC Energy Division Advisor	Mary Sutter	Oversight and Advisory	mary@grounded-research.com	510-387-5538
New Buildings Institute	Amy Cortese	Director of Study	amy@newbuildings.org	503-761-7339
New Buildings Institute	Mark Lyles	Technical Contributor	markl@newbuildings.org	503-761-7339 x107
New Buildings Institute	Mark Frankel	Technical Director	mark@newbuildings.org	503-761-7339
Madison Engineering	Jeremy Lerond	Energy Analyst and Modeler	jeremy.lerond@gmail.com	206-834-0002
Madison Engineering	Kevin Madison	Manager, Energy Analysis	kevinmadisonmeps@gmail.com	206-834-0002

1. Executive Summary

The purpose of this Zero Net Energy (ZNE) Retrofit Readiness Study is to investigate decision-making patterns and funding practices as well as the ZNE potential in public kindergarten through twelfth grade schools and community colleges in California (collectively referred to as “K-14”). California is a national leader in ZNE, although no school in California or elsewhere has yet been retrofit to ZNE performance. The study provides recommendations to California Program Administrators (PAs) and other key market actors on how to best stimulate and enable this market to meet California’s aggressive ZNE targets regarding existing schools and community colleges.

The research approach of this study differs from a typical energy efficiency market characterization. It includes both insights regarding market characteristics (including decision-making and financing) as well as a technical energy “sensitivity analysis.” The study team gathered data from three distinct activities: 1) literature review, 2) stakeholder interviews and 3) engineering modeling. The literature review informed the questions asked during 22 stakeholder interviews where the market structure, barriers and needs to drive school retrofits towards ZNE were discussed with professionals both familiar and unfamiliar with ZNE. The engineering modeling analysis is described further below.

Market Structure and Decision-Making

Schools and community colleges are a strategic early adopter market in efforts to achieve California’s energy efficiency and carbon reduction targets. California has 1,025 school districts with 10,452 public schools and 72 community college districts with 113 total community colleges. Over 8.4 million students attend public schools and community colleges in California each day. Local school boards are the ultimate decision-maker in K-12 schools, they are motivated by educational outcomes for students, and they consult with a broad array of stakeholders during a complicated public process regarding school retrofits. Decisions regarding facilities are based on planning documents that revolve around addressing capacity and student needs and rarely mention energy. Only a few (typically large urban districts) have formal energy plans with district-wide energy savings goals.

Local Community College districts across California are responsible for maintaining, renewing and enlarging the facilities at their institutions. The governing board of each community college district develops a variety of plans regarding facilities with stakeholder input to inform key components of the capital projects. Local community college plans are submitted through a centralized online tool that streamlines the submission of documents and allows for tracking of district facilities.

Funding

While utility bills and day-to-day operations in K-14 schools are paid for with school district general funds, renovations are primarily financed by local school bonds passed by voters and sometimes matched with state bonds funding. In 2016, California voters passed Proposition 51 which allocated $9 billion to new construction and retrofit of school facilities. In addition, local voters passed approximately $28 billion in local school bonds for major school capital projects.

School facility bonds are carefully drafted to be both specific and flexible. They are focused on improving the learning environment for students and not on energy considerations. Local school boards hire design teams and contractors that work in tandem with staff and the public to ensure that renovated facilities meet the needs of the district and the goals as outlined in the bond. Local districts submit plans to the Division of the State Architect for review and to receive state matching funds through the School Facility Program. State review is only to ensure that certain requirements for state funding are met; the State Architect has no control over local decisions.

The California Clean Energy Jobs Act (Proposition 39) allocated state general funds money for energy efficiency projects in schools between fiscal years 2013/14 and 2018/19. Thus far, this program has directed $1.4 billion to school districts across the state. The California Department of Education (CDE) and the California Energy Commission (CEC) created an eight step framework for school districts to use in the development of Energy

Expenditure Plans (EEPs). Once approved, energy efficiency activities outlined in these EEPs (about half of which are lighting-related) will be implemented and are expected to garner 393 GWh of electricity savings and 236,000 MMBtu of natural gas savings along with $80 million and 150,000 tons of carbon dioxide equivalent each year. Discussions in the state legislature are underway to dedicate additional state funds to energy efficiency in schools in future fiscal years.

The California IOUs are administering a separate $8 million Prop 39 ZNE school retrofit pilot project. At this time, initial pilot projects have been selected, and ZNE retrofits projects are underway, some with expected completion in 2018. School district decision-makers report that early ZNE school retrofits are technically feasible, capture more than 30% energy savings in existing schools and offer non-energy effects such as improved daylighting, ventilation and a quieter-operating equipment. Additional pilot elements include marketing and outreach; development and dissemination of case studies, training and education activities and a public recognition program.

Building Energy Model Technical Findings

As part of this research, the team conducted a technical energy sensitivity analysis. The sensitivity analysis uses building energy modeling with California-specific building prototypes (primary school, secondary school, community college and relocatable classroom) to identify the upgrades and conditions that may have the greatest impact on moving towards ZNE performance in the school sector. This analysis allows insights into the sensitivity of these prototypes to changes in existing variables like climate and vintage and the relative impact of different system upgrades on building energy performance.

The sensitivity analysis uncovered broad patterns and opportunities in the California school building stock and can inform efforts to achieve widespread ZNE performance among schools and community colleges. The following list summarizes some key findings.

- Significant improvement possible. Savings of more than 50% appears to be possible across all four building prototypes, in all climate zones and for all building vintages.
- Performance convergence. The results suggest that no matter the climate, vintage or starting “baseline” performance, the results of technically feasible deep energy retrofits converge in a narrow range of performance, expressed as Energy Use Intensity, that is generally between 19-29 kBtu/square foot per year. This number varies slightly by building type with community colleges and portable classrooms using consistently more energy, even after deep retrofits.
- Relative Importance of HVAC. In deep energy retrofits to achieve ZNE, the bulk of the savings seems to come from ventilation and conditioning systems.
- Sequencing. Appropriate sequencing of energy retrofits involves reducing building loads through envelope sealing, lighting and plug equipment measures before replacing ventilation and conditioning systems. This can allow for the installation of smaller systems, reducing first costs.
- Importance of Operations. The results indicate that the energy impacts of unnecessarily long operations could result in these buildings using 10% or more energy than expected. Clearly, a focus on ongoing operations will be a necessary part of any ZNE strategy in schools.

The findings from the technical analysis are also supported by lessons learned in current ZNE projects (of which 38% are education buildings throughout the United States) and in the Proposition 39 ZNE School Retrofit Pilot projects currently underway. For example, research on existing ZNE projects suggest that ZNE project and school teams consistently implement five key approaches that are not standard practice for design. Specifically, they 1) start early with a ZNE goal at the onset of the project, 2) routinely set an energy target, 3) use this energy target to organize decisions during design and construction, 4) prioritize drastic energy load reduction first and then serve these reduced loads with efficiency systems and eventually renewables, and 5) measure *actual* – rather than modeled - energy performance.

Barriers

School decision makers care most about educating students. This research identified three primary barriers to ZNE in the K-14 market: (1) lack of awareness regarding energy and ZNE, (2) the lack of appropriate processes to address energy usage and savings, and (3) the lack of dedicated funds for building maintenance and improvements which has led to significant deferred maintenance challenges. Overcoming these barriers and achieving ZNE in California schools will require coordinated action by many stakeholders across a diverse and complicated market. This path to ZNE will happen at the local level but can be supported by state agency efforts.

Recommendations

This study provides recommendations to address each of these barriers. Briefly, these include:

Lack of Awareness

Program administrators (PAs), IOUs, the CEC and school public interest groups can:

- Continue training workshops to educate school decision-makers about ZNE and its benefits.
- Train market actors in the technical aspects of ZNE.
- Share case studies of ZNE school retrofits.
- Train Facility Managers to operate buildings efficiently through specific programs.
- Where feasible, leverage community colleges to train the next generation of professionals in facilities, energy efficiency retrofits and renewable energy installation.
- Expand interest in ZNE with awards and recognition.

Lack of Appropriate Processes

PAs can help ensure that energy efficiency is included in school district policy and practice in California schools by working with school district staff to:

- Establish a framework that considers energy in practices and expands upon early benchmarking activities to drive project priorization, assessments, and eventual project completion.
- Influence the development of energy policies, plans, and Owners Project Requirements.
- Disseminate of information of how energy can be incorporated into practices.
- Pilot “performance based procurement” approaches that set energy targets in specifications and procurement contracts. Financial incentives can also be based off measured performance outcomes.
- Encourage data collection practices that support energy management decision making.
- Provide technical assistance to “cohorts” of committed districts to assist them in developing a framework of policies and practices on the path to ZNE

Lack of Dedicated Funds for Energy Efficiency

- CEC and Program Administrators should continue the framework established under Prop 39 and ensure that projects outlined in an Energy Expenditure Plan are completed.
- IOUs and Program Administrators should continue the Prop 39 ZNE Pilot project and expand beyond the initial technical proof-of-concept phase to deliver approximately 50-100 additional pilot projects. Use these projects as an opportunity to further investigate costs and uncover opportunities to reduce cost and bring ZNE retrofits to scale.
- IOUs and Program Adminsitrators should support school districts in going beyond lighting retrofits by assisting with specific elements within their policy frameworks (for example, identifying opportunities with remote diagnostics, site assessments, etc.).

- IOUs and Program Administrators should consider supporting bond "eco-charrettes." These are early, integrated design team meetings that include the perspective of facilities and building occupants. At these meetings, participants can set sustainability goals and energy targets to influence overall bond implementation.
- The CEC and CPUC should conduct research on the true value of non-energy effects associated with energy retrofits in schools so they may be accurately reflected in Savings to Investment Ratio and other financing considerations and constraints.
- CPUC and Program Administrators should consider school buildings as an appropriate building type for the energy savings calculation methods permitted by the California Assembly Bill 802 to capture all savings, including operational improvements.
- IOUs and Program Administrators should consider a financial stipend to encourage design teams to stay involved in the project after retrofit installation is complete to ensure ZNE operation.
- Upon allocation of additional state funds dedicated to energy efficiency, the State Architect should ccoordinate an interagency cooperative approach to develop a strategic plan with a prioritized framework. The plan should have well-defined objectives, actions and expected outcomes over a three-, five- and ten-year horizon geared toward transitioning K-14 schools in California specifically targeting ultra-low energy use and eventually ZNE.

2. OVERVIEW

The trend toward Zero Net Energy (ZNE) buildings is growing, and California leads the country with 137 ZNE verified (18) and emerging (119) buildings across all building types.[1] On this list of buildings, the education sector is leading. In California, the education sector represents 38 of the 137 projects representing 28% of all ZNE verified and emerging projects. Three of these have a verified ZNE result to date. However, these known K-12 ZNE schools are almost all new construction and there is not a school retrofit identified with a verified ZNE retrofit outcome, in California or elsewhere.

The enormous quanity of existing schools that could potentially undergo retrofit opportunities to get to ZNE is important to support the State of California's energy goals. In 2016, Investor Owned Utilities (IOUs) in California began a pilot program to demonstrate technical proof-of-concept feasibility in ZNE school retrofits under the auspices of Proposition 39. The first round of these ZNE retrofit projects (four schools) are now under construction and their results toward ZNE can be verified following at least one full year of occupancy (Fall 2018 for the first projects).

In the meantime, the California Public Utilities Commission (CPUC) also directed this ZNE School Retrofit Readiness study to investigate the financing and decision-making structure in the K-14 market. The aim is to better understand the market, uncover potential synergies and/or leverage points, and increase the likelihood of success in any ZNE program in existing schools.

Study Purpose

The purpose of this ZNE Retrofit Readiness Study is to investigate decision-making patterns and funding practices as well as general energy use characteristics and net zero potential in public K-14 schools in California. The study provides recommendations for prioritization of factors and characteristics pertinent to transitioning the existing public schools market onto the path to ZNE and provides recommendations to California Program Administrators (PAs) and other key market actors on how they can work together to best stimulate and enable the K-14 market to meet California's aggressive ZNE targets.[2]

The research plan approach for this study differs from a typical energy efficiency market characterization as it includes both insights regarding market characteristics (including decision-making and financing) as well as a technical "sensitivity analysis." The purpose of the sensitivity analysis is to use energy simulation to understand the range of energy use and ZNE potential of the K-14 building stock in California.

This research does not incorporate information about private or charter schools in California. Although the technical analysis could apply to these buildings where applicable, the structure of decision-making and financing retrofits of private and charter schools was outside the scope of this report.

Definition of Zero Net Energy (ZNE)

This study utilizes the ZNE Source definition from the "Definition of Zero Net Energy (ZNE) for California State Agency Compliance with Executive Order B-18-12" issued May 19, 2016.[3] Hereinafter referred to as a "ZNE building," it is defined as a building that produces as much energy as it consumes over the course of a year when accounted for at the energy generation source.

[1] NBI's 2016 List of Zero Net Energy Buildings is available at http://newbuildings.org/resource/2016-list-of-zne-buildings/

[2] Information on California's Energy Efficiency Strategic Plan is available at http://www.cpuc.ca.gov/General.aspx?id=4125.

[3] https://www.calstate.edu/cpdc/ae/documents/ZNE-Definition-EO-B-18-12-20160519.pdf

Study Objectives, Research Questions and Research Topics

The study had several specific research objectives, questions and topics outlined below. In addition, Table 17 in Appendix A indicates where in the report each question below is addressed.

Research Objectives and Key Research Questions

1. Identify key market actors; drivers (economic, leadership, technology, other market); budgets, funding sources and levels, common business plans and patterns of interactions
   a. What are key market actor drivers, and how can these be harnessed to advance ZNE retrofit goals?
   b. Identify key supply chains (technologies and professionals) and opportunities to incorporate (when can ZNE happen? Bonding, seismic, expansion etc.)
2. Identify barriers, challenges and opportunities
   a. What are key barriers, and how can these be overcome, via: program design; regulatory framework updates; market actor engagement, etc.
3. Identify leading and lagging geographic regions and market actors
4. Identify high priority strategies and partners to advance ZNE retrofits in K-14
   a. What is the range of potential savings available, on a sector level and average per building?
   b. Where are the key opportunities to develop ZNE retrofits in educational institutions?
   c. What are the best strategies and partners to advance ZNE retrofits in K-14?
   d. What lessons can be leveraged to accelerate adoption of ZNE in schools?
   e. What is the range of educational institution and IOU costs for ZNE retrofits?

Besides the typical research objectives and questions, the study also included seven different topics to research, through the lens of the research questions.

Specific Research Topics

1. ***School Districts and Facilities***. A summary of the total California school facilities locations, size and key demographic factors.
2. ***Financing Sources and Approaches***. Identification of the primary and secondary methods for funding capital improvements.
3. ***Management and Decision Making***. A review study of the management approaches and decision making methodology as well as key determinants used for decisions of capital improvements at school districts and community colleges.
4. ***Current Supporting Programs and Policies***. Descriptions of various policies, activities, programs and incentives available to support major energy efficiency retrofits and occupant training toward performance outcomes and ZNE.
5. ***Facility Characteristics***. Representation of the current building prototypes and typical technologies in various eras and climate zones of buildings.
6. ***Energy Characteristics and Net Zero Potential***. Total and comparative energy analysis of the school sector in California and the potential energy savings opportunities through ZNE.

7. ***The Path to All Schools being ZNE Schools***. The conclusions and recommendations for the people + process + market + technology paths to move all existing schools to ZNE.

3. METHODOLOGY

The study team gathered data from three distinct activities: 1) stakeholder interviews, 2) engineering modeling, and 3) literature review to accomplish the objectives laid out in the previous section. This data informed two parts of the study: (1) an overview of K-14 market characteristics and (2) a technical analysis of ZNE retrofit opportunities and potential.

Details about both approaches are described below.

K-14 Market Characteristics, Decision-Making and Financing

The team used secondary research (i.e., a literature review) to inform stakeholder interviews.[4] Using information gleaned from the secondary data collection, the team developed in-depth interview questions to gather information from key stakeholders on the current approaches to managing and delivering K-14 projects and to identify the primary barriers and needs to drive this market sector towards ZNE retrofits. Questions covered six topic areas and, depending on their role, participants answered questions pertinent to their role as outlined in Table 2 below.

Table 2: In-Depth Interview Questions by Role

Section	Department of General Services	IOU	Director of O&M/Facility Manager	Design Expert	LEA School Board
Introduction	X	X	X	X	X
Project Selection Decision-Making Structure	X				X
Project Selection Decision-Making at the State Level	X				
Project Selection Decision-Making at the Local School District Level	X	X	X	x	X
Modernization Implementation Structure		X	X	X	X
School Facility Operations & Maintenance			X		X
ZNE Projects		X	X	X	
Other Interview Participants	X	X	X	X	X

Researchers used a snowball sampling approach to identify in-depth interview participants. A copy of the complete interview guide is provided in Appendix B: Table 3 compares the in-depth interview targets to the actual completed interviews by role. Two seasoned interviewers performed all interviews which were about 60 minutes each and took place between February 27 and March 31, 2016.

[4] Databases reviewed include the California Department of Education (CDE), California Community Colleges Chancellor's Office, the National Center for Education Statistics Elementary/Secondary Information System, the Department of General Service's (DGS) Office of Public School Construction, the Berkeley Center for Cities and Schools among others. Researchers also incorporated applicable information from the US Department of Energy Zero Energy Schools Accelerator, the Collaborative for High Performance Schools (CHPS), the California Commercial End-Use Survey (CEUS), New Buildings Institute's (NBI) ZNE Buildings Database and the U.S. Department of Energy's (DOE) Building Performance Database as applicable

Table 3: Targeted and Completed In Depth Interview Counts

Audience	Targeted Group	Original Targets	Completed
State Government Department Staff (CDE, Office of the State Architect DGS, etc.)	Staff involved with school programs	2-3	3
IOU Program Administrators or Representatives	Staff or consultants involved in Prop 39 ZNE Pilots	2-3	4
School Board Members	Current School Board Member in California	5-6	3
District and School Administrators	District and School Administrators who set budgets for capital expenditures and develop long-term strategies	4-6	4
Facility Managers	Facility Managers in California	2-3	4
A&E Staff who provide professional services to this sector	Principal level design professionals with at least 2 who have experience in low- and/or net zero energy projects	2-4	4
		21-29	22

Note: The original research plan called for 4 interviews of "staff supporting the K-14 sector," but these were removed from the interview targets.

Technical Analysis of ZNE Retrofit Opportunities

To evaluate the impact of building type, age, and climate in ZNE retrofits, researchers used a building simulation approach called a sensitivity analysis to uncover factors and technical characteristics that may be most important in transitioning existing schools to ZNE. The overarching goal of the sensitivity analysis was to examine potential savings associated with energy efficiency improvements in K-14 schools for all prototypes, across all climate zones and for each building vintage that is available within the Database for Energy Efficiency Resources (DEER)[5]. Researchers were interested to discover savings performance patterns that would provide guidance for an overall market transformation strategy to ZNE in CA K-14 schools. Specific goals for the sensitivity analysis were to:

1. Provide guidance on the types of energy improvements that can bring the K-14 building stock onto a ZNE pathway by exploring multiple building performance upgrades and understanding the relative significance of these strategies.
2. Estimate how common building characteristics identified in the DEER database, including building vintage, climate, building type and operational characteristics, impact potential savings and maximum performance potential in school buildings.

5 Information on the Database for Energy Efficiency Resources (DEER) can be found at the Commissions DEER website, www.deeresources.com. DEER contains ex ante values as well as calculation methods used for determining cost-effectiveness of a selected group of common energy efficiency measures. Many DEER savings values are developed using energy modeling of 28 prototypical building types including the four building types covered by this study: primary school, secondary school, community college and relocatable classroom. Prototype models are based on California specific assumptions including configuration, construction, system designs and operations which vary based on vintage and climate zone. This report includes detailed information covering the modeling assumptions for the prototypes incorporated into this study.

3. Identify the types of retrofits that will most commonly lead to the greatest energy use reductions, and evaluate how consistently these strategies apply across the school building types and conditions evaluated.
4. Extrapolate the savings potential identified in this analysis across the school sector in California.

The analysis was focused on strategies to achieve maximum energy savings as a prelude to achieving zero net energy for the prototypes. The engineering computer simulation was based on standard DEER modeling practices and four school prototypes (primary, secondary, portable and community college). Modelers created a unique baseline for each prototype, in each climate zone and for each building vintage and then improved system level efficiency parameters (envelope, HVAC and internal gains) in the energy simulation, one at a time and then in bundles, comparing the packages and interactive effects of multiple packages against the appropriate baseline. Through creating a set of savings values, the team estimated the relative savings that might be expected for a set of deep retrofit strategies.

Technical details about the sensitivity analysis can be found in Technical Approaches to Achieving ZNE as well as Appendix C: Background on Technical Sensitivity Analysis and Baseline and Improved Energy End Use. The measure packages are listed in Table 20: Energy Efficiency Packages.

Study Limitations

This study focused primarily on public K-14 schools in California. This specifically excludes private and charter schools primarily due to significant different decision-making and financing structures. During the in-depth interviews, it became apparent that many Local Education Agencies or school districts may be responsible for the operations and maintenance (O&M) of some charter school facilities, but this was not investigated in this research. While the decision-making and financing structure of charter and private schools may be different, to the extent that these schools are housed in buildings that resemble the four building prototypes, the technical recommendations would also apply to private and or charter schools.

A second limitation of the study is the literature review. While researchers made efforts to uncover and review programs, decisions, rulings, evaluation results, etc. pertinent to energy efficiency and ZNE in existing K-14 schools in California, other information may exist which was not reviewed as part of this research.

A third limitation might be the small sample size plus the fact that researchers found it challenging to schedule and complete interviews with school board members. Therefore, this research may underrepresent the viewpoint of this key market decision-maker.

Finally, the technical approach outlined in this research provides interesting insights on the influence of system level improvements on energy performance. However, as typical with energy modeling exercises, this is only as accurate as current modeling tools allow.

4. California K-14 Schools, Decision-Makers and Financing

This K-14 ZNE Retrofit Readiness Study investigates decision-making, financing and technical opportunities to retrofit public K-12 and community colleges in California. The section summarizes general information about the number of school districts, enrollment and counts by utility. K-12 and community colleges are analyzed separately. This section goes on to outline decision-making and financing structures important in the California K-14 schools market.

Public K-12 Schools and Enrollment

In the 2015-2016 school year, over 6.2 million students attended kindergarten through twelfth grade in California public schools. Local Education Agencies (commonly referred to as "school districts") are legal entities with administrative control over public elementary through secondary schools. According to the California Department of Education, California has 1,025 school districts with 10,452 public schools. The districts are comprised of 526 elementary school districts, 77 high school districts, 343 unified school districts and 79 other districts. Unified school districts combine elementary and high schools into one unified district. Other school districts include alternative, community day schools, juvenile hall, special education and other state and county schools.

Table 4 outlines both enrollment and number of schools by type of California public school.

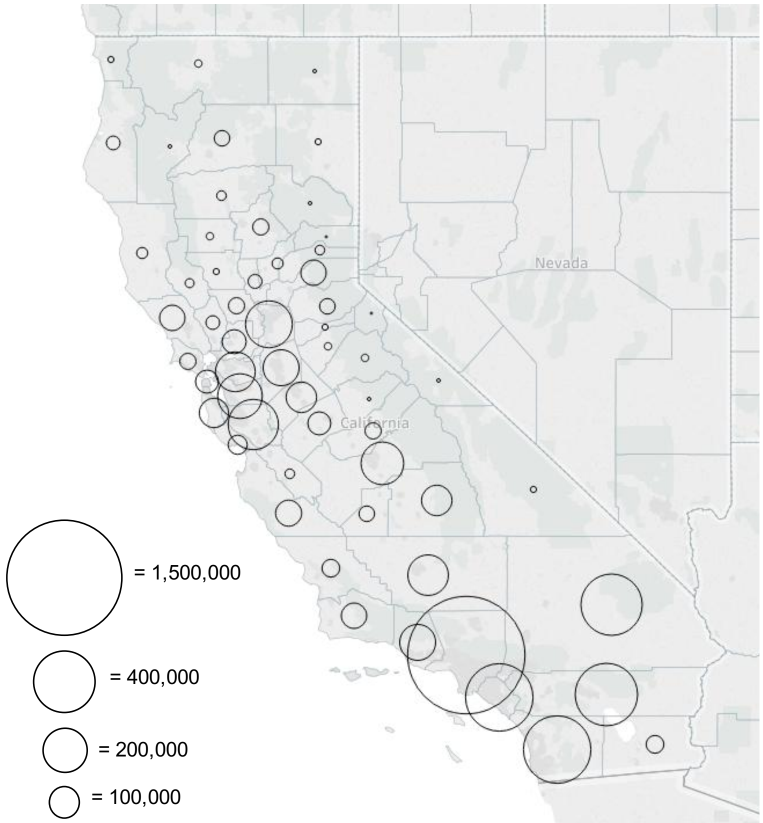
Table 4. California School Enrollment by School Type

School Type	Number of Schools	Enrollment
Elementary	5,858	3,106,462
High	1,339	1,769,487
Middle	1,298	990,159
Other	610	36,537
Continuation[6]	452	55,899
K-12	262	152,693
Alternative	261	62,005
Community Day	193	3,669
Special Education	132	21,147
Junior High	48	28,679
Total	10,453	6,226,737

K-12 school enrollment by county varies across the state. Figure 1 shows enrollment by county overlayed on a map of California. As expected, enrollment generally tracks with large population and urban centers.

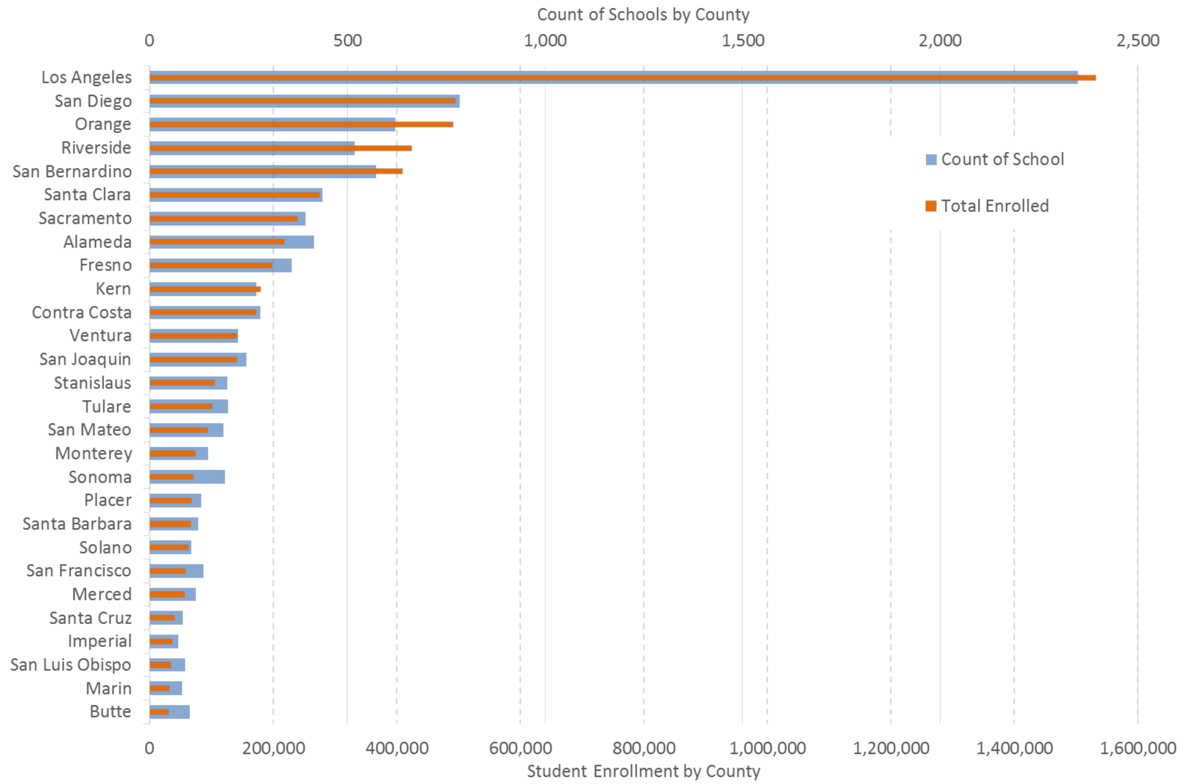
[6] A "Continuation" school is an alternative high school where students, often at risk students in danger of not graduating, go to earn credits toward their high school degree.

Figure 1: K-12 Enrollment by County



Plotting the number schools and total enrollment and county reveals that Los Angeles County far exceeds other counties both in number of schools and number of students. Figure 2 provides an overview of the 28 counties with the largest enrollment and number of schools.

Figure 2: Top 28 Counties by School Count and Enrollment



K-12 Enrollment and Schools by IOU

California IOUs are interested to know school counts and enrollment by utility service territory. Using the zip codes for each school, researchers determined how many K-12 schools are located in various IOU service territories.

K-12 by Electric IOUs

As shown in Table 5, 8,149 K-12 schools are located within the IOU electric service territories. This accounts for 78% of the total count of California publicly funded K-12 schools.

Additionally, Table 5 shows that almost 70% of California schools served by three electric IOU are served by Pacific Gas and Electric (PG&E) and Southern California Edison (SCE). San Diego Gas and Electric (SDG&E) serves 8% of schools located in the state. Although more schools are in PG&E service territory, enrollment in SCE service territory is higher, with SCE serving 38% of students and PG&E serving 32% of students.

Table 5: California Schools and Enrollment by Electric IOU

Electric IOU Service Territory	Estimated Number of Schools in Service Territory	Estimated Percent of Schools served by Electric IOUs	Estimated Student Enrollment in Service Territory	Estimated Percent of Enrollment in Electric IOU Service Territory
PG&E	3,902	37%	1,962,368	32%
SCE	3,328	32%	2,391,031	38%
SDG&E	827	8%	557,913	9%

Electric IOU Service Territory	Estimated Number of Schools in Service Territory	Estimated Percent of Schools served by Electric IOUs	Estimated Student Enrollment in Service Territory	Estimated Percent of Enrollment in Electric IOU Service Territory
Subtotal	8,149	77%	4,922,465	79%
Other	2,396	23%	1,315,425	21%
Total	**10,453**	**100%**	**6,226,737**	**100%**

K-12 by Gas IOUs

Table 6 shows that there are approximately 9,500 K-12 schools located within the service areas of the three primary gas IOUs accounting for just over 90% of all K-12 schools in the State. Roughly half of the number of schools and more than half of the student enrollment are served by Southern California Gas (SCG) company. The schools within the service areas of these three gas IOUs account for approximately 5,918,662 students which equates to 95% of the total K-12 student population in the state. Only 918 K-12 schools housing 308,075 students are not located within the three gas IOU service territories.

Table 6: California Schools and Enrollment by Gas IOU

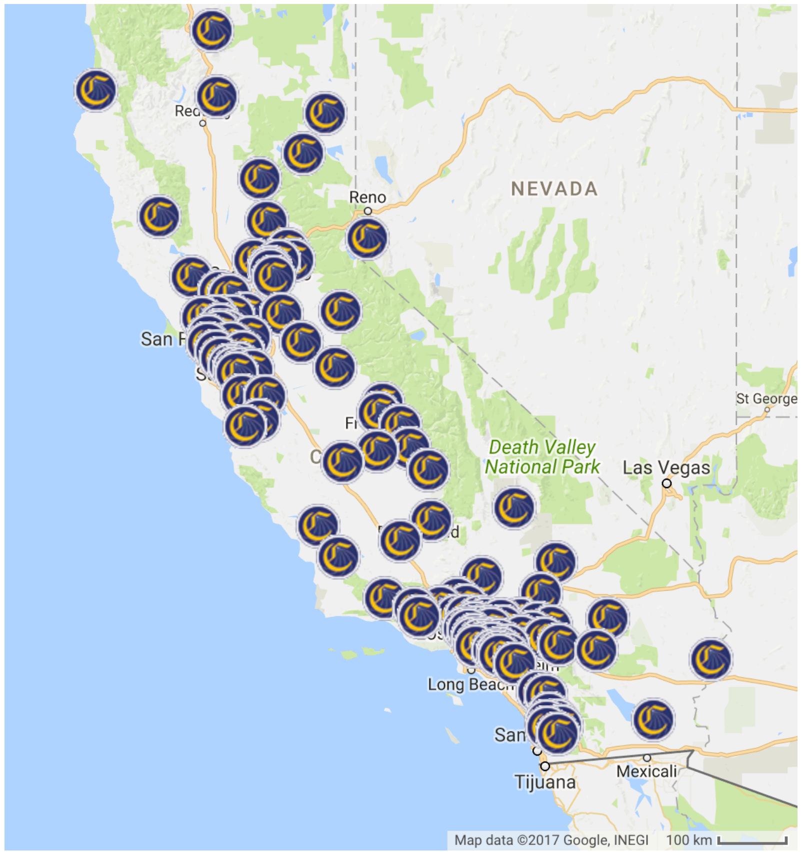
Gas IOU Service Territory	Estimated Number of Schools in Service Territory	Estimated Percent of Schools served by Gas IOUs	Estimated Student Enrollment in Service Territory	Estimated Percent of Enrollment in Gas IOU Service Territory
SCG	4,902	47%	3,441,525	55%
PG&E	3,880	37%	1,979,332	32%
SDG&E	753	7%	497,805	8%
Subtotal	9,500	90%	5,918,622	95%
Other	918	9%	308,075	5%
Total	**10,453**	**100%**	**6,226,737**	**100%**

Community Colleges (Grades 13-14) and Enrollment

The California Community College Chancellor's Office maintains statistics about community colleges in the "Management Information Data Mart" available at http://datamart.cccco.edu/. According to 2015-2016 statistics, California has 72 community college districts with 113 total community colleges. Total enrollment for this same period is 2,353,983 students. Figure 3 is a map of community colleges in California from the California Community College Chancellors Office.[7]

[7] Chancellor's Office Map downloaded from http://californiacommunitycolleges.cccco.edu/Findacollege

Figure 3: Community College Locations in California



Community College Enrollment by IOU

Using the same data mapping through zip codes approach as outlined in the Public K-12 Schools and Enrollment section, researchers allocated community colleges by electric and gas utility.

Community College Electric IOUs

Table 7 shows that 57 (79%) of the 72 Community College districts are served by the electric IOUs accounting for 69% of enrolled community college students. As noted PG&E serves 38 percent of districts, SCE serves 32% and SDG&E serves 7%. A large number (n=15) and proportion (23%) of districts are not served by CA electric IOUs.

Table 7: Community College Districts and Enrollment by Electric IOU

Electric IOU	# Districts	% of Districts	Enrollment	% of Enrollment
PG&E	27	38%	689,001	29%
SCE	23	32%	686,914	29%
SDG&E	5	7%	237,371	10%
Subtotal	57	79%	1,631,521	69%
Other	17	23%	740,697	32%
Total	**72**	**100%**	**2,353,983**	**100%**

Community College Gas IOUs

Table 8 shows that 61 (85%) of the 72 Community College districts are served by the Gas IOUs accounting for 93% of enrolled community college students. Eleven (15%) Community College districts are not served by the gas IOUs.

Table 8: Community College Districts and Enrollment by Gas IOU

Gas IOU	# Districts	% of Districts	Enrollment	% of Enrollment
SCG	31	43%	1,226,683	52%
PG&E	25	35%	729,570	31%
SDG&E	5	7%	237,371	10%
Subtotal	61	85%	2,193,624	93%
Other	11	15%	160,359	7%
Total	**72**	**100%**	**2,353,983**	**100%**

School Decision-Makers

The K-14 schools market is a complex network of stakeholders and decision makers. ***The primary driver of all key decision-makers in the K-14 school market is to educate students***. Operating safe and healthy schools is paramount, and energy is a low priority. As such, facilities design, construction and operations are simply a means to the end result of educational outcomes for students. Efforts on ZNE and deep energy efficiency must consistently align with this educational objective if this goal will be successful.

Decisions regarding facilities are largely made at the local level. While local school boards decide which projects to pursue and whether to put bond measures on the ballot to finance them, they are influenced by a complicated process that includes input from a variety of other stakeholders including the public, staff and consultants. Local facility managers make decisions regarding building operations. While the state has an oversight structure to ensure compliance with laws and other regulations, the state decision-makers do not directly control which projects happen, when they happen, or exactly what happens for new construction, existing building renovation and/or operations.

Below, we introduce the primary decision-making agencies and organizations, and outline individual roles and actors within those agencies who influence decisions.

State Market Actors

California Department of Education (CDE) - The CDE is the agency responsible for overseeing all aspects of public schools in the state. Overall management of the CDE is by the elected State Superintendent of Public Instruction and an eleven-member School Board of Education appointed by the Governor. The CDE is responsible for establishing educational policy and standards and managing programs relating to curriculum and instruction, testing and accountability, professional development and specialized programs such as adult education, charter schools, early childhood development, English as a second language, nutrition, special education and others according to Title 5 in the California Code of Regulations. Title 5, Chapter 13, Subchapter 1 covers School Housing and sets standards for the planning and approval of school facilities.

The CDE maintains data and statistics regarding the numbers of schools, teachers and students across the state. This is the primary source of information used to summarize school counts and enrollment in the previous section entitled Public K-12 Schools and Enrollment.

The Schools Facilities & Transportation Services Division maintains resources regarding best practices, facility design, health and safety, master planning, overcrowded schools and financing for renovation projects. (They are part of the Services for Administration, Finance, Technology and Infrastructure Branch of the California Department of Education.)

State Superintendent of Public Instruction (SSPI) – The SSPI is a non-partisan elected official who serves as the leader of the CDE.

California Energy Commission (CEC) – Among other things, the CEC is responsible for administration of the California Clean Energy Jobs Act (Proposition 39) in the K-14 market. They have delegated responsibility for a ZNE retrofit pilot project, to the CPUC and Investor Owned Utilities in California (PG&E, SCE, SCG, and SDG&E)[8].

California Department of General Services (DGS) – The DGS is the overall business manager for the state of California. They provide a wide variety of services to the other state agencies regarding facilities, procurement, sustainability, legal services and funding for school construction, among others.

DGS Division of the State Architect (DSA) – The DSA within DGS employs about 300 individuals who are responsible to ensure that local school district plans comply with rules and regulations regarding facilities, including Title 24, seismic and the Americans with Disabilities Act (ADA). Eventually, as ZNE policies phase in and become the rule of law, DSA will be the agency that ensures compliance. It also approves the application under state-wide bond implementation which allows the Office of Public School Construction to disperse funds according to formulas set by the State Allocation Board as part of the Schools Facility Program.

State Allocation Board (SAB) – The SAB is made up of the Director of Finance, the Director for DGS, the Superintendent of Public Instruction, three members of the Senate, three members of the Assembly and one member appointed by the Governor. The State Allocation Board sets the minimum requirements for participation in the state Schools Facilities Program which allocates state obligation bond money to local districts.

Office of Public School Construction (OPSC) – OPSC is part of DGS and serves as the staff to administer the School Facilities Program.

Local School District Market Actors

Local Education Agencies (LEAs) - LEAs are commonly referred to as school districts. School districts may be described as urban, suburban, rural, large, medium and/or small. Their size, location, and ability to raise money influence how the facilities in the school district are operated and managed. Key decision-makers within the school district are introduced below.

School Board - Elected school board members are the primarily decision maker for school districts and school facilities. They routinely seek input from the community, students, staff and a wide-range of consultants in decision-making. Like other market actors, school boards are most interested in educating students. Facilities are only one small area of interest or concern.

Most school board members have little background or experience with facilities and have little awareness or understanding of ZNE, though this is increasing as more ZNE school projects come on line and the ZNE school market develops. All three of the school board members interviewed noted that they were unfamiliar with ZNE in the interviews. They also indicated that they believed that the Facility Director, introduced further below, was well aware of challenges and opportunities associated with facilities, including energy performance.

Across the state, it varies whether school board members represent a particular zone within a school district or the district overall. Sometimes this influences decisions, for example in advocating for one facility over another.

[8] Advice letter 3563-G/4587-E is available at https://energydesignresources.com/media/20130147/3176-E-Part-1-of-1-.pdf?tracked=true

Superintendent – A local school superintendent is responsible for the overall functioning of the school district. They report directly to the school board, oversee the development of plans and budgets, and manage a team of Assistant Superintendents and/or Directors (depending on the size of the district). Community relations is a major part of a superintendent's job. Superintendents in smaller districts tend to be involved across a wide range of day-to-day activities, while larger school districts have more staff support.

Assistant Superintendent/Director - These Directors (sometimes called Assistant Superintendents) are staff that cover areas such as Education, Business, Finance, Administration, and Facilities. The specific titles for these roles vary by district, for example, Business and Finance might be Chief Business Official and Facilities might be Transportation, Facilities and Grounds. No matter the name of the Director, these individuals work alongside one another and have many competing priorities that require attention, bandwidth and budget. The four school district administrator staff interviewed said that they were only somewhat familiar with ZNE during interviews conducted as part of this research.

Facilities Director/Assistant Superintendent – The operation and maintenance of safe, healthy and functioning schools is the responsibility of the Facilities Director. The Facilities Director may manage a group of staff that generally includes a team of Facilities Managers (deployed across the district to various facilities to address specific maintenance issues) and custodians. Generally, custodians seem to be on site, while facility staff are deployed to various schools as needed. The size of the facilities group depends on the number of schools in the district.

Facilities staff interviewed as part of this research had experience and thus familiarity with ZNE projects. Every Facilities Director interviewed as part of this research characterized deferred maintenance problems in their school district as significant. Typically, the Facilities Director participates in the long range facility planning process, outlined in detail below, as part of the Leadership Team, alongside the Business and Education Directors, among others. Like all other stakeholders, Facilities Directors and staff are committed to student educational outcomes and how their work impacts these outcomes. While they are interested in energy, they are more interested in maintaining healthy and safe schools.

Facilities Directors understand better than anyone how these school building systems function. The facilities group is obviously interested in ease of maintenance. Sometimes this means limiting the diversity of equipment types or "doing it the way it's been done before." Their buy-in on new systems is critical to a ZNE result because ZNE buildings must be operated optimally to maintain ZNE status.

Sustainability Manager – Districts in larger, typically more urban, settings may have a Sustainability Director. Some districts have an entire sustainability group. They may work in the Administration or Facilities department. Sustainability staff often work in association with teachers and students on a variety of "green" projects such as waste, energy and water reduction. Sustainability staff that we talked to also spoke of responsibilities regarding Collaborative for High Performance Schools (CHPS) verification. Smaller districts interviewed as part of this research mentioned that having this position was not something they could afford. Instead, these districts may rely on sustainability support services from the County Office of Education.

Energy Managers – Some districts have an Energy Manager on staff. Often, this individual works in the Facilities group within a school district though they may work with the Sustainability group instead. They are responsible for collecting and reviewing energy and water bills, benchmarking and analyzing consumption, and recommending opportunities for improvement.

County Office of Education – California has 58 County Offices of Education that provide services to school districts. The superintendent in the county office approves district budgets and serves districts by providing support for tasks that are more economical to do regionally, such as juvenile detention, special and vocational education. Sustainability is another area where county employees at the Office of Education can support school districts.

Consultants Serving School Districts

A wide variety of consultants serve as subject matter experts for school districts. Some of these are outlined below.

Architects & Engineers – Some architects specialize in school design. These architects work directly for the school district and remain up to date on how facilities enhance or deter from educational outcomes. School architects manage a team of engineers and other consultants in new construction and renovation. They understand the challenges facing school facilities and know how to manage a public input process typical in school design. Some districts have a "District Architect" that serves on call for the district and is on a short list for major projects. Engineers and the rest of the team are not necessarily on call.

Many districts require that their facilities achieve Leadership in Energy and Environmental Design (LEED) certification or Collaborative for High Performance Schools (CHPS) verification (described in more detail below), therefore architects and engineers tend to think of energy in terms of "percent better than code" because energy is addressed with performance estimates predicted in energy models as part of these programs. Rarely do design teams follow up to see how the buildings are actually performing. Individual architectural experience and commitment to energy efficiency matters as different designs can create dramatically different energy outcomes.

Construction Manager – Smaller districts tend to hire a Construction Manager to serve as the LEA's authorized representative during the construction process. Larger districts may have this role represented on staff.

Contractor – The contractor is the company responsible for building and delivering a facility according to the plans drawn by the design team. A key part of their work includes developing cost estimates for facility construction projects. Interviewed design professionals familiar with ZNE cautioned that having contractors on board early in design is critical to integrated design and delivering a successful ZNE project.

Bond & Legal Consultants – Bond consultants help school districts to research and write the bond. These consultants review district needs, borrowing capacity and community willingness to spend. They conduct market research in the community to appropriately position the bond to increase the likelihood of passage. Bond consultants also draft the actual bond language that goes to voters.

Long Term Plan and Facility Master Plan Consultants – A variety of other consultants help with the development of the long term and master plans for school districts. These consultants include demographers, facility assessors, and cost estimators.

Energy Service Companies (ESCOs) – ESCOs coordinate and implement energy reduction projects while guaranteeing savings to the owner, in this case, the school district. School district staff and IOUs interviewed mentioned that ESCOs have been helpful in defining projects and arranging Power Purchase Agreements using Prop 39 funds.

Public Interest Groups

Schools are a foundation of our society and have many interested public stakeholders. Their interests are diverse and varied, ranging from parents and students to community groups that may use the facilities for after-school day care, meetings or other activities such as sports. Community members often sit, (sometimes alongside staff and/or school board members) on stakeholder committees that are created for various reason. In the context of this research, some of these committees might include the Long Range Planning Committee, the Bond Oversight Committee, or committees created to advise teams on a particular major renovation or new construction project.

Below are several public interest groups of specific interest when considering ZNE.

Collaborative for High Performance Schools (CHPS) – CHPS is a non-profit organization dedicated to making better learning environments in schools. CHPS provides resources to school district staff and professionals about high performance school design, construction and operation. CHPS has collected research and information about the benefits of energy efficient, high performance schools, including higher test scores, increased daily average attendance, increased teacher satisfaction and retention, reduced environmental impacts and reduced liability.[9] They offer resources and "best practice manuals," trainings, a high performance building rating and recognition program for creating healthy, green schools.

Coalition for Adequate School Housing (CASH) – CASH membership contains over 1,500 school districts, county offices and private sector businesses including: architects, attorneys, consultants, construction managers, financial institutions, modular building manufacturers, contractors, developers and others that are in the school facilities industry. According to its website, CASH is a voice in Sacramento to advocate for funding to build, modernize, and maintain K-12 public school buildings in California.

School Energy Coalition (SEC) – The SEC is a membership organization made up of school districts of all sizes, community colleges and businesses that specialize in energy efficiency. They advocate on behalf of energy and water efficiency in California K-14 schools at the state and federal level.

California Conservation Corps (CCC) – The CCC is a state agency that hires 18-25-year-olds for a year of service doing natural resource work and emergency response. The CCC has worked with UC Davis to support school districts with Prop 39 assessments.

US Green Building Council Center for Green Schools (USGBC CGS) - The Center for Green Schools at the U.S. Green Building Council works with school decision makers, community volunteers and thought leaders in the public and private sectors to drive progress at the intersection of sustainability, education, public health and the built environment. The USGBC manages the Leadership in Energy and Environmental Design (LEED) building rating system.

Utility Providers and Program Administrators – For the most part, utility services for California schools come from municipal and Investor Owned Utilities (IOUs). These traditional utilities also oversee energy efficiency programs that offset incremental costs associated with energy efficiency, such as Savings by Design and the School Energy Efficiency Program. California IOUs also administer the three-year Prop 39 ZNE Pilot Project on behalf of the CEC.

School districts' utilities are sometimes more complicated than one gas and one electricity provider. Many districts span multiple service territories therefore they have multiple utilities. Other districts' representatives mentioned that sometimes the district purchases gas and/or renewable electricity from a company other than the utility responsible for distribution. This was of concern especially regarding utility energy efficiency programs because if the energy (either electrical or natural gas) is not provided by an IOU, then incentive programs do not apply.

Programs

Below are summaries of the key programs for the K-14 School building market in California.

School Facilities Program (SFP) - The SFP is the primary method of distributing state general obligation funds to local school districts. The two primary programs are New Construction and Modernization. (Modernization may involve more than an energy efficiency "retrofit," as commonly referred to in the energy efficiency community). These programs use specific funding formulas and match requirements set by the State Allocation Board. The SFP is described in detail in the section regarding funding and decision-making called California K-14 Schools, Decision-Makers and Financing.

Proposition 39 (Prop 39) – Prop 39 is a limited duration program administered by the CEC which provides up to $500 million per year from the California general fund to the California Clean Energy and Jobs Fund for five fiscal years starting in 2013 for energy efficiency and clean energy projects in existing schools. Further details on funds available and specific school districts requirements to obtain Prop 39 funding are discussed in detail in the section regarding funding and decision-making in more detail below.

[9] http://www.chps.net/dev/Drupal/node/48

Prop 39 - ZNE Pilot Project (Prop 39 ZNE Pilot) – Separate from the CEC's Prop 39 program, the California IOUs are administering an $8 million pilot project for ZNE retrofits to existing school buildings. IOUs aim to facilitate 13-18 ZNE school building retrofit projects between 2016-2019, as well as to develop a scaled incentive program to operate subsequent to the completion of the pilot. Thus far, round one pilot projects have been selected and potential round two projects are currently being assessed. Additional pilot elements include marketing, education and outreach; development and dissemination of case studies; development of institutional training activities; monitoring and verification.

Bright Schools Program – The CEC Bright Schools Program provides "no-cost" energy audits to school districts.

7x7x7 Design Energy Water – This state-wide "award" program administered by the DGS DSA highlighted retrofit projects by seven design teams in seven schools across seven climate zones. The State Architect created the 7x7x7 program to encourage new thinking about transitioning K-12 schools in California to ZNE and zero net water. During this special, one-time program, teams designed a retrofit schematic design promoting energy and water reduction, while simultaneously improving the built environment for quality education. Preliminary cost estimating analyses are included with the designs in the case studies for these 7x7x7 architectural "thought experiments." These case studies plus other resources, including basic principles of building energy and water plus the role of behavior and education on a ZNE outcome, can be found on their website.

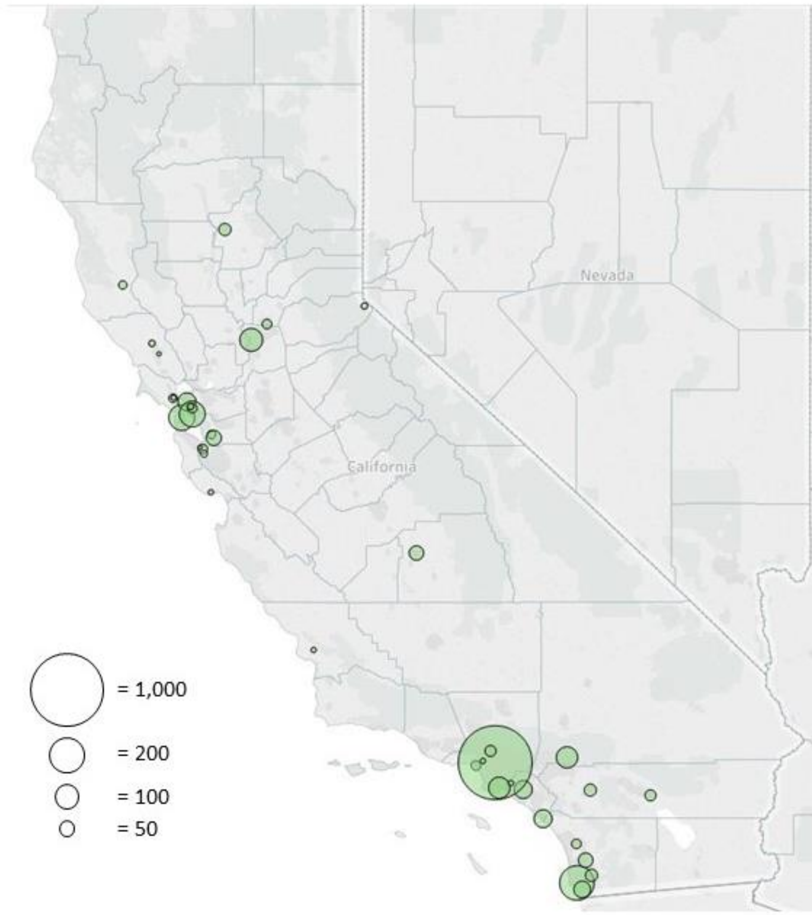
Collaborative for High Performance Schools (CHPS) – CHPS is both an organization and a program. Specifically, the CHPS program offers design criteria plus verification of high performance school construction and operations based on the CHPS criteria. Currently, 42 school districts in California have school board approved policies that require CHPS verification (or equivalent) for their facilities. This represents 24% of the schools in the state and 27% of student enrollment, as outlined in Table 9. This list represents potential "early adopter" districts. The map that follows shows where these districts are located and the relative size of each district.

Table 9: California Districts or Schools with a CHPS Policy

District or School	Count of Schools	Count of Students
Los Angeles Unified School District	1043	697,483
San Diego Unified School District	228	129,345
Oakland Unified School District	130	45,634
San Francisco Unified School District	128	54,058
Long Beach Unified School District	88	88,366
San Bernardino City Unified School District	88	57,000
Sacramento City Unified School District	83	48,206
Capistrano Unified School District	64	52,371
Santa Ana Unified School District	63	56,417
West Contra Costa Unified School District	62	30,733
Chula Vista Elementary School District	48	27,236
Fremont Unified School District	44	33,308
Visalia Unified School District	41	27,422
Poway Unified School District	39	34,833
Cajon Valley Union School District	30	16,237
Chico Unified School District	29	13,454
Hemet Unified School District	29	23,577
Coachella Valley Unified School District	24	18,256
Burbank Unified School District	23	16,174
Berkeley Unified School District	20	8,856
Palo Alto Unified School District	20	11,104
San Marcos Unified School District	20	18,106

District or School	Count of Schools	Count of Students
Natomas Unified School District	19	11,733
Santa Monica Malibu Unified School District	18	11,572
Ukiah Unified School District	16	6,412
New Haven Unified School District	14	12,924
San Rafael City Schools	14	5,770
Los Altos School District	10	4,275
Dry Creek Joint Elementary School District	9	8,044
Windsor Unified School District	9	5,582
Lake Tahoe Unified School District	8	4,184
Roseville Joint Union High School District	8	10,655
Albany Unified School District	7	3,900
Beverly Hills Unified School District	6	4,943
Cypress-Fairbanks Independent School District	6	3,913
High Tech High Learning Center	6	2,500
Live Oak School District	6	2,194
Mill Valley Unified School District	6	2,416
Coast Unified School District	5	801
Menlo Park City School District	4	2,324
Roseland School District	4	1,996
Total	**2,519**	**1,674,314**

Figure 4: California K-12 Districts with a CHPS Policy by School Count



US Department of Energy Zero Energy School Accelerator Program (ZESA) – ZESA is a partnership between US Department of Energy (DOE), National Renewable Energy Lab, and others including New Buildings Institute (NBI), Rocky Mountain Institute, the Northeast Energy Efficiency Partnerships, CHPS, and school districts from across the United States. ZESA is part of the US Better Buildings Program. The aim of ZESA is to support districts interested in ZNE. DOE facilitates small groups that discuss best practices in predesign, design and O&M. Through a facilitated process, ZESA supports districts in the development of a policy framework that supports ZNE new construction. Districts complete monthly assignments, and that eventually will be compiled to create an outline for a ZNE plan.

California Green Ribbon Schools - The U.S. Department of Education's Green Ribbon Schools (ED-GRS) recognition award honors schools, districts, and Institutes of Higher Education for excellence in resource efficiency, health and wellness, and environmental and sustainability education. The recognition award is part of a larger U.S. Department of Education effort to identify and communicate practices that result in improved student engagement, academic achievement, graduation rates, and workforce preparedness; and reinforces federal efforts to increase energy independence and economic security. California K-12 public and private schools, early learning centers, and school districts are eligible to seek ED-GRS nomination from the California Department of Education (CDE).

Savings by Design (SBD) – SBD is California's non-residential, new construction energy efficiency program. It encourages energy efficient building design and construction practices by providing financial incentives to the owner and team for exceeding Title 24. The statewide program is funded by public purpose charges on utility bills in the state. While SBD is geared toward new construction, it applies to major renovations that involve a complete multi-system replacement, area reconstruction, or equipment installed to increase the capacity of existing systems due to existing or anticipated new load handling requirements.

School Energy Efficiency Program (SEEP) – California IOUs offer the SEEP program to help school districts identify, evaluate and implement energy efficiency retrofit measures that provide an improved learning environment. The program connects schools with financial incentives for energy efficiency.

California ZNE School Awards Program – In 2016, the California IOUs presented the inaugural ZNE school awards to industry leaders and professionals. This recognition program is part of the Prop 39 ZNE Pilot program which also includes on-the-ground ZNE retrofit pilots, trainings and case study development.

Other Groups and School Associations – California has other groups, associations and organizations dedicated to green and high performance schools. An example is a group organized by Green Tech San Diego that facilitates regular meetings for cohorts of school facilities professionals in an effort to share lessons learned.

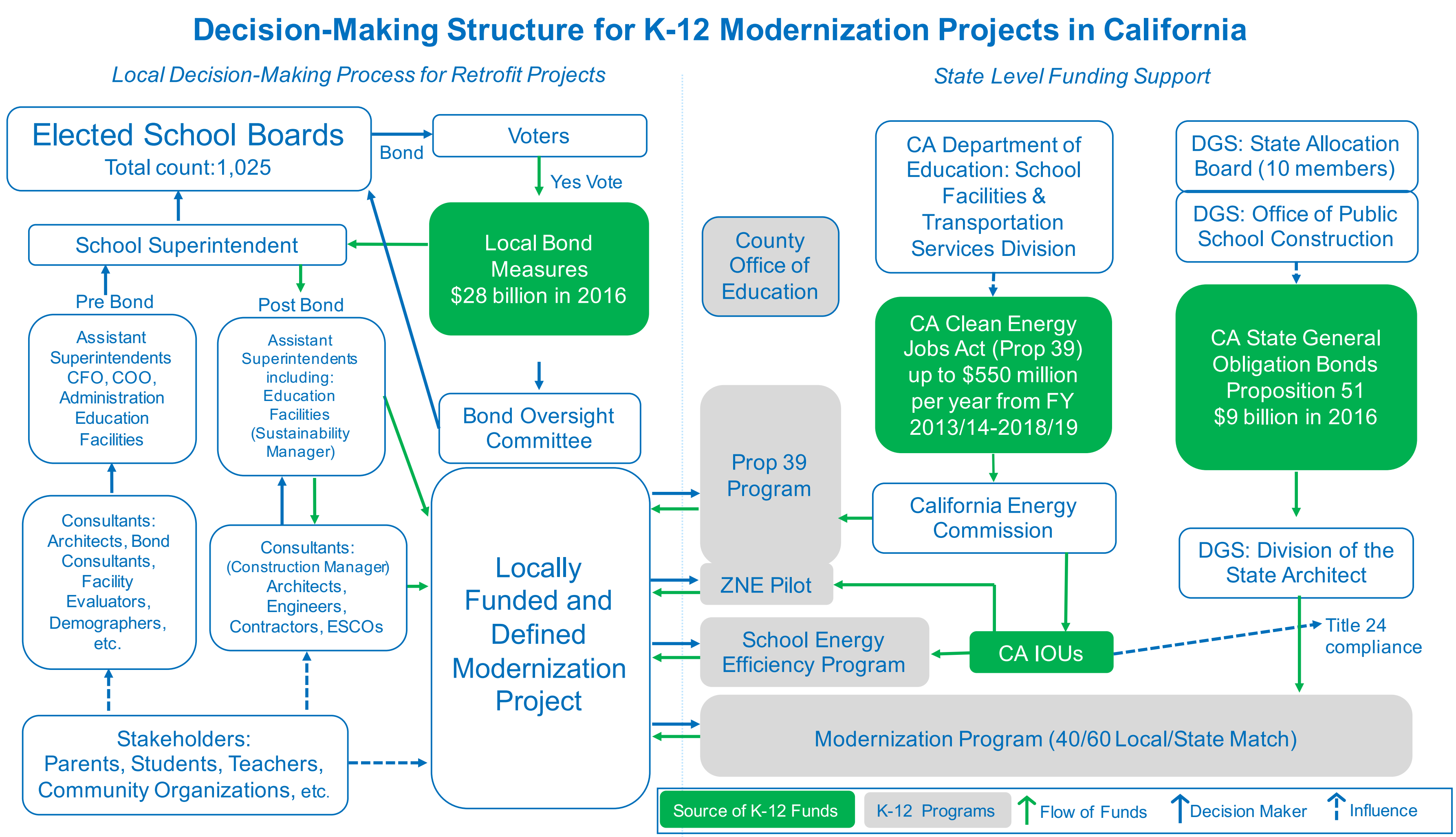
Funding and Decision-Making Process in K-14 School Facilities

This ZNE Retrofit Readiness Study investigates one small aspect of school decision-making and funding, specifically regarding the retrofit of K-14 school facilities. This is distinguished from funding and decision-making for new construction activities or for other educational expenses covered in the general funding formula (such as administration, teachers, etc.).

School renovations are driven by the local school district. School boards make the ultimate decision, though they rely on staff, consultants and public stakeholders who all influence their decision through engagement in a complicated public process. Among the important decisions made by school boards is whether to send a funding bond to the voters for approval. These bonds provide financing for new construction and existing school renovation. Money raised at the local level may be matched with state funding provided the project meets certain criteria as set out by the SFP and/or other program requirements. While the state does provide funding, it has no say on which projects move forward as long as program requirements are met.

A graphic of the decision-making and structure for Modernization (a.k.a. retrofit) projects in California is shown in Figure 5. Details regarding steps in the process, plus insights on how decisions are made both before a bond is sent to the voters and after it is approved, are described further below.

Figure 5: Decision-Making Process for K-12 Modernization Projects in California



Capital versus Operational Budgets

School funding comes from a variety of sources and many of the stakeholders and decision-makers mentioned in the previous section influence how this money is spent. Schools budgets are split between general operation and maintenance (O&M) and capital spending. Though these are separate, they affect one other.

General Operational Funds - General operating funds typically come from local property taxes as well as funding from the state calculated by the Local Control Funding Formula (LCFF). In 2016-17 total revenue for K-12 school general funds is $86.9 billion with 61% from state funds 25% from local taxes 9% from federal funds and 5% from miscellaneous local funds. This funding is for total school operations, including teachers, administrations, curriculum and staff development, food, library and counseling services as well as facilities, utilities and transportation.

General operational funds at school districts pay for Operations and Maintenance (O&M though sometimes referred to as “Maintenance and Operations”) funding pays for daily custodial services, routine maintenance, utilities and building security. This minimum O&M does not address significant deferred maintenance considerations to address seismic, energy upgrades or ADA standards. In addition, general funds do not address the need for more space due to enrollment growth nor the need for modernized schools.

Capital Funds - Capital funding for facilities comes from state and/or local bonds as well as a few smaller sources. Any state or local entity that issues a bond must pay back the bond with interest, and there is a maximum amount any district or the state can borrow. The state of California manages the School Facility Program that allocates state bond funds to local districts according to requirements and matching funding formulas set by the SAB.

School Facility Program (SFP)

Since established by Senate Bill 50 in 1998, the SFP has provided funding grants to school districts to buy property, construct new schools and modernize existing school facilities. Funding for these programs has come from state obligation bonds including Prop 1A in 1998 ($6.7 billion), Proposition 47 in 2002 ($11.4 billion), Prop 55 in 2004 ($10 billion) and Proposition 1D in 2006 ($7.33 billion), and Proposition 51 in 2016 ($9 billion) for a total of $44.43 billion since 1998. Only Prop 51 monies are available now, and this implementation has just begun.

Requirements for the SFP have changed over the years based on legislative changes, the direction of the SAB, and available funding. For example, at one time, the SFP made additional funds available to encourage new construction projects to be 15% better than Title 24. Those funds have been expended and this aspect of the SFP discontinued. Additionally, the SFP used to require a certain percent of funds be retained for O&M, but this is no longer a requirement of the program. Currently, the SFP provides great independence and flexibility to local school districts in their local projects. In return, these districts accept responsibility for the outcome of the project.

DSA is responsible for ensuring that districts are providing adequate and safe facilities with SFP funds. School districts must obtain DSA approval for their project’s plans and specifications before submitting a funding application to the OPSC for final approval. DSA review is to confirm compliance with California requirements for structural safety, fire and life safety and accessibility. The two major funding programs within the SFP are the New Construction and Modernization programs.

The SFP Modernization Program - A district is eligible for modernization grants when facilities are 25 years or older and have not previously received state Modernization funding. In addition, the school district must raise match funding at the local level to participate. The SFP Modernization program provides state funds on a 60/40 state and local sharing basis for retrofits that educationally enhance and improve existing school facilities. Projects eligible under this program include modifications such as air conditioning, plumbing, lighting, and electrical systems. Applications are submitted in two stages: an application for eligibility and an application for funding. Districts applying for SFP grants are required to meet state prevailing wage requirements.

State Propositions

State propositions sometimes create funds for school projects. Each of these funds has a particular process to allow local districts to access these funds. Proposition 51 and Proposition 39, two current funding mechanisms, are described below.

Proposition 51 (Prop 51) - Prop 51, passed in November 2016, is the first state-wide school bond since 2006. Prop 51 stores $9 billion in a "2016 State Schools Facilities Fund" and a "2016 Community College Capital Outlay Bond Fund" to be allocated according to the requirements and funding formula as outlined in the SFP. The fund will be distributed in the following amounts:

- $3 billion for new school construction
- $3 billion for the modernization of school facilities
- $2 billion for acquiring, constructing, renovating and equipping community college facilities.
- $500 million for charter school facilities
- $500 million for career technical facilities

According to the language in the bond, Prop 51 funds will be distributed according to current SFP funding formulas.

Proposition 39 (Prop 39) - Another state-wide proposition that impacts school facilities is Prop 39, the CA Clean Energy Jobs Act. Prop 39 is a voter approved initiative that changed corporate taxes and transfers up to $500 million per year for five fiscal years from the CA General Fund to the CA Clean Energy Job Fund, beginning in the 2013-2014 fiscal year.

According to the Prop 39 guidelines,[10] Prop 39 funds are available to school districts and community colleges for "energy efficiency and clean energy projects, as well as related energy planning, energy training, energy management, and energy projects with related non-energy benefits." Prop 39 funds may be used for Power Purchase Agreements if these meet particular requirements.

While the Prop 39 funds are officially distributed by the SSPI within the CDE, the CEC administers the Prop 39 application and overall process. The eight step process is as follows:

1) Collection of utility billing data
2) Benchmarking
3) Eligible energy project prioritization
4) Project sequencing which prioritizes efficiency over renewables
5) Energy efficiency measure identification through an energy survey, ASHRAE Level 2 audit or data analytics
6) Cost effectiveness that achieves a minimum Savings to Investment Ratio (SIR) greater than or equal to 1.01 according to the following formula:

   SIR = NPV/(Project Installation Cost – Rebates – Other Grants – Non Energy Benefits), where:

   NPV: Net present value of project cost savings is the total energy cost savings realized over the useful life of the equipment plus an annual maintenance cost savings of 3% of total project cost.

   Project Installation Cost: The total of all project design, equipment, and labor costs. Assumes a cost escalation rate of 4%, a discount rate of 5% and an inflation rate of 2%.

   Rebates: Utility rebates or other incentives that reduce the project costs.

10 http://www.energy.ca.gov/2013publications/CEC-400-2013-010/CEC-400-2013-010-CMF.pdf page

Other Grants: Any matching grant funds (not including Proposition 39 awards) used to finance the project. This is funding that does not need to be repaid.

Non-Energy Benefits: Other associated project benefits such as enhanced comfort, better indoor air quality, and improved learning environment. Non-energy benefits are capped at 5% of the project installation costs. According to the Prop 39 Program Implementation Guidelines[11]: non-energy benefits are expected to provide savings, avoided costs, and other monetary benefits. For example, the health benefits of improved indoor air quality, which may improve student and teacher health and result in reduced absenteeism. These costs are quantified as a percentage of the project installation cost. The Energy Commission SIR calculator automatically accounts for non-energy benefits.

7) Energy Expenditure Plan (EEP)
8) Energy project and job creation tracking and reporting

Prop 39 guarantees funding for school districts over its five-year period. Funds are distributed on a formula that is based on Average Daily Attendance (85%) and the number of Free and Reduced Price Meals (15%). Local projects must provide secure approval from the CEC before the CDE may distribute funds.

According to a CEC Prop 39 snapshot[12], the funding allocations for the four fiscal years 2013-2017 amounted to over $1.4 billion. The CEC has approved $112 million in planning funds for school districts and $920 million in Energy Expenditure Plan, which are also supported by other financing methods. County offices of Education have received $12 million (as well as $140 million to charter schools and a small amount to state special schools).

CEC has approved more than 18,000 measures suggested by school districts. As shown in Table 10 , more than half of these are lighting projects, and about a quarter are HVAC related. “Other” projects include kitchen, energy storage, electrical, Power Purchase Agreements, pool and irrigation. Estimated annual savings from approved plans are 392.8 GWh of electricity savings, 236,029.7 MMBtu of natural gas savings, plus propane savings and fuel oil savings. This is estimated to be an annual cost savings of $80,386,892 and 149,294 tons of carbon dioxide equivalent each year.

Table 10: Snapshot of Prop 39 Energy Efficiency Retrofit projects by Fiscal Year

Energy Conservation Measure	Total Number of Measures Approved	% of Total Measures Approved
Lighting	9488	51
Lighting Controls	1976	11
HVAC	2791	15
HVAC Controls	1895	10
Plug Loads	890	5
Generation (PV)	399	2
Pumps, Motors, Drives	351	2
Building Envelope	296	2
Domestic Hot Water	179	1
Other	233	0
Totals	18,364	99%

[11] Proposition 39: California Clean Energy Jobs Act Program Implementation Guidelines, December 2013 page E-2 available at http://www.energy.ca.gov/2013publications/CEC-400-2013-010/CEC-400-2013-010-CMF.pdf

[12] CEC snapshot available at http://energy.ca.gov/efficiency/proposition39/documents/Prop_39_Snapshot.pdf

Note: Numbers do not add up to 100% due to rounding errors

Local K-12 Decision-Making and Funding

Local school boards are the ultimate decision-maker when it comes to K-12 schools and facilities. They are primarily motivated by student educational outcomes and this influences every decision they make as an elected school board official. At regular school board meetings, board members receive recommendations and input from the Superintendent and staff (who often work in partnership with consultants for various activities) as well as public comments from many community groups and individuals.

Votes of school board members represent final decisions on many topics critical to school facilities. This might include overarching decisions like whether to send a bond to local citizens or whether to require CHPS verification in local schools. In addition, with Superintendent and staff support, School Boards appoint representatives for participation on certain committees that have influence over school facilities (for example, a Long Range Facility Master Planning Committee or a Bond Oversight Committee), and board members vote to formally approve their recommendations.

The following sections outline specific aspects of local decision-making regarding school facilities, starting with the primary source of financing - local bond measures. The section then describes the plans and practices that influence decisions about how facilities are managed, maintained and renovated in local school districts.

Local Bond Measures

Local bond measures are the primary funding source for school construction and renovation projects. In 2016, local California school districts and community colleges passed $28 billion in local school bonds in 206 separate voter approved bond measures.[13] Sometimes, but not always, local bond funds are matched with state funding secured through the SFP.

School boards decide whether a bond will be put on the ballot for voter approval. They hire bond consultants and lawyers to manage this process. School district representatives that we spoke to described the bond authoring as a very careful and deliberate political process. Bond consultants conduct research on the value of the bond and the specific language used in the bond itself. Regarding the bond amount, consultants investigate bond capacity or how much the district can afford to borrow. This is based on the amount of current outstanding bonds and the assessed valuation of property within the district. The appetite for local voters to accept more debt is another important consideration.

In addition to the bond amount, the bond language is very carefully drafted to garner sufficient support at the ballot box. Bond consultants survey voters to identify willingness to spend and community priorities based on the needs as outlined in the Facilities Master Plan (explained further below). Bonds might address the need for a new building due to overcrowding, the need to address deferred maintenance, or perhaps the need for enhanced Information Technology to meet a specific educational goal.

As the school district interview participants that we talked to explained, bonds must be specific enough that voters understand what is going to happen with the money, but flexible enough to not stymie projects, or particular aspects of projects, from moving forward. Bonds typically name certain facilities and generally describe projects that the funding will enable. Local bond implementation includes an oversight committee to ensure that the bond is spent according to the initial intent. When established, this group reports its findings to the school board.

Local School District Plans Regarding Energy

Facilities Master Plan – The Facilities Master Plan is an evolving document that assesses school facilities and establishes an approach on how to accommodate current and future student and teacher needs and address significant deferred maintenance challenges. Updated approximately every five years, the Facilities Master Plan

13 https://ballotpedia.org/School_bond_elections_in_California

serves as a guide for investments and capital improvements across a school district's portfolio. Some districts may not have an updated Facilities Master Plan. Not all Facilities Master Plans are alike. Some districts (often large and urban) have sophisticated Facilities Master Plans while others may not include as much depth or detail.

The Facilities Master Plan serves as the foundational document that drives planning and implementation of school facility projects and decision-making regarding possible bond measures. Generally, it outlines overall educational program goals, current facility assessments, predicted needs based on a demographic analysis, and an implementation plan that prioritizes current and future needs. It also outlines and recommends a variety of funding sources and financing options, including local bond issuance, and provides recommendations on how to align these with district priorities.

The Facilities Master Plan is developed with input from a number of key stakeholders. Interview participants described the plan development as "a data heavy process." A Leadership Team spearheads the plan development and consists of the Superintendent, Assistant Superintendents, principals, educational planners and other outside consultants like demographers, cost estimators and architects. The Leadership Team sets the overarching vision, mission and goals in the Facilities Master Plan. This group gathers data, explains what they have learned to stakeholders and interested citizens involved in the public process. Their aim is to build support for recommendations and financing options.

During this research, we learned that many, but not necessarily all, districts have Facilities Master Plans. Plans vary in comprehensiveness, though none incorporate energy considerations. The lack of energy considerations is important because local bond measures are typically written based on the Facilities Master Plan, and this plan is required to obtain state funding through the SFP. Absent having energy efficiency in these plans or other policy within the school district, there is a high likelihood that efficiency will not be considered for funding.

If energy is formerly addressed by a school district, it may be in a variety of other documents and plans, such as an Energy Master Plan, a Sustainability Plan, a Climate Action Plan, Owners Project Requirements (OPRs) and/or project specifications as explained further below.

Owners Project Requirements (OPRs) – OPRs are used by owners (in this case school districts) to formally outline objectives and expectations for a particular project. They describe the project, budget consideration, functional space and use requirements (building program and occupancy patterns), design process expectations, sustainability goals, building component and equipment specifications and specific performance criteria. A "template" OPR document can guide overall district level objectives and then can be modified with requirements for a particular project fairly easily. OPRs on a particular project often evolve over the course of a project and these modifications are carefully tracked.

San Francisco Unified School District (SFUSD)'s comprehensive sustainability approach is documented in OPRs that establish district-wide energy targets, load reduction strategies (envelope and lighting), passive strategies (like solatubes), high efficiency lighting and HVAC equipment and then renewables. The SFUSD OPRs are an outstanding example of incorporating efficiency into practices. Even there, SFUSD staff and design teams are just now having to come to terms with the fact that they will not be specifying the same equipment any more. This change will be a challenge to overcome.

Energy Master Plan– Few districts have Energy Master Plans. Those that do tend to be larger districts primarily because those districts use more energy and have more motivation to save on energy costs. The Energy Master Plan sets district wide energy conservation goals, explains actions and timelines for achieving the goals and identifies potential sources of funding for plan implementation. Sometimes, these plans also discuss transportation issues because of the gas use associated with the fleet of buses.

San Diego Unified School District (SDUSD) is a leading example of energy planning. SDUSD has over 200 schools and in 2014 spent $25 million on water, electric and gas utility bills[14]. This has encouraged them to develop a comprehensive Energy Plan and district wide energy reduction targets (expressed in overall district level percent reduction over a baseline year's consumption). Prop 39 and local bond funding has been instrumental in energy reduction efforts which have provided direct savings to the SDUSD general fund.

Sustainability Plans – A few districts have Sustainability Plans that outline energy and other opportunities to make school buildings and operations more "green." Sometimes, these sustainability plans are based on topics as outlined in CHPS guidelines and criteria. These tend to be the large, urban districts. An example is the Oakland United School District where a Sustainability Manager has been hired (partially paid for by Prop 39) to ensure CHPS-verification of facilities, among other things. In addition to energy efficiency and renewable energy, sustainability plans often cover topics such as transportation, water conservation, waste reduction, healthy food, gardens and integration of sustainability into educational objectives. Some Sustainability Plans call for the development of a Climate Action Plan.

Carbon Reduction Plan – A carbon reduction plan is a very new concept in school planning efforts and only a few large districts have even considered or begun developing these carbon plans. San Francisco Unified School District is developing a comprehensive Carbon Reduction Plan which is expected to be formally adopted in 2017. Also, in 2015, the San Diego Unified School District passed a resolution calling for a partnership with the City of San Diego on the municipal Climate Action Plan. While the resolution calls for 100% renewable energy by 2035, walkable/bike-able neighborhoods, clean energy programs, mass transit, and social equity to address those most impacted by climate impacts, it makes no mention of energy efficiency. In the interviews, we learned that San Diego's Climate Action Plan is expected to be done at the end the 2017 fiscal year. It is being guided by the SDUSD Environmental Sustainability Action Committee.[15]

Procurement

School districts use a variety of approaches to procure new construction and/or energy efficiency renovation projects. Below, we explain a number of contractual approaches that districts use, including: design-build, design-bid-build and lease-leaseback and Energy Service Company (ESCO) options. Selected approaches are influenced by state public contract and education rules and regulations. Integrated Project Delivery (IPD) is another contractual approach, but it is not available to public school districts in California so it is not addressed here.

- Design-Bid-Build – This approach to procurement is where an owner splits building procurement into separate contracts for design and construction. An architect/engineering team comes up with initial designs and a contractor is separately hired to build to these designs, often based on low first cost bid.
- Design-Build – Design-Build is an approach where one entity is awarded a single contract for architecture, engineering and construction of a project. The approach has not been widely used which may be due to stringent state requirements that were officially changed in July 2016 with the passage of AB 1358[16]. AB 1358 allows design-build procurement for projects in excess of $1 million through 2025. Notably, AB 1358 allows districts to develop their own prequalification rating system and allows leeway to consider factors other than lowest cost (including experience and life cycle cost greater than 15 years). AB 1358 also introduces a "skilled and trained workforce" obligation.
- Lease-Leaseback – Lease-leaseback is a procurement method allowed by Education Code section 17406. Interview participants cited lease-leaseback as a method increasing in popularity among school districts. Once formally approved by the school board, this lease-leaseback project delivery method allows school districts to lease real property from a contractor who builds on district property. Districts may enter

14 SDUSD Energy Master Plan Presentation available at https://www.sandiegounified.org/sites/default/files_link/district/files/special-projects/2014%20Energy%20Management%20Plan%20EnviroSusCommitteeMeeting_V2.pdf

15 https://www.sandiegounified.org/environmental-sustainability-advisory-committee-esac

16 The complete text of AB 1358 is available at https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB1358

agreements based on qualifications, value and total guaranteed maximum price. Lease-leaseback offers districts flexibility on financing because costs are paid back over several years. Again, prevailing wages must be paid in accordance with the California Labor code.

- Energy Service Company (ESCO) – An ESCO is a business that identifies, manages and implements an energy savings retrofit and/or renewable energy project. They also assume the risk associated with project outcomes because their compensation is linked to the actual cost associated with energy savings. Some school district interview participants indicated that ESCOs have been fundamental in arranging financing and turn-key delivery of Prop 39 energy efficiency projects.

In addition to project procurement, researchers inquired about bulk equipment procurement. The State of California has the California Multiple Award Schedules (CMAS) that establishes a multiple award contract with multiple suppliers for commodities, equipment and/or services and makes these contracts to state and local government, including the university system, community colleges and local school districts. Through CMAS, the state enters into a "base" contract and local entities can take advantage of centralized purchasing offers provided by individual suppliers to the state. The contracts are not a result of a competitive bid process and CMAS may have multiple suppliers for the same product or service. Some district representative interviewed had experience using CMAS, though they found it a challenge to use.

Energy Practices in K-12 Schools

Educating students is the primary driver of school decision-makers. As outlined in the Facilities Master Plan, allocation of funding for renovation projects is based on goals to achieve educational outcomes with little, if any, attention to energy outcomes. Prop 39, with its dedicated funding for energy efficiency for all school districts across the state, has sparked attention to energy efficiency practices and projects. Prop 39 establishes a project framework that requires benchmarking, project prioritization, sequencing, assessments, energy planning and project tracking. Often these projects are encouraged and facilitated by outside consultants who facilitate the project on behalf of the school district.

Below is a summary of typical energy practices in K-12 schools.

Benchmarking – Many school districts in California do some type of energy (and water) benchmarking. Prop 39 requires that school districts benchmark and assess buildings to obtain funds for retrofit projects. Typically, facility managers reported that benchmarking was another thing on the list of things to do. While it was helpful in understanding the Energy Use Intensity (EUI) associated with school energy performance, facility managers are not always fluent in the EUIs for their buildings, and they did not necessarily use benchmarking as a decision-making tool. Tools such as Green Button Connect which provides an easy and secure access to utility bills in a standard format as well as proprietary systems like 'School Dude" utility tracking solutions are available to assist school districts and utilities with benchmarking.[17]

Energy Expenditure Plan – Prop 39 requires the development of an Energy Expenditure Plan that includes a utility data release to allow CEC to have access to monthly utility data, benchmarking EUIs for every school discussed in the plan, a list of energy efficiency measures, description, cost and savings, and a job creation benefits estimate.

Facility Characteristics Tracking – Generally, local school districts do not have a database or tracking spreadsheet that summarizes key building characteristics (building age, size, equipment, etc.). Many facility managers mentioned a proprietary software tool called School Dude that tracks work orders for maintenance activities. Recently, School Dude began offering a utility benchmarking service for school districts as an enhancement to the software license.

Collaborative High Performance Schools (CHPS) verification – 42 school districts in California have a policy that requires CHPS verification for projects. This represents only 4% of districts in number, but 33% of students

[17] Information about Green Button Connect is available at https://energy.gov/data/green-button and School Dude utility tracking solutions is available at https://www.dudesolutions.com/industries/education/utility-management .

(2,029,518) and 23% of school buildings (2,416). Some larger, urban districts had a staff member ensure this documentation was complete.

Power Purchase Agreements (PPA) - Many districts enter into PPAs with a solar developer to bring renewables to their district. Solar companies facilitate the overall development, installation and maintenance of the solar array in return for lower and fixed energy costs to the district over a contracted time horizon (for example, 20 years). Since the solar company owns the system (and presumably the Renewable Energy Credits associated with the system), they have a vested interest to ensure that the system is working optimally. One advantage of PPAs is that they allow school districts to fully realize tax benefits associated with solar installations because the for-profit company can take the tax credit if they own and operate the system for at least five years. Since school districts do not pay taxes, they cannot capture this benefit on their own. Typically, the solar companies that facilitate these PPAs are sophisticated with much experience in the nuances associated with these contracts.

Costs associated with PPAs are permitted expenditures under Prop 39 as long as certain conditions are met. The project must meet the Savings-to-Investment Ratio requirements. In addition, contracts may not be awarded through a sole source agreement, the vendor shall be responsible for the design, installation, operation and maintenance of the system. The vendor must provide a performance guarantee ensuring at least 95% of estimated production over at least a five-year period. Finally, the Renewable Energy Certificate owner shall be clearly defined in the PPA.

Community Colleges Decision-Making and Funding

The 72 Community Colleges Districts across California have the responsibility to maintain, renew and enlarge (where needed) the facilities at their institutions on behalf of the students that they serve. This is the responsibility of the governing board of each community college district and is accomplished through a Five-Year Capital Outlay planning process that is submitted on an annual basis.

Education Master Plan and Facilities Master Plan - Districts develop an Education Master Plan and a Facilities Master Plan to inform key components of the Capital Outlay Plan.

Capital Outlay Plan - While the Capital Outlay plan is the responsibility of the community college governing board, the work behind this planning process falls to an executive committee of community college administers that address and respond to local needs and priorities through the involvement of key stakeholders such as facilities staff, community representatives and students. Upon completion, the Capital Outlay Plan must be submitted to the Facilities Planning Utilization (FPU) unit of the Chancellor's Office and approved to receive state funding for projects.

An important piece of the Capital Outlay Plan is the Five-Year Construction Plan which helps districts define their projects and priorities and considers enrollment trends and space inventory among other things. Districts seeking State funding for specific projects in the Construction Plan are required to go through a two stage proposal process that is overseen by the FPU. Similar to K-12 market, all community college construction projects must be reviewed and approved by the DSA for compliance with all applicable codes and standards.

Facility Utilization Space Inventory Options Net (FUSION) - All Community College districts are required to submit their Capital Outlay Plans through an online tool known as FUSION that is operated and maintained by the Foundation for California Community Colleges. This tool is meant to streamline the submission of documents required by FPU and provide the Chancellors Office a resource that allows them to track the utilization of district facilities. According to feedback from community college interview participants, this tool is currently being updated to FUSION2 to better help community college districts address their current and future facilities.

Summary of School Funding

Table 11 summarizes available funding sources for school retrofits.

Table 11: Funding Sources Available for School Capital Retrofits

Funding Source	Amount	Description
Local School Bonds	$28 billion	In two elections during 2016, 206 local school and community college districts passed bonds to support school construction. These districts will be pursuing projects and can be the focus of PA efforts to ensure efficiency is incorporated into these projects.
Prop 51	$9 billion	State wide bond measure passed in 2016 for distribution through the SFP with DGS review for school modernization projects available to K-12 and community college districts.
Prop 39	Up to $500 million / year for five fiscal years (FY2013/14-FY2018-19); $1.4 billion allocated so far	State-wide funding from the California general fund distributed through the CDE/CEC to support school energy efficiency. IOUs separately added a ZNE pilot component.

Challenges Faced in School Decision-Making and Funding

In addition to the overall lack of awareness and attention to energy considerations in regular business practices, deferred maintenance and inequity across districts also creates considerable challenges for energy efficiency in California schools. Research by the Berkeley Center for Cities and Schools (Berkeley) explains how equity and deferred maintenance are interrelated. It suggests that the state matching funding formula in the SFP tends to lead to inequity in school facilities[18] because the local district can only meet the requirement for match funding if they can borrow. Ability to borrow is determined by the valuation of local assessed (or taxable) property, the current amount of outstanding bonds, and the willingness of local voters to pass bonds. As a result, districts with a high asset valuation of local property and voters with a willingness to approve bonds are first into the queue for state matching funds, disadvantaging poor districts across the state.

In their research, Berkeley finds significant disparity in funding for O&M in schools across the state. While best practice suggests certain thresholds of spending for operations, routine maintenance and modernization are necessary to operate and maintain facilities, Berkeley finds that less than half of districts in the state meet these benchmarks. Moreover, they find that a high assessed value in districts leads to more spending in school facilities. Importantly, districts with lower assessed value tend to spend more on O&M and less on capital expenditures on a per student basis.

This leads to another challenge for California school facilities, deferred maintenance. Berkeley's research found that a structural pattern of underinvestment in California K-12 public schools has led to significant deferred maintenance issues. Every participant we spoke with indicated that deferred maintenance is a massive problem. This is true across the state and may be more pronounced in poorer districts.

Deferred maintenance will be a considerable challenge to overcome as the level of funding coming from local bonds and SFP are dwarfed by the magnitude of the problem. One interview participant noted that the $9 billion state-wide bond passed last year was a simply a "drop in the bucket" to address these needs. Underinvestment in O&M has led to asset deterioration/devaluation and tends to hit school districts unevenly, with schools in less wealthy districts having a higher level of devaluation.

18 Going it Alone Can California's K-12 School Districts Adequately and Equitably Fund School Facilities? Policy Research Working Paper November 2015 by Jeffrey M. Vincent Liz S. Jain from the UC Berkeley Center for Cities and Schools

Implications of Decision Making and Funding on Efforts to Encourage ZNE

The research on K-14 school market decision-making and financing structure has important implications that should be considered when developing an approach to encourage ZNE. First and foremost, school district decision-makers are primarily interested in educational outcomes. The research confirms that schools have a complex and long term process for capital planning for new construction and modernization of existing schools to support students, however few districts consider energy in policies as part of this process. This suggests that the overall lack of interest in and awareness of ZNE must be addressed, and, preferably, benefits tied to educational outcomes. Moreover, this complexity is exasperated by the fact that decisions are made locally, and this decentralized approach requires that more 1,000 school districts address ZNE individually.

The enormity of the deferred maintenance problems in CA schools also implies that schools may not be ready for ZNE. It also may serve as an opportunity to advance energy efficiency, for example when building structure (such as roof replacement) or energy using systems are impacted. Years of underinvestment in operations and maintenance have led to deferred maintenance challenges, and these concerns will need to be addressed, maybe even before energy efficiency and ZNE. This pattern of underinvestment in operations is also significant because ZNE buildings will likely need to perform optimally in order to achieve a zero result (see discussion on the importance of operations in the next section).

The California school market has been flooded with capital due to 206 successful local school bond measures. In 2016, voters in the state passed $28 billion in local bonds and an additional $9 billion of state-level bond funding for distribution through the SFP. Leveraging this money, the CDE and CEC may distribute up to an additional $500 million for energy efficiency retrofits through Prop 39 through the 2018-2019 fiscal year. The framework already established through Prop 39 provides an effective approach to energy efficiency upgrades.

5. Technical Approaches to Achieving ZNE

Goals of Energy Sensitivity Analysis

This technical sensitivity analysis seeks to identify broad priorities and performance patterns regarding ZNE performance in the school sector. A "sensitivity analysis" uses energy modeling building prototypes to identify the upgrades and conditions that may have the greatest impact on ZNE energy performance in the school sector. This study aims to understand the sensitivity of these prototypes to existing variables like climate, vintage and the relative impact of different system upgrades on building energy performance. Specifically, this analysis targets the following goals:

1. Provide guidance on the types of energy improvements that can bring the K-14 building stock onto a ZNE pathway by exploring multiple building performance upgrades and understanding the relative significance of these strategies.
2. Estimate how common building characteristics identified in the DEER database, including building vintage, climate, building type and operational characteristics impact potential savings and maximum performance potential in school buildings.
3. Identify the types of retrofits that will most commonly lead to the greatest energy use reductions, and evaluate how consistently these strategies apply across the school building types and conditions evaluated.
4. Extend the savings identified in the sensitivity analysis into the population of California buildings in the school sector.

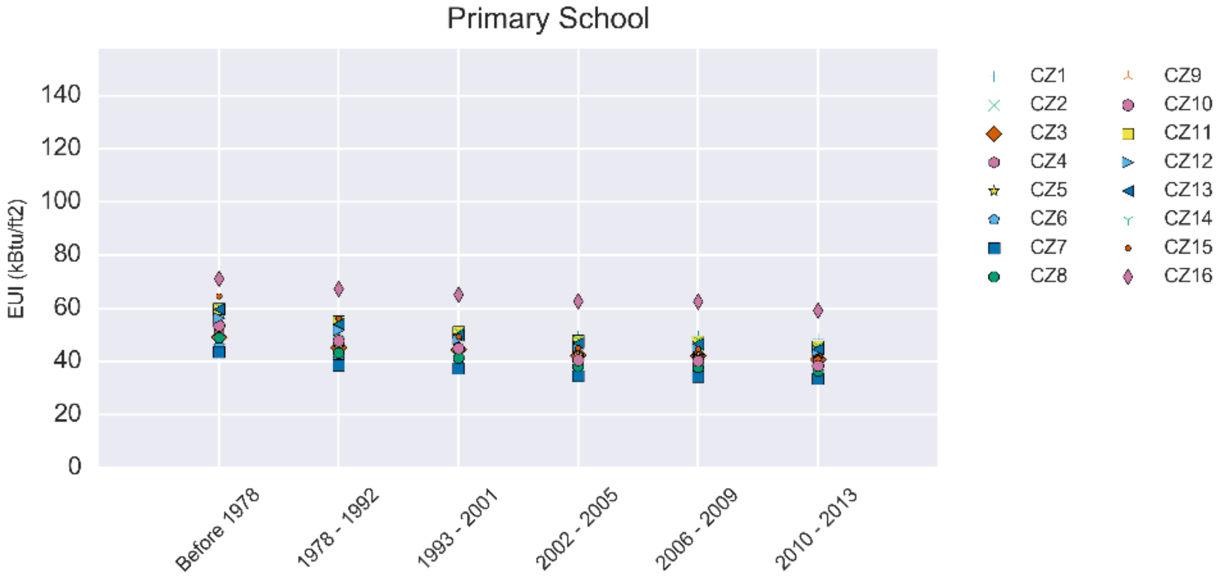
The results of this analysis have uncovered broad patterns and opportunities in the school building stock that can inform efforts to achieve widespread ZNE performance in this sector. Key findings fall into several categories, and are described below.

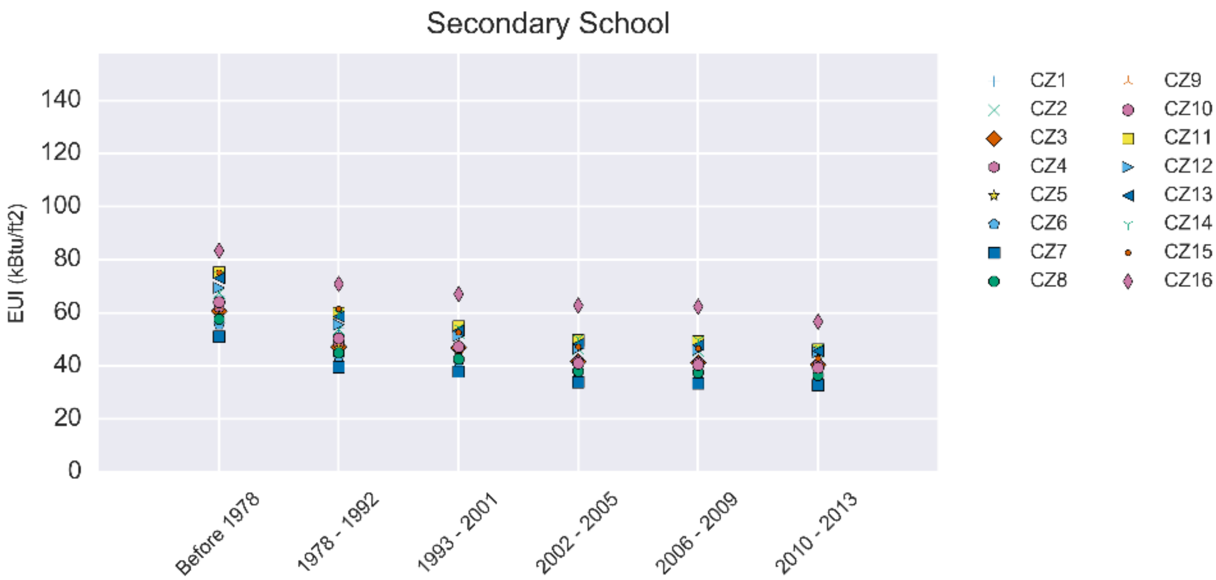
Baseline Building Performance by Vintage across Climate Zones

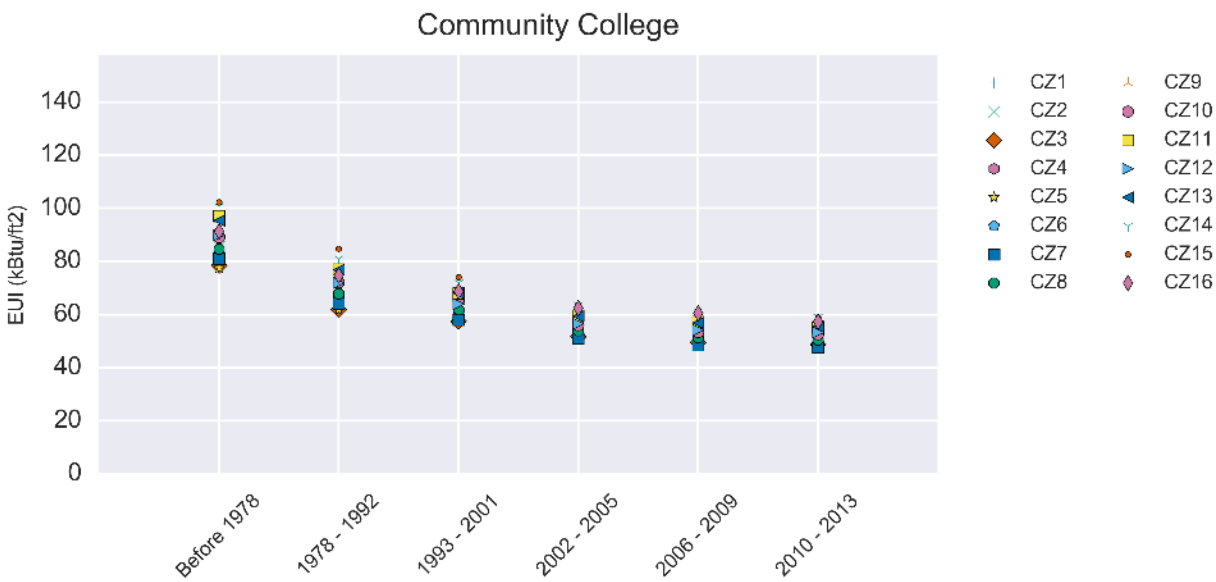
The analysis focused on four main educational building types: primary schools, secondary schools, community colleges and relocatable classrooms. These types of education buildings have unique load and use patterns, and performance varies by Climate Zone and building vintage. Energy model simulations show predicted energy consumption normalized by building size, commonly reported as site Energy Use Intensity (EUI) and reported in kBtu / square foot per year.

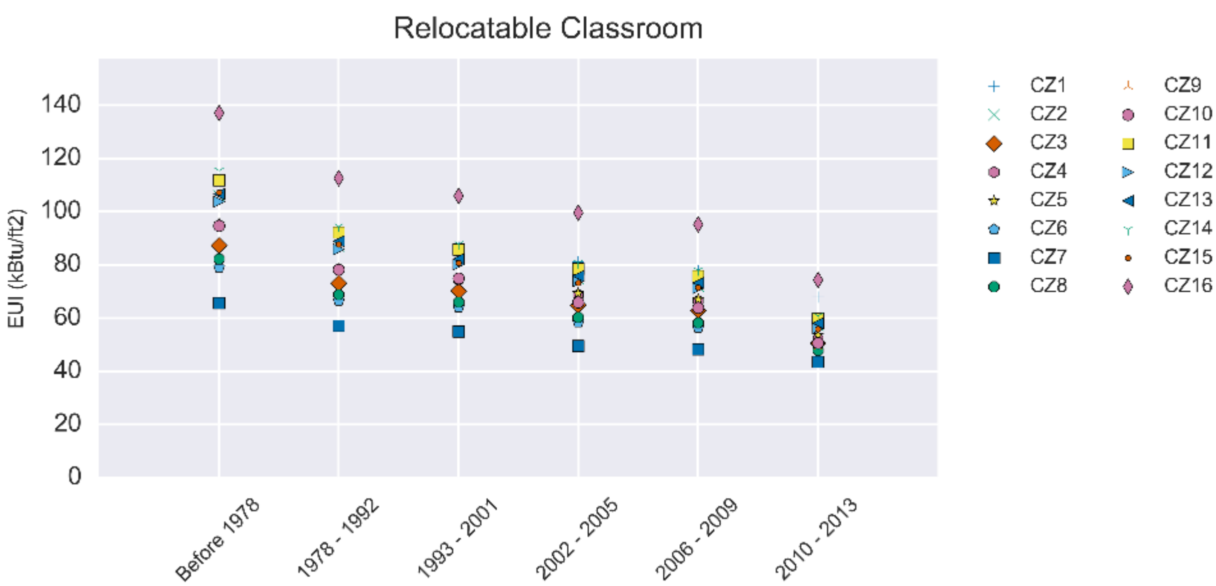
Figure 6 shows the range of EUI for the baseline model different building vintages of each building prototype type, across each of California's 16 climate zones.

Figure 6: EUI By Vintage For Baseline Buildings In Each Prototype and Climate Zone









These charts suggest that older vintage buildings are using more energy than their more recent counterparts. This is not surprising given the more recent influence of energy codes. In addition, community colleges are generally the most energy intensive buildings, with relocatable classrooms just behind those.

While Figure 6 shows that older buildings, particularly those located in the warmest and coldest climates (1 and 11-16), have the highest EUIs, Figure 7 and Figure 8 show that the majority of floor space for primary schools and community colleges of all vintages is located in milder climates (2-10). In this context, the very high EUIs shown for older buildings in extreme climates could be considered "outliers" of the overall population since they represent a relatively small portion of the total floor space of schools. In mild climate zones, the relative impact of poor envelope performance, more common in older schools, outweighs other performance factors. This impact can be seen in Figure 9, which shows the climate-weighted range of performance (EUI), based on vintage, for the building prototypes before and after the performance upgrades are implemented in the analysis. Despite the generally higher EUIs in Figure 6 for the oldest buildings, the EUIs of the older vintages in milder climates are within a comparable range to the EUIs of other vintages. So a larger population in milder climates offsets poorly performing buildings in more extreme climates and therefore the weighted value for EUI shows up in a narrower range.

Figure 7: Statewide Floor Space Distribution – Primary School

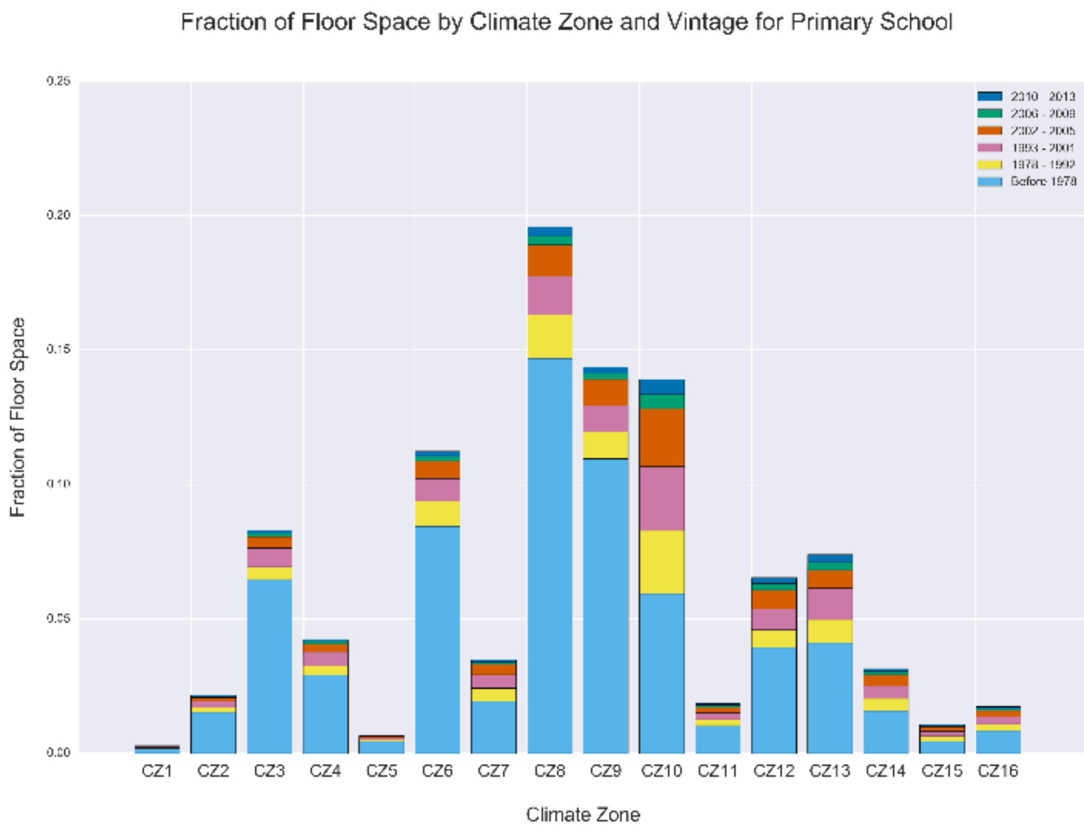
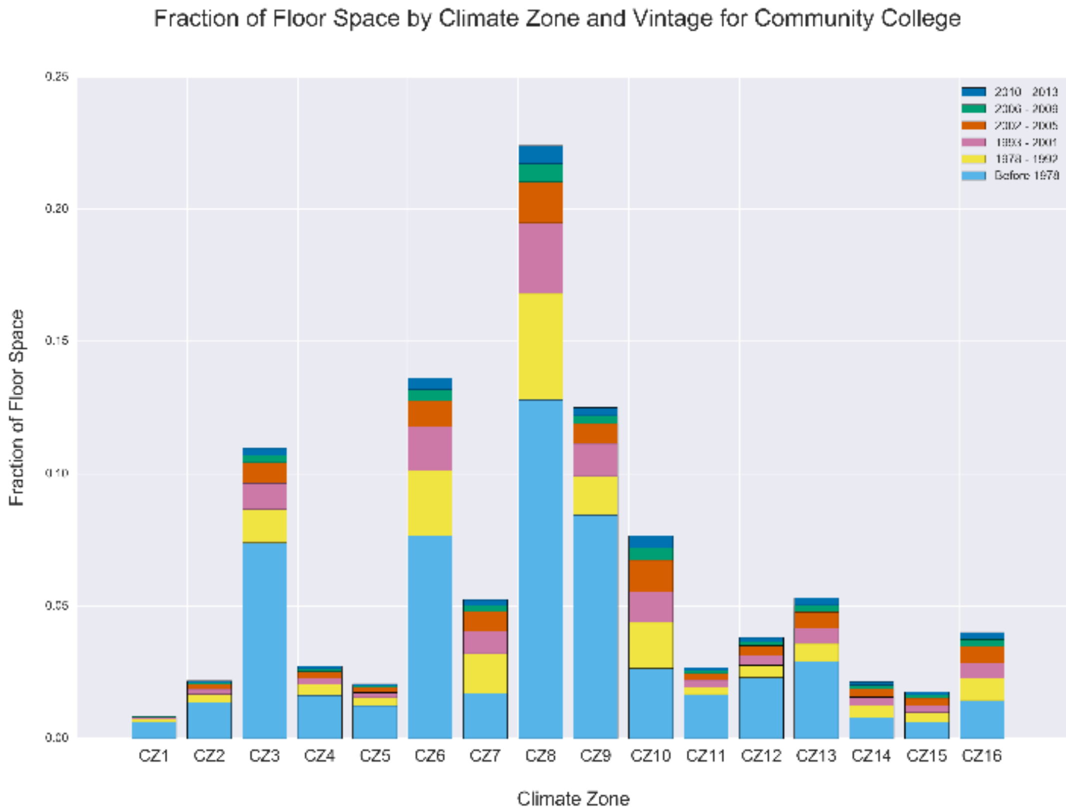
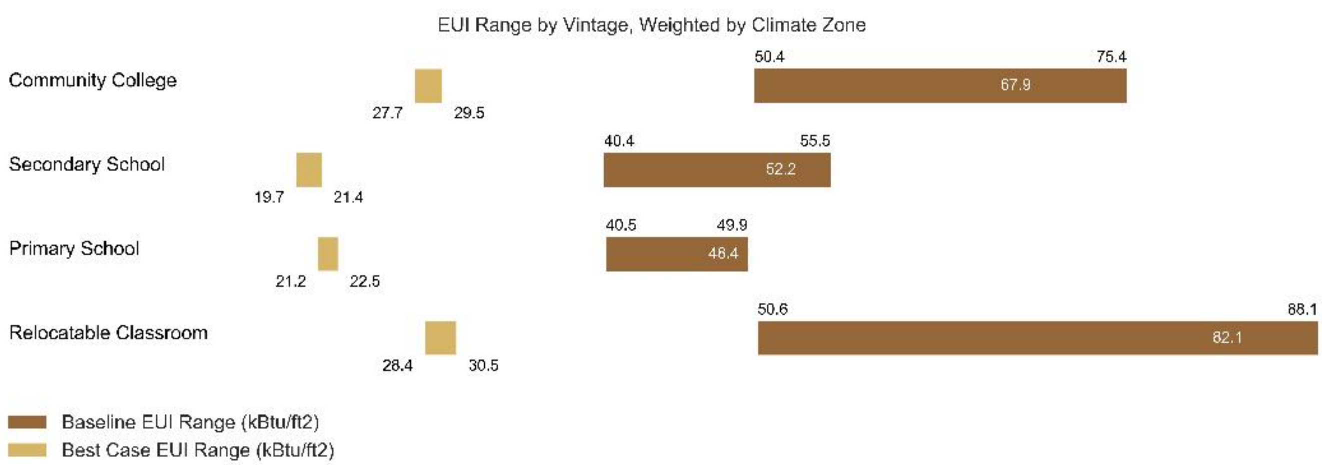


Figure 8: Statewide Floor Space Distribution – Community College



In Figure 9, the right-hand values (dark brown) represent the baseline building models. The average value (EUI) of the existing building prototypes is indicated within the range of performance for each building type. The light brown values on the left show the EUI range of the "best" energy performance observed in the simulation when applying the various measure packages. See Table 20 in Appendix C for a list of these measures.

Figure 9: EUI Range by Vintage, Weighted by Climate Zone



Opportunities by Climate Zone

Climate has a significant impact on building performance, as seen in the results of the simulation of the same building type in different climate zones. Figure 10,

Figure 11 and Figure 12 show the results by climate zone for the primary school, secondary school, and community college respectively. Numbers on the right side of each bar (represented by the full length) shows the baseline EUI for the existing building in that climate zone. The different shades in each bar represent the reduction in energy use gained from energy savings of different measure categories (see Table 20 for a listing of measures in each of these groups):

- HVAC system upgrades
- Management of internal gains
- Envelope performance improvements
- Domestic hot water system improvements

The remaining shaded area on the left side of each bar represents the final EUI once the building is fully upgraded. This is the remaining site energy use that would need to be offset by renewable energy systems in order to achieve ZNE.

Figure 10: Baseline and Improved EUI by Climate Zone for Primary School Prototype

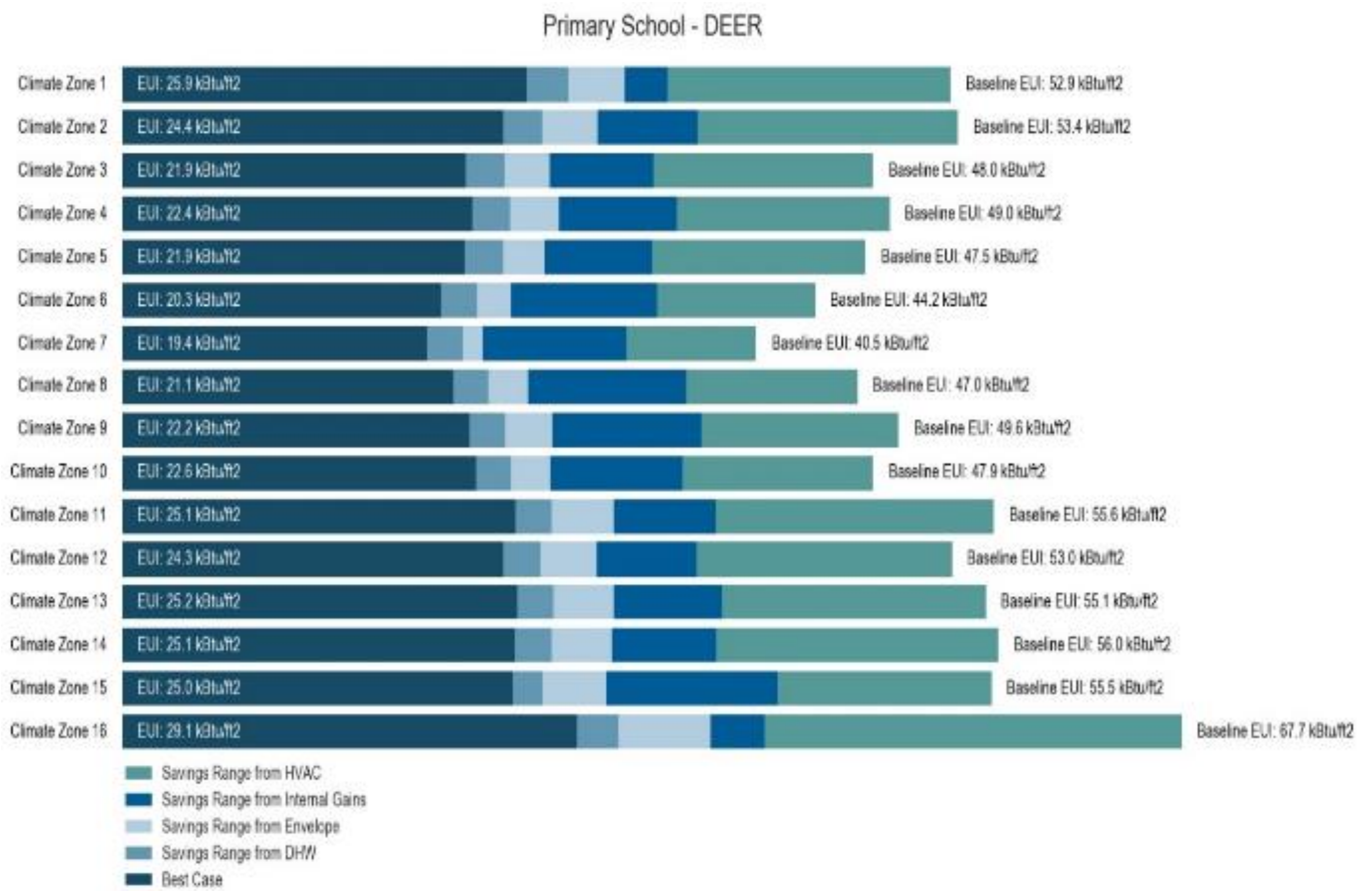


Figure 11: Baseline and Improved EUI by Climate Zone for Secondary School Prototype

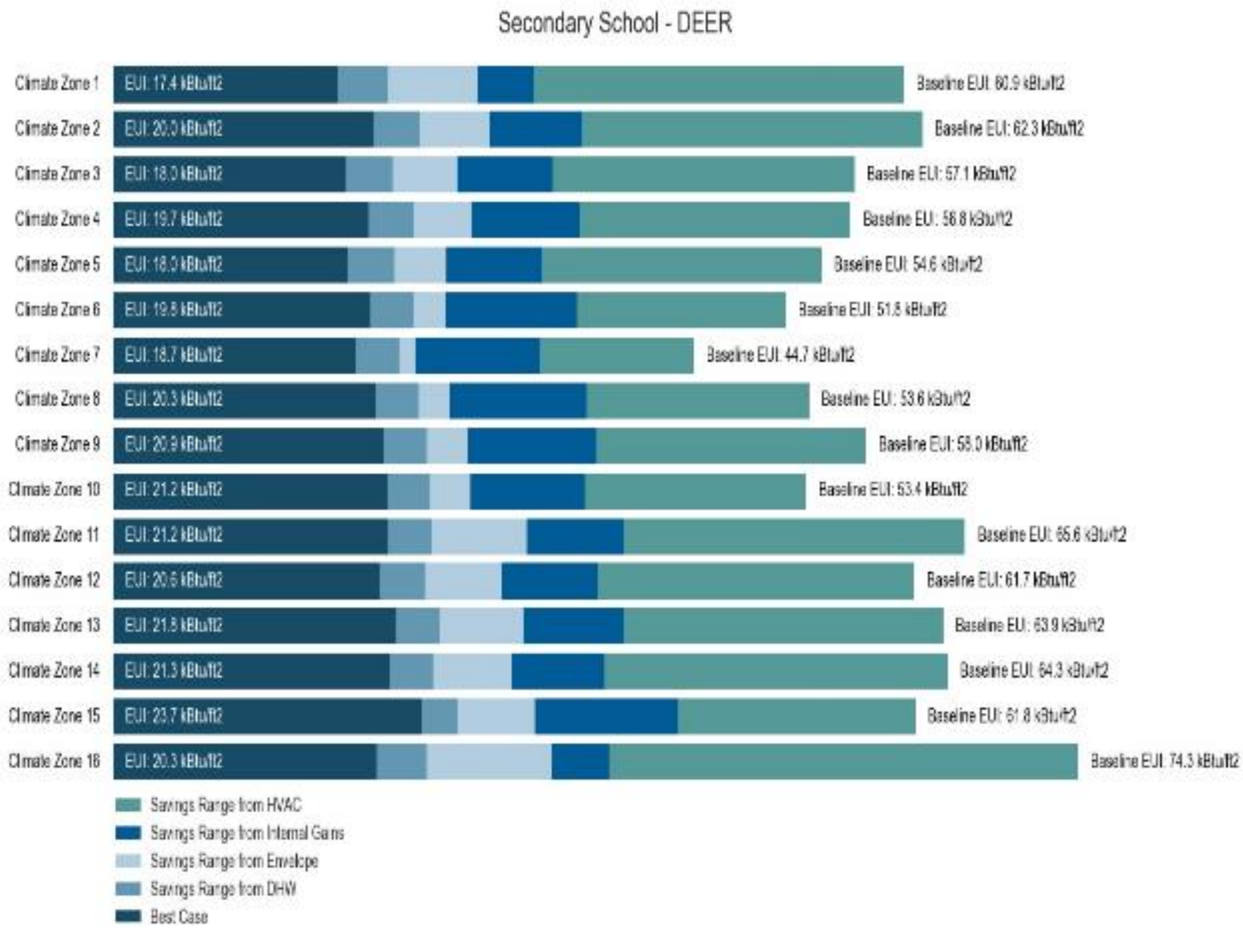
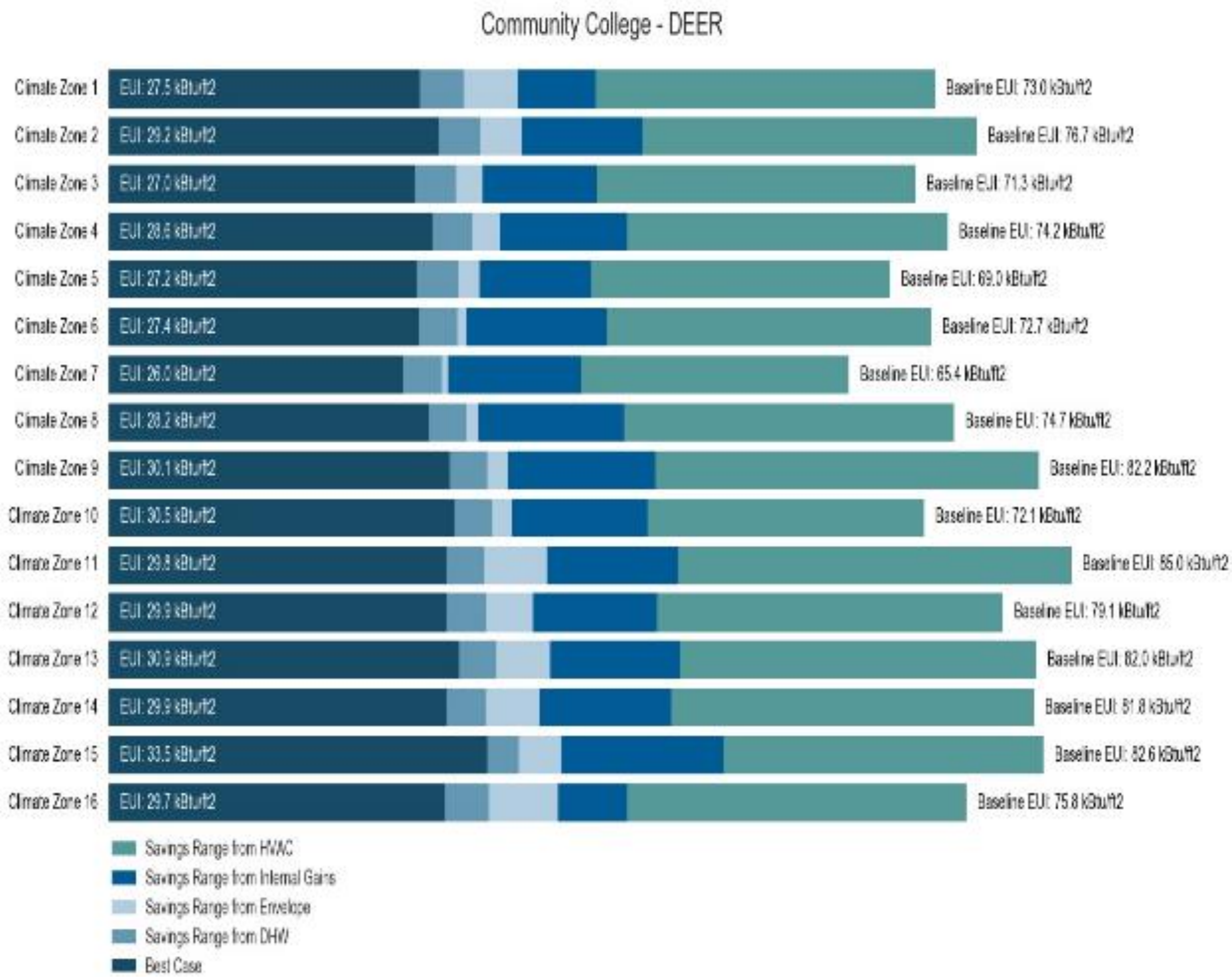


Figure 12: Baseline and Improved EUI by Climate Zone for Community College Prototype



Implications for ZNE School Retrofits

The Baseline and Improved EUI by Climate Zone charts reveal a few interesting results. First, all building prototypes show opportunity for significant improvement. Second, despite a range of starting baseline performance levels across various climate zones, the resulting EUI converges in the range of 20 to 30 kBtu/square foot per year. And third, HVAC seems to comprise a majority of the savings opportunities. Each of these findings is discussed further below.

Significant Improvement - The sensitivity analysis results indicate that significant performance improvements are technically possible for all buildings. On average, the achievable energy use improvement for the primary, secondary and community college building prototypes analyzed was approximately 50%. The range of energy performance possible for these buildings is impressively low, landing close to or within the range of performance already being demonstrated in completed ZNE buildings. (The 2016 Getting to Zero Building List shows the average EUI from the list of 53 ZNE-verified building is 22 kBtu / square foot year.[19]) This suggests that deep retrofit strategies do represent a way to bring the existing building stock to exemplary performance levels.

19 Getting to Zero 2016 List by NBI available at http://newbuildings.org/wp-content/uploads/2016/10/GTZ_2016_List.pdf

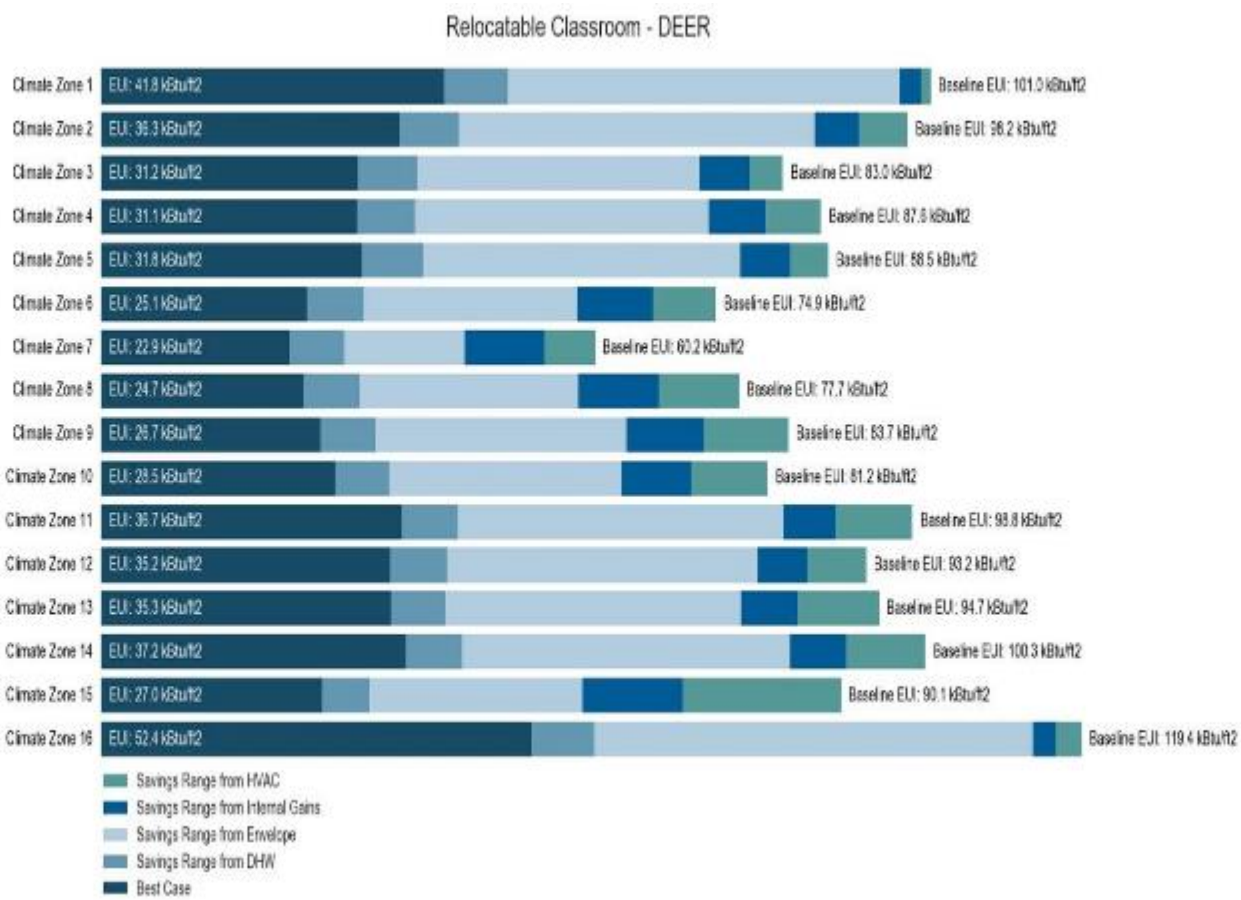
Performance Convergence - Another significant outcome of the sensitivity analysis is that the ZNE performance EUI for all of the building types converges in the low twenties for the primary and secondary school prototype, and the high twenties for the community college prototype no matter the climate zone. The fact that these EUIs are similar and within a fairly narrow performance range suggests that it is possible to set generalized EUI performance targets for ZNE school buildings that can be broadly applied across the state. The pattern of convergence also suggests that building age does not play a significant a role in building performance once significant upgrades are adopted. This suggests that all buildings can aim for the same EUI in the range of 20-30 kBtu/square foot per year no matter where they are in California or when they were built, although the costs to retrofit to this level might be different depending on the local circumstances.

HVAC Savings - HVAC system improvements are consistently the source of the majority of performance improvement while envelope performance improvements account for only a small percentage of the improvement.

Relocatable Classrooms

Relocatable classrooms demonstrate a very different performance pattern than the other three prototypes. Despite significant performance improvements, these buildings still perform substantially worse after retrofit than the primary and secondary school building types with which they are most closely associated as seen in Figure 13.

Figure 13: Baseline and Improved EUI By Climate Zone for Relocatable Classroom Prototypes



Relocatable classrooms are prolific due to past policies that encouraged them. A California Air Resources Board study in 2013[20] indicates that "the population of schools with one or more portable classrooms is estimated to consist of about 6,900 schools, with a total of about 145,000 traditional classrooms and about 85,000 portable classrooms." This report identifies many environmental problems with these classrooms, including inadequate ventilation, poor acoustic performance, inadequate thermal comfort, and indoor air quality and/or moisture problems.

Relocatable classrooms pose special challenges for upgrades which are different than the other building types analyzed. For relocatable classrooms, upgrades to HVAC and reduced internal gains (lighting and equipment loads) impact performance much less. Instead, upgrades to building envelope performance become the major improvement needed to drive low energy use in these buildings. One reason may be the high ratio of building skin to volume for relocatable classrooms.

Impact of Retrofit on End-Use Breakdown

As buildings are improved, the breakdown of relative end use shown in each prototype changes significantly. Figure 14 shows the before and after EUI for primary school buildings as well as the final and baseline energy use distribution, while Figure 15 shows this for secondary school buildings, Figure 16 for relocatable classrooms, and Figure 17 for community college buildings.

20California Portable Classroom Study available at https://www.arb.ca.gov/research/indoor/pcs/pcs.htm

Figure 14: Energy Use For Primary School Buildings Before And After Upgrade

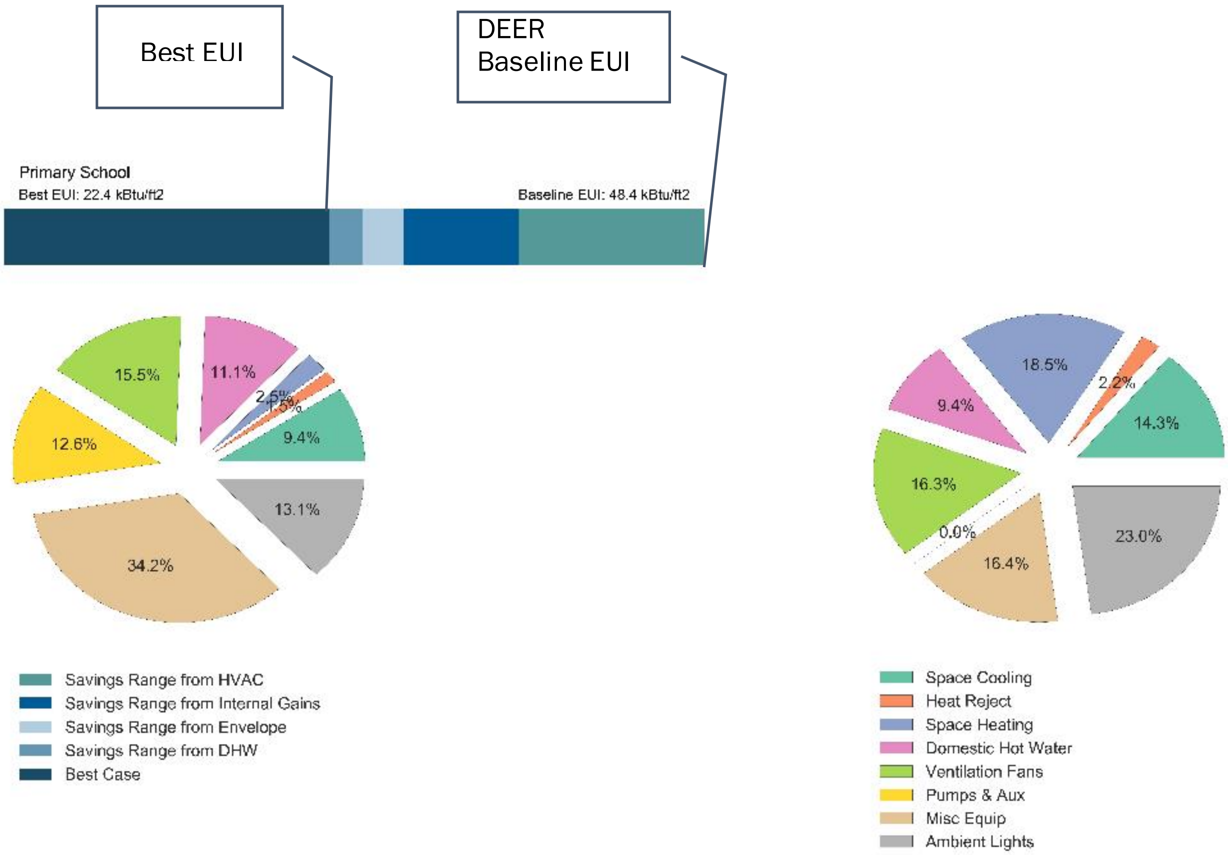


Figure 15: Energy Use For Secondary School Buildings Before And After Upgrade

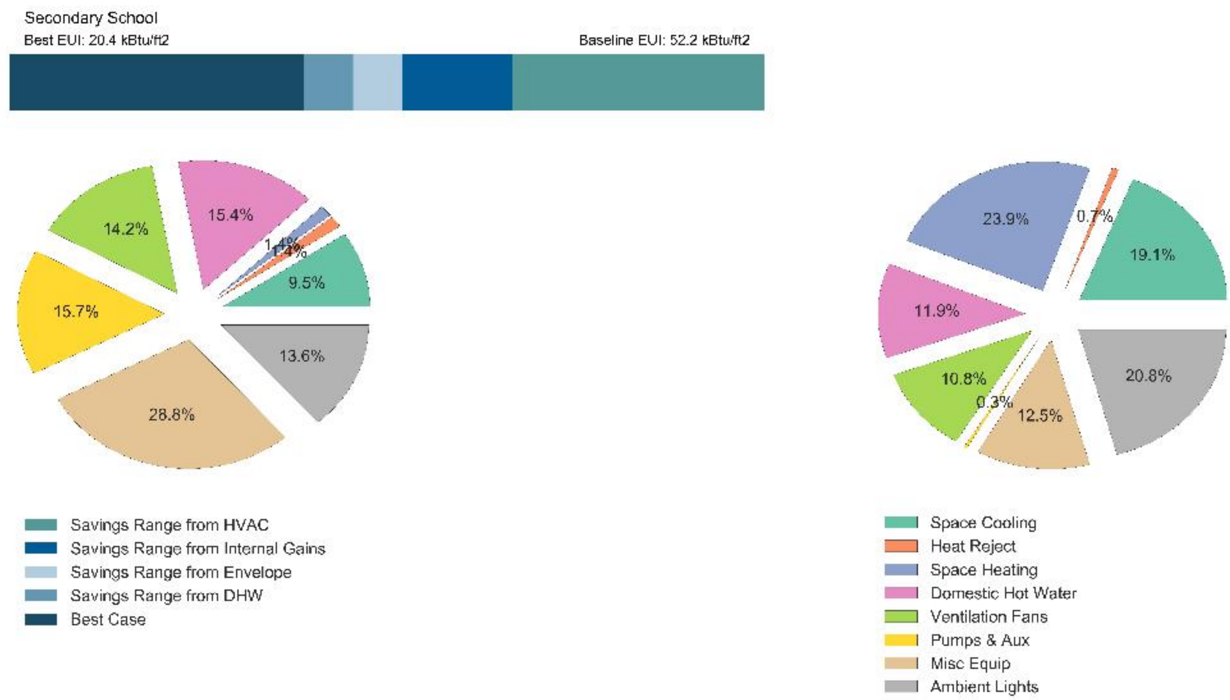


Figure 16: Energy Use For Relocatable Classroom Buildings Before And After Upgrade

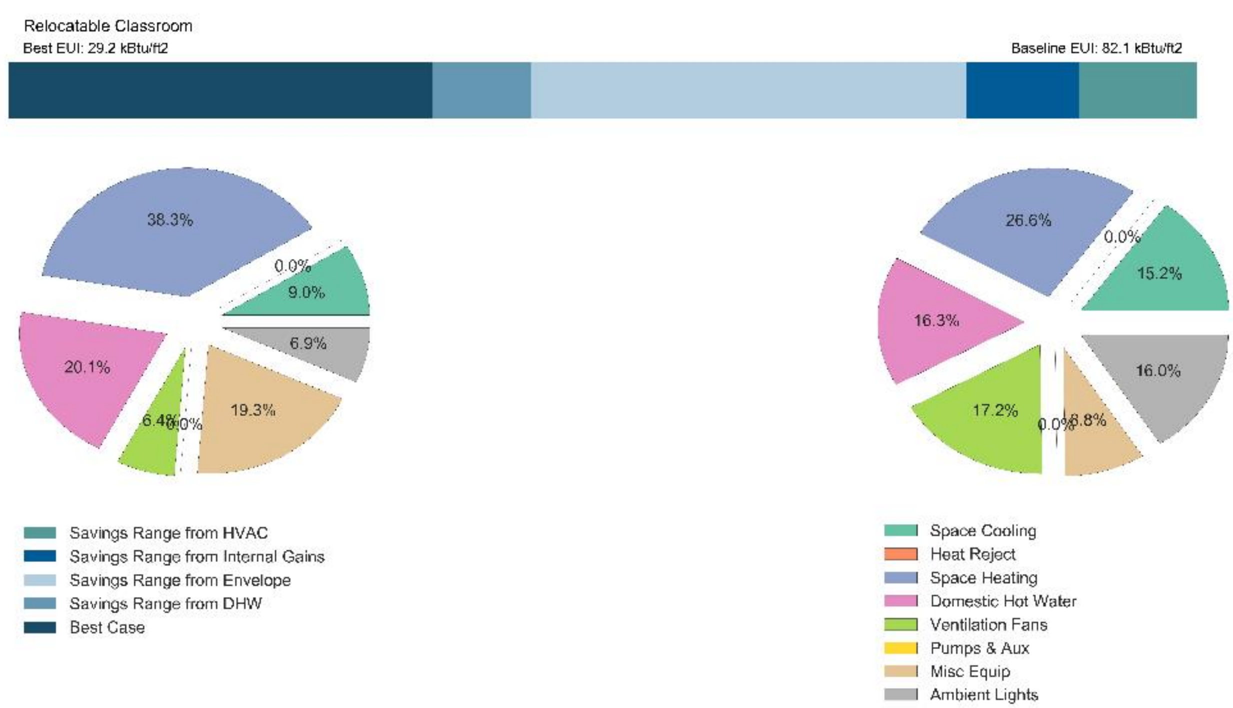
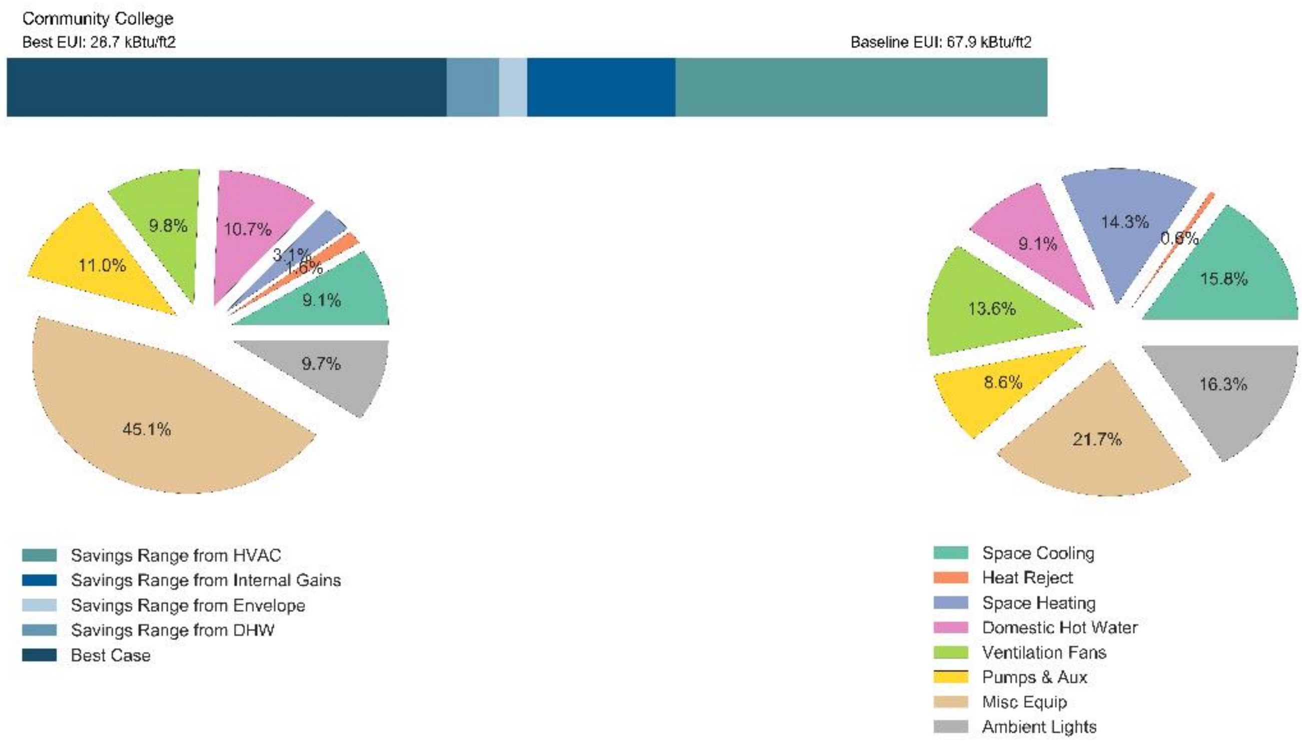


Figure 17: Energy Use For Community College Buildings Before And After Upgrade



The baseline and improved distributions shows significant reductions in heating, cooling, and lighting energy as a percentage of total building load, and a shift to loads driven by internal gains from lights and equipment. The most significant change is in the proportion of building energy represented by miscellaneous equipment. This category includes computers, printers, lab equipment, and other equipment categories that generally have more to do with building's functional and occupant program needs than with building design features. In other words, as the pie shrinks and "regulated" loads (envelope, lighting and HVAC loads) get smaller, the percent of the pie from equipment increases. These loads are primarily driven by the functional needs of the space as well as the operational practices and occupancy patterns – all important in efforts to achieve a ZNE result.

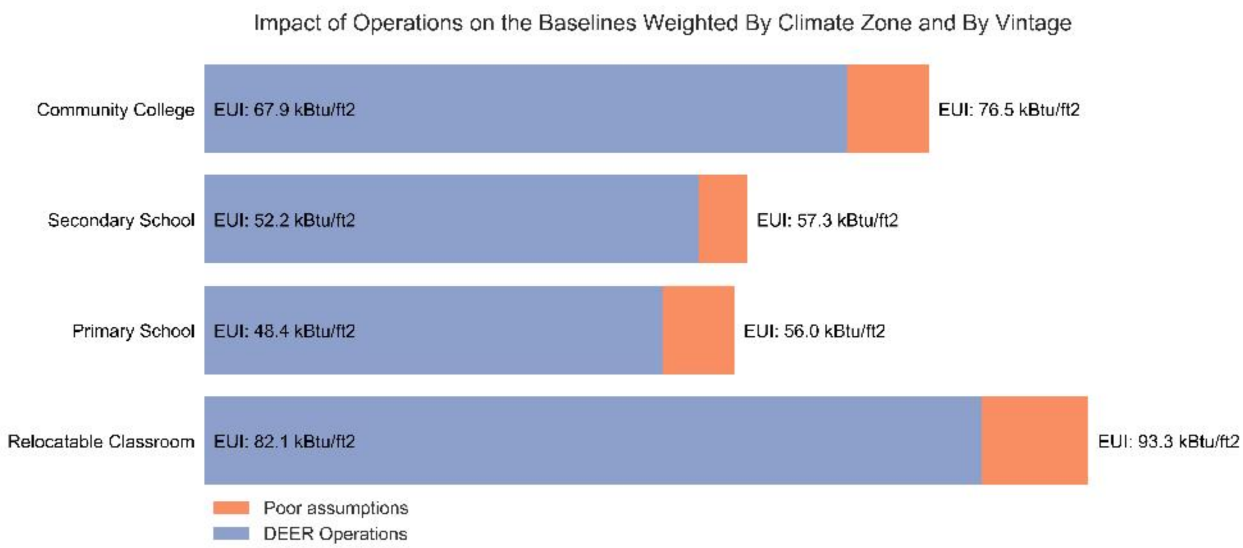
The significant relative increase in these loads means that in high performing buildings, tracking and managing these loads becomes much more important to overall building performance than it was before the upgrade. This has implications on how these buildings will need to be managed and maintained to achieve the performance levels targeted. Similar results are seen in the changing components of the pie chart in the other building prototypes.

Impact of Operational Characteristics

The research team acknowledges that the DEER assumptions for building operations and scheduling are intended to represent typical conditions across a population of buildings. These typical conditions include poor and good maintenance and operational practices as well as a range of operating hours that may be shorter or longer than the DEER assumptions. Most buildings in operation today have opportunities to improve performance whether it is through improving equipment loads or through better building management strategies. These may include occupant engagement to decrease equipment loads (i.e. turning off computers at night), better aligning building operating hours with actual occupant use patterns (off-hour management), or a host of other strategies that are related to building management and operation more than to design characteristics.

A portion of the savings opportunity represented by better off-hour building management has been considered in this analysis. Figure 18 demonstrates the energy impact on each building type of a lack of effective management of off hour equipment loads. In this analysis, slight modifications were made to building operating schedules to represent building operations outside of typical occupied hours, and failure to effectively manage nighttime plug loads. This aligns with the best professional judgement of the team which includes modelers and technical experts with significant experience in the field. (See Appendix C: Background on Technical Sensitivity Analysis for specifics of the modifications.)

Figure 18: Marginal Energy Impact of Operational Assumptions, By Building Type, Weighted



These simple adjustments to operating schedules can significantly impact energy usage; in this case representing an increase of over 10% of total energy in each of the baseline building types. Yet the assumptions in this analysis represent only a fraction of the types of operational issues that can significantly impact building energy use. As operation and equipment use become much more significant components of total building energy use in upgraded buildings, the potential impact of operational parameters is expected to increase.

Additional Potential Savings for Plug Load Reductions

As part of the energy simulation analysis discussed, the following three internal gains measure packages were examined.

1. 50% installed lighting power reduction
2. Advanced daylighting, lighting on/off and plug load controls
3. Items 1 and 2 modeled together.

Aggressive plug load reduction measures that would dramatically reduce the overall connected plug load were not considered as part of the analysis. The savings of an aggressive plug load measure would result in a much lower EUI than any of the three internal gains measures listed below, the regression model would not be a reliable predictor of savings as it would require extrapolation beyond the EUI constraints of the analysis.

However, the modeling team estimated the impact of plug load reduction measures via the simulation for a limited set of cases. The provide a general indication of the savings potential and are presented in Table 12 below.

Table 12: Range Of Estimated Savings From Plug Load Reductions In Older Vintage, Sample Climates

Case	Whole Building *Simulated* Energy Savings (%)	
	Best Case	Best Case + 50% Plug-Load Reduction
Community College, CZ16, Before 1978	61%	71%
Community College, CZ15, Before 1978	58%	68%
Community College, CZ5, Before 1978	56%	69%
Secondary School, CZ16, Before 1978	73%	77%
Secondary School, CZ15, Before 1978	57%	60%
Secondary School, CZ5, Before 1978	61%	67%
Primary School, CZ16, Before 1978	66%	72%
Primary School, CZ15, Before 1978	65%	71%
Primary School, CZ5, Before 1978	56%	64%
Relocatable Classroom, CZ16, Before 1978	65%	66%
Relocatable Classroom, CZ15, Before 1978	57%	59%
Relocatable Classroom, CZ5, Before 1978	55%	57%

Range of Potential Savings

The range of potential savings at the building level as well as in the sector overall is a research objective of this study. The sensitivity analysis provides some insights as to the range of energy savings that may be possible at the building level. Using the ranges of performance shown in Figure 9 (which excludes additional plug load savings beyond what is included in the internal loads package), we can estimate the building level savings opportunities for each building prototype based on the simulation results. This ranges from 54-65% savings depending on the prototype and climate zone over the DEER baseline model predictions. Specific ranges are covered in Table 13.

Table 13: Range of Building Level Savings from Application of Retrofit Packages

Prototype	Baseline EUI average (kBtu/square foot per year)	Improved EUI range (kBtu/square foot per year)	Percent Savings
Primary School	48.4	21.2-22.5	54-56%
Secondary School	52.2	19.7-21.4	59-62%
Relocatable Classroom	82.1	28.4-30.5	63-65%
Community College	67.9	27.7-29.5	57-59%

Sector level savings estimate the total savings by climate zone. DEER provides estimates of the total building area by climate zone as shown in Table 14.

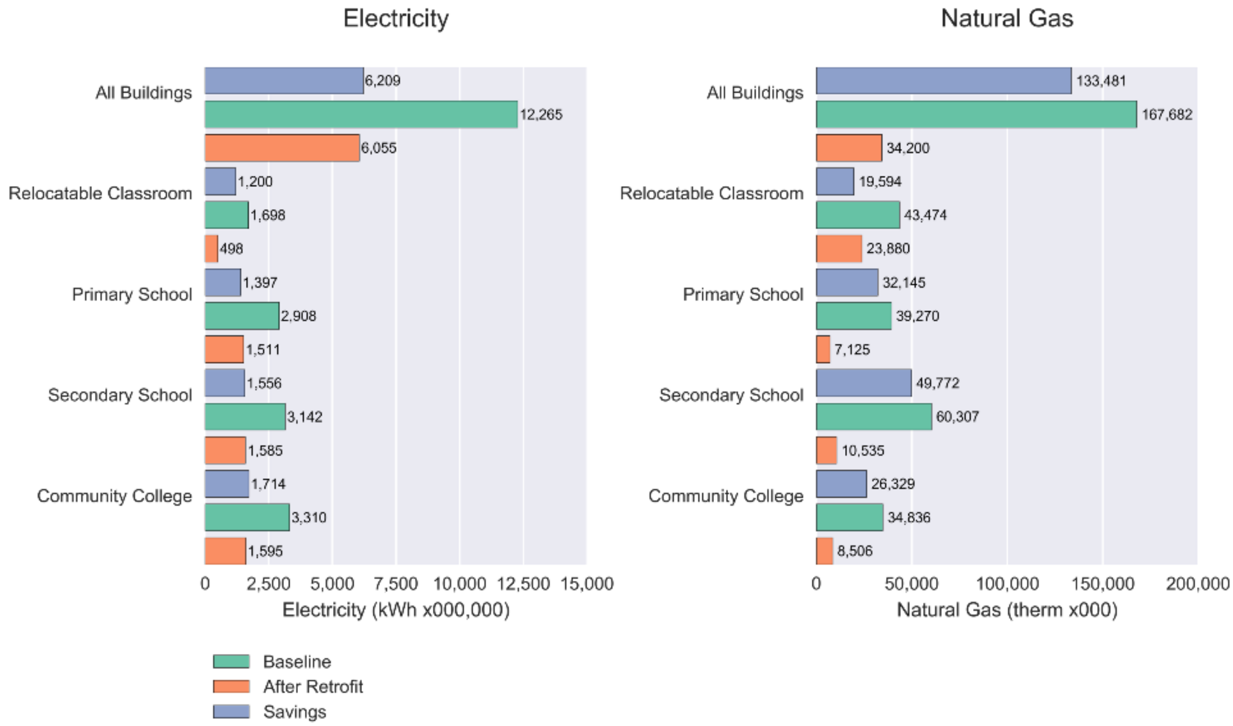
Table 14: DEER Estimates of Building Area (square foot) by Climate Zone and Prototype

Building Type	Community College	Primary School	Secondary School	Relocatable Classroom	All Buildings
Total Area (million sq. ft.)	139.43	228.60	240.04	98.26	706.33
CZ 01	0.46	0.53	0.87	0.26	2.12
CZ 02	4.28	4.16	6.17	1.98	16.59
CZ 03	9.55	19.05	19.92	8.18	56.70
CZ 04	4.28	10.52	9.21	4.33	28.34
CZ 05	1.97	1.45	1.59	0.63	5.63
CZ 06	16.44	27.96	24.36	11.49	80.24
CZ 07	5.42	8.73	7.40	3.56	25.11
CZ 08	20.80	47.78	43.46	19.83	131.88
CZ 09	24.28	31.20	36.41	13.80	105.68
CZ 10	11.11	33.12	31.71	13.91	89.85
CZ 11	4.14	3.51	5.36	1.69	14.70
CZ 12	4.80	13.78	17.07	6.20	41.85
CZ 13	8.17	15.93	18.94	7.08	50.12
CZ 14	6.46	6.00	9.04	2.87	24.37
CZ 15	5.26	2.25	2.81	1.02	11.34
CZ 16	12.00	2.64	5.72	1.45	21.81

Note: Total square foot for year 2017 from the CEC forecast data as of May 30,2015 (the most recent data). File with floor space sent to team member from Mohsen Abrishami at the CEC. Square foot for specific building types based on the total from the CEC and the proportion of square foot from DEER prototypes.

With the simulation results for each prototype by climate zone (and vintage) and the floor area by prototype in particular climate zones (and vintages), we can calculate the overall sector savings opportunities associated with the deep energy reductions represented in the sensitivity analysis. Estimates for overall sector savings from all four building prototypes is 6.209 GWh and 133.5 million therms. Electric and gas savings by prototype across all climate zones are represented in Figure 19.

Figure 19: Statewide Site Energy Use and Savings



The ZNE source definition requires an additional step to convert site energy savings (as predicted in the sensitivity analysis simulation) to source energy. In order to do this, we used the site to source power conversion methodology from the *2015 International Green Construction Code*[21] (IgCC) which lists an electricity generation energy conversion factor of 2.89 for the California eGrid sub-region as published by the Environmental Protection Agency (EPA) and a natural gas conversion factor of 1.09. As shown in Table 15, community colleges represent the largest source electricity savings potential from going to ZNE while the secondary school market represents the largest total potential source energy savings opportunity from going to ZNE. In total, the source energy savings from getting the K-14 market to ZNE represents savings opportunity of approximately 61 million Btu's.

21 2015 International Green Construction Code, International Code Council, 2015 (34)

Table 15: Potential Source Energy Savings

Prototype	Potential Source Electricity Savings (Million BTU x 1,000)	Potential Source Gas Savings (Million BTU x 1,000)	Total Potential Source Energy Savings (Million BTU x 1,000)
Primary School	11,049	2,865	13,915
Secondary School	12,323	4,403	16,727
Relocatable Classroom	9,526	1,725	11,252
Community College	12,684	2,251	14,935
All Buildings	49,146	12,126	61,272

6. Current Status of ZNE in California Schools

ZNE is possible in all California climate zones. As of October 2016, California has 18 ZNE verified buildings including two new construction ZNE school facilities. Another 139 buildings (including 28 schools) are actively pursuing ZNE though they are in design, construction or have not been operating for a year to verify ZNE performance.[22]

The IOU's ZNE school retrofit pilot project is demonstrating that ZNE retrofits are technically feasible with twelve sites in process. Moreover, these proof-of-concept retrofit projects are well-received by school decision-makers due to the non-energy impacts like better thermal comfort, ventilation, daylighting and acoustics in the classroom.

Despite this success and growth in this new market, interviews conducted as part of this research and lessons learned from IOUs as part of the Prop 39 ZNE pilot program suggest there is a lack of familiarity with ZNE, especially ZNE retrofits. The participants interviewed as part of this research purposely focused on professionals with experience in ZNE. The exception to this was the school district participants. Of these eleven individuals, three had experience with ZNE projects so they were familiar. Of the remaining eight school district staff, three were unfamiliar and five were only somewhat familiar with ZNE.

This is not surprising because, while ZNE retrofit pilot retrofit projects are in process, no school has yet to be retrofit to ZNE status. According to the IOU staff involved in the pilot, these projects are on track to achieve success with ZNE. These ZNE pilots represent a variety of California climate zones and districts of all sizes, including urban suburban and rural schools, yet it is only a small number of schools dispersed throughout the state.

Commonalities in ZNE Projects

While the Prop 39 ZNE Retrofit Pilot projects may not yet be complete, interview participants involved in ZNE projects echoed common themes that NBI and others have learned in research and experience about successful ZNE new construction and existing building retrofits.

ZNE building teams **set an EUI consumption target early**, even before design begins. This is distinguishable from common practice in the industry of "percent better than code." The sensitivity analysis suggests this EUI target should be between 20-30 kBtu/square foot per year, although some Prop 39 ZNE pilots are aiming for EUIs lower than 20 kBtu/square foot per year.

ZNE projects **consider the energy loading order in the sequencing of energy improvements.** ZNE projects make every effort to reduce loads and, simultaneously, first costs with careful attention to passive systems, a tight envelope, lighting load reduction, and plug load reduction. Mechanical systems can then be downsized before renewables offset the remaining load. This manages first costs associated with HVAC and photovoltaic equipment.

Another commonality of **ZNE projects is that they consistently have a champion on the team.** This might be an architect, project facilitator, facility manager, school board member or a parent. However, there is always someone who ensures the team stays on track toward the ZNE result.

Finally, a significant differentiator between ZNE and other "high performance" buildings is that ZNE buildings verify performance once occupied. **They are not only designed to ZNE, they are *operated* at ZNE.** Occupants in ZNE buildings are engaged and committed to a zero result. Unlike buildings with LEED certification, ZNE buildings do not stop with predicted energy performance estimates from energy models done late in design. Instead, ZNE buildings rely on actual energy outcomes in order to ensure they are operating at ZNE.

[22] Winter 2016 California ZNE Watch List is available at http://newbuildings.org/wp-content/uploads/2016/12/CA_ZNE_Watchlist_FallWinter_2016.pdf

Commonalities in Prop 39 ZNE Retrofit Pilots

In addition to the common themes associated with successful ZNE projects cited above, Prop 39 ZNE Retrofit Pilot projects have commonalities in the retrofit process as well as the technical measures proposed. From a process perspective, **Prop 39 ZNE teams carefully assessed the site both from an efficiency and from a renewable perspective.** This included understanding unique design features through observation as well as conversations with maintenance staff and building occupants.

Energy models calibrated with actual utility bills and weather data have been used to predict savings in Prop 39 ZNE retrofit pilot projects. One participant described this as a "no stone left unturned" approach where t**eams consider a host of energy conservation measures to achieve the energy target.** This is consistent with other research on deep energy retrofits which concludes that energy and cost savings of 50% are clearly achievable and that integrated design, multiple measures and monitoring are more critical to low energy buildings than any one technology.[23]

Another commonality experienced in Prop 39 ZNE projects are challenges associated with the **tight summer construction timelines.** This is when many schools perform retrofits and is only a short window. Teams had plan ahead and expect the unexpected, such as, unfavorable rulings by plans examiners, scheduling conflicts, asbestos, etc. For example, one Prop 39 ZNE team was delayed because additional weight capacity on the roof from HVAC equipment replacement triggered DSA review challenges (even before considering installation of photovoltaic equipment). In this instance, the team worked with the HVAC equipment manufacturer to re-engineer the unit to be lighter in weight so DSA review was not triggered.

Part of the ZNE pilot projects has involved **communicating both the energy and non-energy effects associated with ZNE retrofits to school decision makers.** For example, this includes research that has been done on the benefits of daylighting and its connection to student performance, [24] as well as the negative impacts that low ventilation rates[25] and poor acoustics[26] can have on student attention and learning.

Among the few early ZNE retrofit pilot projects, we also observe a **common measure menu**, including:

- **Daylighting and controls** (including solatubes) – In some Prop 39 pilots the original daylighting was in place, but was "disabled" or covered with paint or solid surfaces. Uncontrolled glare and the need to black out rooms were a large part of the rationale for defeating the original design. (Blacking out rooms is seen by school staff as important for projection equipment, but this is less of a concern with modern self-illuminated equipment although perceptions about the need to black out rooms may change more slowly.) In order to ensure that the daylighting measures are not defeated again in the future, daylighting is being controlled to address glare and daylighting discomfort issues.
- **Lighting** – Advanced LED systems with controls that integrate with daylighting opportunities is part of the Prop 39 ZNE pilot projects. In some cases, LED lamp replacement is happening instead of fixture replacement per stringent Savings to Investment Ratio requirements (see further discussion below).
- **Envelope** – Envelope measures are more focused on sealing and caulking rather than window replacement or increased insulation in Prop 39 projects.

---

[23] *A Search for Deep Energy Savings*, Higgins (August 2011) available at http://newbuildings.org/wp-content/uploads/2015/11/NEEA_Meta_Report_Deep_Savings_NBI_Final81520111.pdf

[24] Daylighting in Schools: Investigating the Relationship Between Daylighting and Human Performance, Heshong Mahone Group (1999) available at http://h-m-g.com/downloads/Daylighting/schoolc.pdf

[25] Ventilation Rates in schools and pupil's performance, Bakó-Biró (2011) available at http://www.co2indicator.nl/documentatie/Ventilation-Rates-in-Schools-and-Pupils-Performance.pdf

[26] Acoustical Barriers to Learning: Children at Risk in Every Classroom, Nelson, P.B. & Soli (2000) available at http://lshss.pubs.asha.org/article.aspx?articleid=1780235

- **Plug load** – Installation of Energy Star classroom and kitchen equipment are sometimes included in Prop 39 pilot projects. Kitchen equipment in some schools provides an extra energy load which can present an additional challenge to get to a ZNE result.
- **High efficiency HVAC including energy recovery systems** – High efficiency HVAC equipment is a common retrofit strategy. Additionally, ceiling fans have been used to enhance natural ventilation strategies.
- **Building Energy Monitoring System (EMS)** –EMSs are not necessarily included in the energy modeling analysis in these Prop 39 pilots, although they are a helpful measure for the facility managers for ongoing operations and maintenance of ZNE.
- **Photovoltaic systems** - Stringent roof weight considerations are enforced by DSA. Covered play areas or parking have been alternatives.

Challenges Associated with Cost Effectiveness

The current **Prop 39 Savings to Investment Ratio (SIR) methodology limits investment in energy efficiency measures needed to get to ZNE.**

- One participant noted that the SIR[27] of replacing light fixtures (and triggering Title 24) couldn't compete with LED lamp replacement.
- HVAC system replacement does not pass SIR requirements unless the equipment was close to replacement anyway.
- Roof replacement happens infrequently, therefore incorporating insulation and structural support for equipment is advised at that time. However, cost effectiveness tests typically do not support added roof insulation due to low gas prices.
- Replacement of noisy, inefficient "Bard" heat pumps is commonly recommended although the SIR does not fully support these. Inexpensive Bard units are especially prevalent in relocatable classrooms where the acoustics associated with this inefficient equipment impact student performance.
- Non-energy effects are quite valuable in schools, especially those that address acoustic performance and/or indoor air quality. However, the "value" of these in the SIR calculations under the Prop 39 framework established by the CEC is limited to 5%. Traditional cost effectiveness tests do not apply to the Prop 39 ZNE pilot program.

Possible Range of Costs for ZNE Retrofits

The range of costs for ZNE retrofits depends on a number of factors. One important factor is the current energy performance of the building being retrofit and thus the scope of the deep energy reductions necessary to enable ZNE performance. Another is the size and installation costs associated with the renewable system needed to bring the school retrofit to ZNE.

Early Prop 39 pilot projects provide some insights as to the expected costs associated with deep energy reductions plus renewable (photovoltaic) installation. These projects have left no stone unturned regarding efficiency opportunities and are generally pursing energy reductions of between 25% and 40% over an existing building baseline conditions. Early costs estimates suggest that the installed cost of energy saving equipment for a few of the early pilots is in the range of $300,000-$400,000 per school, though this depends significantly on existing conditions, local labor costs, whether the renewable system is ground, parking structure or roof mounted etc. Solar costs also depend on system size and details associated with the particular installation. In early Prop 39

[27] Savings to Investment Ratio must be over 1.01 per the CEC guidelines available at http://www.energy.ca.gov/2016publications/CEC-400-2016-005/CEC-400-2016-005-CMF.pdf

pilots, this is also approximately $400,000 per building. All of these costs could be more or less depending the local building and labor conditions.

Additional Lessons Learned from Prop 39 ZNE Pilot Projects

The Prop 39 ZNE Pilot projects have been ongoing during the course of this research. During the public review process, researchers received comments from the IOU staff implementing the Prop 39 pilot. These comments are provided in their entirety in Appendix D: California IOU Lessons Learned from the ZNE Schools Retrofit Pilot.

7. Addressing Market Barriers to ZNE Retrofits

The K-14 school market faces many barriers that may prevent or delay success in its transition to ZNE. Moving towards ZNE will require a coordinated and ongoing effort by many stakeholders and decision makers in the K-14 school market. School decision-makers must be aware that ZNE retrofits are possible and that there are many benefits of ZNE so that they allocate bandwidth and funds to obtain those benefits. Ensuring that the appropriate processes are in place will facilitate school districts in their efforts to strive for ZNE. In addition, market actors must be able to design, implement, and operate facilities to ZNE standards.

Even with increased awareness and processes in place, schools have multiple competing uses for any available resources. Therefore, a funding source dedicated to reducing energy use in facilities can focus attention on ultra-low energy and may enable school districts to stretch other funds and take needed steps towards ZNE. Absent these funds, existing projects to address deferred maintenance can be leveraged to incorporate energy efficiency when the building shell or systems are incorporated into that project scope.

Below, we discuss these barriers in more detail and provide possible approaches to overcome them. The possible approaches can be categorized as recommendations and considerations. For the purposes of this report, recommendations are those areas that appear to clearly and directly help overcome a barrier and are recommended actions. "Considerations," while worthy of discussion, are less of a priority for action.

Lack of Awareness

Interviews conducted as part of this research, feedback from the IOU staff involved in the Prop 39 ZNE Pilot program and the study's team's 20 years of experience working in energy efficiency and high performance schools suggest that lack of awareness about ZNE, specifically ZNE *retrofits*, is a primary barrier. Many school decision makers are unaware of ZNE retrofit opportunities or the benefits of high performance schools, other market actors may not be aware of ZNE technical specifications or how to sell and deliver ZNE to school clients, and facility managers, while familiar with how to operate school buildings, may be unaware of how to operate buildings to successfully reach ZNE.

Since school decision-makers including board members, superintendents and business officials, have little awareness, there is little demand for ZNE (or using energy efficiency as a first step towards ZNE). Importantly, many of these vital decision-makers may not understand the CHPS-documented educational benefits expected from energy efficient, high performing schools (e.g. higher test scores, increased daily average attendance, increased teacher satisfaction, etc.).

Similarly, on the supply side, architects, engineers, contractors, ESCOs and other technical professionals also need increased training and education on ZNE. Feedback that the study team has received at industry events and conferences suggest that design professionals may question whether ZNE retrofits are possible and how much they cost. They need skills and tools to help "sell" ultra-low energy and ZNE to clients and as well as increased capability to technically deliver retrofits beyond lighting that drive toward very low energy targets at a reasonable cost.

Design professionals also express concern about being "on the hook" for a ZNE outcome. ZNE creates a shared responsibility between the design & construction team (who is responsible for the building structure and systems) and the facility managers (who are responsible for operating and maintaining the structure and systems) and the occupants (who use and benefit from the structure and systems). The design and construction team may need to be involved in a project for a short time after the renovation to help educate the facility manager and occupants in how to operate the building to ZNE standards.

To help overcome the lack of awareness barrier:

- **Educate School Decision Makers about ZNE and its benefits**: Demonstrating how ZNE is achieved and ZNE benefits is a potential strategy to increase awareness among school decision makers.
  - The PA led Prop-39 pilot study is already developing case studies of the Prop-39 ZNE school retrofits. More case studies should be developed as other projects come online.
  - The PAs involved in the Prop-39 study should partner with existing organizations who regularly contact school decision makers to disseminate the case studies and messages about the benefits of ZNE (specifically at industry trade groups such as the California School Board Association, the California Association of School Business Officials, the Association of California School Administrators, Coalition for Adequate School Housing and others).
  - PAs should disseminate this information at local conferences of key decision makers (i.e., the California School Board Association, the California Association of School Business Officials, the Association of California School Administrators, Coalition for Adequate School Housing and others).
  - The PAs should help facilitate tours of ZNE retrofit facilities for school decision-makers.
- **Train Market Actors in the Technical Aspects of ZNE**: Relevant market actors include technical school district staff, architects, engineers, and other construction professionals.
  - The PAs should continue the existing Workforce Education & Training (WE&T) program which develops the market capacity to deliver energy efficiency by training architectural, engineering and construction professionals. In support of state energy efficiency goals, WE&T should ensure that technical information such as ZNE energy targets discussed in this report, the ZNE energy loading order, and technical details about ZNE retrofit opportunities, design and costs are included in relevant education and training events. Tours of demonstration buildings might also be part of these workshops.
  - Additionally, the Collaborative for High Performance Schools, the US Green Building Council's Regional Chapters and Schools Committees, the American Institute of Architects, the Renewable Energy Networks and school-specific trade groups may already have training and education events about other "green" building topics. PAs should consider leveraging these existing organizations to networks to conduct outreach, trainings and tours about ZNE retrofits.
- **Train Facility Managers to Operate Buildings Efficiently:** The Building Operator Certification (BOC) has been in place for close to 20 years, with trainings in over 30 states and is a possible avenue for increasing facility manager building operator skills. The PAs have supported BOC and should continue to do so for school district building operators.
- **Train Building Occupants to Use Energy Wisely:** Operational issues also pertain to training the students, teachers and other occupants on how to efficiently operate the classrooms to ensure the behavioral aspect of achieving energy efficient operation. The PAs should include occupant training as an element in their programs.
- **Community colleges can serve as opportunities for workforce development** with regard to energy efficiency. Where feasible, PAs can partner with community colleges to continue and expand these workforce development programs to train the next generation of professionals who can track, diagnose and improve building energy performance as part of building retrofits and ongoing operations.
- **PAs should recognize and celebrate ZNE:** A ZNE recognition program is one aspect of the Prop 39 ZNE Pilot Program. Recognition programs are one way to increase the profile of ZNE and reward individuals, teams, school districts and schools with exemplary experience in ZNE. PAs should continue to fund this recognition and might consider integrating it with the California Green Ribbon School awards.

Lack of Appropriate Processes

As described earlier in the report, a number of relevant policy documents help schools prioritize and implement facility improvement efforts (i.e., the Facilities Master Plan, Owners Project Requirements, Energy Master Plans and Energy Expenditure Plans). The Facilities Master Plan is the basis for prioritizing capital investments and is based more on educational needs rather than energy considerations. Owners Project Requirements (OPRs) outline programmatic and standard equipment information and may not include high performance specifications and equipment. Energy Master Plans outline energy savings goals and approaches. Energy Expenditure Plans are required by Prop 39 and outline particular energy retrofit projects, but are predominantly lighting retrofits (which does not go far enough down the ZNE path). According to our in-depth interviews, energy is typically not addressed specifically in two of these important policy documents (Facilities Master Plan and Owners Energy Requirements) and not all districts have Energy Master Plans. This results in energy not being prioritized. According to those interviewed in this research, influencing policies, plans and specifications can spur action and encourage long-term adoption of energy efficiency at school districts.

Some approaches to overcome this barrier include:

- **Ensuring Energy Efficiency is included in Relevant Processes**: School district decision makers and PAs can play a role in increasing energy efficiency in the relevant processes.
    - PA dissemination to school district officials (described above) should include information on how the relevant policy guidance documents (Facilities Master Plan, Owners Project Requirements, Energy Master Plans, etc.) can include information specific to energy efficiency and ZNE so that these officials can ask for its inclusion. See discussion below about relevant information to include.
    - School districts should adopt and PAs can incentivize the development of school district level Energy Master Plans and Energy Expenditure Plans so that energy considerations may eventually be integrated into the overarching Facilities Master Plan. In order to achieve ZNE, these plans should go beyond lighting replacement. The plans can focus on absolute efficiency targets and/or measured performance outcomes over time and multiple bond cycles (see next bullet). Creating these plans requires knowledge of the current portfolio of facilities within a school district and their energy use. While energy consumption can be facilitated using Green Button Connect, this does not track facility characteristics (envelope conditions and system type) that would also be helpful to track and understand.
        - This effort could be integrated into PA programs that currently exist (and where schools are customers) such as the School Energy Efficiency Program, Strategic Energy Management (SEM) and/or Behavioral, Retro-commissioning and Operations.
        - PAs should continue the ZNE pilot program offering for schools that facilitates on-the-ground projects, case studies, and training programs about the projects.
        - PAs should consider piloting “performance based procurement” approaches that set energy targets and base incentives, in part, off of measured outcome results.
        - PAs can influence the development of data collection systems like FUSION v.2 for community colleges by suggesting key data fields that should be included and tracked to assist community colleges in facilitating data collection and improvements on the path to ZNE. PAs should also consider making suggestions about data collection fields available to K-12 schools.
        - PAs could create a pilot program in the public sector that leverages the approach taken by the US DOE Zero Energy School Accelerator program that pairs technical experts with cohorts of committed districts to establish a roadmap toward ZNE.[28] In this type of pilot, small groups of districts work simultaneously with technical experts to develop and establish a framework

[28] This approach at DOE is focused on new construction but can be extended to existing building practices and ZNE retrofits.

of policies and practices on the path to ZNE.[29] Topics for investigation over the course of the process might include benchmarking, prioritizing opportunities across the district, drafting an OPR and/or Energy Master Plan, what to expect from assessments, tracking building characteristics, setting energy targets, selecting team and "performance based procurement" contracting, operations and maintenance, renewable systems, etc. This "cohort" approach to intervention might look at large districts and small ones differently. PAs can support larger districts that already have an overarching district-level energy policy framework by encouraging them to expand this to ZNE. Smaller districts can benefit from lessons learned already in larger districts with more experience. Cohorts may be geographically oriented (such as the one that exists in San Diego). Specifically, PAs can contribute a consistent technical support team of subject matter experts to advise and facilitate these cohorts with the outcome of updated policies, practices, and eventual energy savings.

- **Ensuring Energy Targets are in Specifications and Processes**: School districts should include technical specifications in OPRs to clarify intent with their design and construction teams. For example, Energy Use Intensity (EUI) targets can be used in a "performance based procurement approach" in contracts with the design and construction professionals. In addition, energy targets can be used by school districts, design and construction teams to evaluate "value" engineering cost-cutting suggestions so that energy implications are considered. (Currently value engineering looks only at first costs and not ongoing costs based on energy use.) This research suggests that generally an EUI of approximately 20-30 kBtu/square foot per year is an appropriate energy target for permanent school buildings.[30] Specific energy targets for permanent buildings depend on the type of school but hold true across all California clime zones. PA programs and OPRs can include specific energy targets for "permanent" building types which depend on climate zone as follows:
  - Primary School – 19-29 kBtu/square foot per year
  - Secondary School – 18-24 kBtu/square foot per year
  - Community College – 26-33 kBtu/square foot per year
- In addition to energy targets in OPRs, facility management plans should include language to ensure that natural events are leveraged. For example, when new equipment is needed, mandatory district-level policy can trigger efficiency improvement to desired technical specifications.
- Facility management plans should detail the appropriate sequencing or "energy loading order," specifically:
  1. Deploy passive systems (such as daylighting, natural ventilation, etc.) first
  2. Reduce loads (through envelope sealing, lighting load reduction with LEDs and controls, plug load reduction, operational management approaches, etc.)
  3. Serve loads with efficient equipment and reduce the size of the equipment due to reduced loads
  4. Provide renewables to serve remaining energy loads

Lack of Dedicated Funds for Energy Efficiency

Significant underinvestment in general facilities maintenance and operations, described earlier in the report, has led to massive deferred maintenance issues. This means that school buildings need so much attention outside of energy using systems that it may be difficult to fund energy system upgrades absent funding sources dedicated to

---

[29] We note that a cohort approach has been successfully used in the Pacific Northwest for SEM programs (see http://neea.org/docs/default-source/reports/small-to-medium-industrial-sem-energy-savings-validation.pdf?sfvrsn=12)

[30] Relocatable classrooms will continue to present challenges for energy efficiency and may not be appropriate for an energy target.

energy efficiency. Interview participants consistently characterized deferred maintenance needs in California school buildings as significant or even enormous. One interview participant noted that the $9 billion state-wide bond passed last year for schools to use for this deferred maintenance was a simply a “drop in the bucket.” These findings are consistent with the University of California Berkeley Center for City and Schools research report that found a structural pattern of underinvestment in California K-12 public schools.[31]

In 2016, in addition to $9 billion in state bond funds for deferred maintenance, 206 districts passed $28 billion in local bond funding. While the local bonds may have little or no attention to energy efficiency or ZNE, they will take years to implement and there still may be opportunities to leverage these 206 districts to encourage incremental energy efficiency improvements. PAs should continue to encourage these projects to go further with regard to energy performance by participating in traditional resource acquisition programs.

Prop 39 has provided a dedicated funding mechanism available across all school districts to pay for a systematic approach toward improving energy performance. While this funding is expected to expire in the next fiscal year, talks are underway in Sacramento to continue some source of continued and dedicated funding for energy efficiency and renewable energy. School districts and all market actors should encourage the continuation of funding from the general fund dedicated to energy efficiency and renewable energy projects in K-14 schools.

- The Division of the State Architect, California Department of Education, California Energy Commission and CPUC should consider developing a coordinated interagency approach to transition schools in California to ZNE. DSA is the agency responsible for ensuring that local school district plans comply with rules and regulations regarding facilities and should spearhead this interagency cooperative approach. The aim of this effort is to develop a strategic plan with a prioritized framework with well-defined objectives, actions and expected outcomes over a three-, five- and ten-year horizon geared toward transitioning K-14 schools in California specifically toward ultra-low energy targets and eventually ZNE.
- The CDE and CEC should consider the principles of equity outlined by the Berkeley Center for Cities and Schools in the funding distribution.[32]

Absent a large influx of capital, some approaches to ameliorate the lack of energy efficiency funding include:

- **With current funding**:
  - The CEC oversees Prop 39 funds and should:
    - Ensure that all projects covered in an approved Energy Expenditure Plan are completed and tracked in annual progress reports and final project completion report.
    - Ensure programs with dedicated energy efficiency funds can include paying for staff engaged in ongoing energy savings opportunities in the district (as is currently allowed by the funding mechanism).
    - Encourage that assessments under Prop 39 begin with low-cost remote diagnostics to uncover high priority opportunities across the district. This can limit investment in walk through audits and focus limited resources on high priority opportunities across the school district’s portfolio.
    - Encourage Prop 39 audits to consistently investigate solar opportunities (roof condition, warranty, structure, etc.) while on the site.
    - Include considerations of roof conditions and characteristics (specifically the roof replacement cycle) before providing solar incentives. For example, renewables on the roof are not advised if the roof might be replaced soon.

31 Going it Alone Can California’s K-12 School Districts Adequately and Equitably Fund School Facilities? Policy Research Working Paper November 2015 by Jeffrey M. Vincent Liz S. Jain from the UC Berkeley Center for Cities and Schools
32 Going it Alone Can California’s K-12 School Districts Adequately and Equitably Fund School Facilities? Policy Research Working Paper November 2015 by Jeffrey M. Vincent Liz S. Jain from the UC Berkeley Center for Cities and Schools, page 7.

- The PAs include K-12 and community colleges in their public-sector energy efficiency programs and should:
  - PAs should continue the Prop 39 ZNE pilot program offering for schools beyond the technical proof-of-concept which is currently being demonstrated in the first dozen sites. The pilot continuation should aim for between 50-100 sites across the state in order to capture a diversity of school vintages, decision making processes, operational practices and installed measures. An expanded pilot will offer additional opportunities to investigate transitioning ZNE to scale by further understanding approaches, measures and costs necessary to retrofit a diversity of existing schools to ZNE. In addition to facilitating on-the-ground projects, PAs should continue case studies, and training programs about the projects.[33]
  - Support specific aspects of the district's energy policy framework (for example, paying for remote diagnostic and prioritization analysis, on-site assessments, etc.).
  - Consider supporting "eco-charrettes" with stipends to pay for a facilitator and/or team members to participate in a meeting to address energy performance of a newly passed bond. This charrette is an opportunity to leverage the flexibility in bonds and seize the opportunity to set aggressive energy targets for all projects covered under the implementation of the bond that address building envelope and energy using systems. This charrette is a variation on the integrated team meeting that takes places at the beginning of a "green" building construction project. Instead of happening at the beginning of a particular project, this bond charrette would take place after bond passing and is an opportunity for stakeholders meet early in the process to agree on common energy goals that will be achieved in bond implementation.
  - Support Energy Managers at the district or county level (to serve multiple small districts) with a continuous energy improvement model to capture ongoing savings and direct projects to other utility incentive programs (existing building retrofit and/or new construction programs) where appropriate.
  - Consider highly leveraged statewide or regional purchasing and installation programs

- **Doing more with current funds**:
  - CEC, CPUC and PAs should compile and/or conduct research the true value of non-energy effects to educational stakeholders so that this is recognized appropriately in the SIR and cost effectiveness calculations. This consideration is based off research which has been compiled by the Collaborative for High Performance Schools[34], that talks about the many benefits of high performance schools which all have the same technical attributes of ZNE. These benefits include higher test scores, increased daily average attendance, increased teacher satisfaction and retention, reduced environmental impacts and reduced liability.
  - PAs should consider school buildings as an appropriate building type under the AB 802 Normalized Metered Energy Consumption approach to capture all energy savings – including operational improvements – associated with this building type. This supports a ZNE transition that relies on actual energy performance rather than on predicted energy performance to estimate savings from energy efficiency measure installation.

[33] This recommendation is based on experience of encouraging early adoption of new technologies and concepts in order to provide critical mass required for market acceptance.Researchers have not estimated funding required or performed a cost effectiveness analysis.

[34] Non energy impacts of high performance schools are summarized by CHPS and available at http://www.chps.net/dev/Drupal/node/48.

- PAs should continue a financial stipend for the design team to stay involved post-construction into occupancy of the existing building retrofit to ensure that the ZNE energy target is achieved within the first 12-24 months after occupancy. (Typically, the design team moves onto the next project after their building is occupied, however a clear link during and after the “hand off” of the building would be valuable to ensure a ZNE result.)

Study Recommendations and Considerations

Several possible approaches to addressing market barriers to ZNE retrofits are listed in the section above. The school market is complex and overcoming barriers cannot happen because of the actions of a single organization. Table 16 below summarizes specific recommendations and considerations by market entity. For purposes of this report, recommendations are those areas that appear to clearly and directly help overcome a barrier and are recommended actions. “Considerations,” while worthy of discussion, are less of a priority for action.

Table 16. Recommendations and Considerations by Decision Maker and Organization

Decision Maker / Organization	Barrier	Recommendation	Consideration
School District Decision Makers	Lack of Awareness	1. Review ZNE case studies 2. Learn about the benefits of ZNE, high performance schools	None
	Lack of Appropriate Processes	1. Attend available trainings that discuss embedding energy use in key policy documents 2. Ensure that school district policies establish energy goals, plans and practices that strategically advance district facilities toward ultra-low energy and ZNE. Ensure these plans and policies to leverage the natural events in a building lifecycle for energy efficiency improvements. 3. Incorporate specific energy outcome targets, technical specifications and building best practices such as benchmarking in policies, plans and practices. 4. Support facility managers in their efforts to transition school district buildings to ultra-low energy and ZNE	None
	Lack of Dedicated Funds	1. Encourage the continuation of funds dedicated to energy efficiency and renewable energy in schools.	None
California Energy Commission	Lack of Appropriate Processes	1. Support technical advancement of FUSION by providing recommendations on priority data fields to collect	1. Provide this information about data collection fields to K-12 schools as well

Decision Maker / Organization	Barrier	Recommendation	Consideration
	Lack of Dedicated Funds for Energy Efficiency	1. Ensure that Prop 39 projects are completed, tracked and documented in annual and final project completion reports 2. Ensure programs with dedicated energy efficiency funds can include paying for staff engaged in ongoing energy savings opportunities in the district (as is currently allowed by the Prop 39 funding mechanism). 3. Encourage Prop 39 audits consistently investigate solar opportunities while on site 4. Research the full value of non-energy effects that can accompany ZNE so that they can be recognized in the SIR calculation methodology	1. Encourage Energy Expenditure Plans to go beyond lighting to achieve deeper levels of savings 2. Focus limited dollars for walk through audits by first conducting low-cost remote diagnostic assessments 3. Include considerations of roof conditions and characteristics before incentivizing roof placed solar arrays 4. Develop a coordinated interagency approach to develop a strategic plan with a prioritized framework with well-defined objectives, action and expected outcomes over a three-, five- and ten-year horizon geared toward transitioning K-14 schools in California specifically toward ultra-low energy and eventually ZNE 5. In allocating funding, consider issues of equity as suggested by the Berkeley Center for Cities and Schools
Department of General Services Division of the State Architect	Lack of Dedicated Funds for Energy Efficiency	None	1. Facilitate an inter-agency effort to develop a coordinated approach to develop a strategic plan with a prioritized framework with well-defined objectives, actions and expected outcomes over a three-, five- and ten-year horizon geared toward transitioning K-14 schools in California specifically toward ultra-low energy and eventually ZNE
Program Administrators	Lack of Awareness	1. Ensure planned Prop 39 ZNE pilot case studies have information on process, strategies, costs and benefits and develop more as these projects come on line 2. Conduct tours of ZNE retrofit facilities 3. Disseminate information about case studies and benefits to specific target audiences	1. Leverage existing organizations to disseminate case studies (e.g. California Association of School Business Officials, the Association of California School Administrators, Coalition for Adequate School Housing and others) 2. Support facilities staff by offsetting costs for BOC training

Decision Maker / Organization	Barrier	Recommendation	Consideration
		4. Continue ZNE recognition program as started under Prop 39 ZNE pilot 5. Continue workforce education and trainings; include specific ZNE technical information as well as process considerations depending on audience 6. Continue the BOC program 7. Train Building Occupants to Use Energy Wisely in ZNE projects as part of PA programs 8. Recognize and celebrate ZNE projects and teams	3. Leverage county office of education to deploy SEM to smaller districts. 4. Partner with community colleges to deliver workforce development programs about energy efficiency retrofits and renewable energy installation
	Lack of Appropriate Processes	1. Continue and expand the ZNE pilot program 2. Incentivize the development of school district level Facilities Master Plans or Energy Master Plans by integrating this activity into PA programs that currently exist (and where schools are customers) such as School Energy Efficiency Program, Strategic Energy Management, and/or Behavioral, Retro-commissioning and Operations. 3. Support technical advancement of FUSION by providing recommendations on priority data fields to collect	1. Create a pilot program in the public sector that simultaneously works with small groups of districts (i.e. "a cohort") to develop and establish a framework of policies and practices on the path to ZNE 2. Pilot "performance based procurement" programmatic approaches that use energy targets 3. Provide this information about data collection fields to K-12 schools as well
	Lack of Dedicated Funds	1. Continue and expand the Prop 39 ZNE pilot program offering for schools to 50-100 sites across the state. Use this as an opportunity to further investigate costs and opportunities to scale ZNE retrofits in the school market. 2. Support specific aspects of the district's energy policy framework (for example, paying for remote diagnostic and	1. Support Energy Managers at the district or county level (to serve multiple small districts) with a continuous energy improvement model to capture ongoing savings and direct projects to other utility incentive programs (existing building retrofit and/or new construction programs) where appropriate

Decision Maker / Organization	Barrier	Recommendation	Consideration
		prioritization analyses, onsite assessments, etc.) 3. Determine the cost effectiveness of supporting "eco-charrettes" with stipends to pay for a facilitator and/or team members to participate in a meeting to address the energy performance of a newly passed bond. Deploy the activity if found to work within the current constraints of programs. 4. Continue providing a stipend to ZNE project teams to stay involved post occupancy	2. Consider highly leveraged statewide or regional purchasing and installation programs 3. Research the full value of non-energy effects that can accompany ZNE. (placed as a consideration rather than a recommendation because of the known difficulty when attempting to include non-energy effects in current EE programs) 4. Include school buildings when applying the Normalized Metered Energy Consumption model (placed as a consideration rather than a recommendation because the PAs do not have full control over which building types can be included)

Conclusion

School district decision-makers are primarily interested in educational outcomes and operating safe and healthy schools. Energy performance is not a driver in school decision making. A compelling body of research compiled by the Collaborative for High Performance Schools and others suggest that the educational goals of school decision-makers are fully compatable with the outcomes associated with high performance, ZNE schools. Clarifying the connection and raising awareness of how energy efficient schools influences student educational outcomes is one important aspect of transforming the school market to ZNE.

However, reaching ZNE in California schools will take more than increasing awareness. It will require coordinated action by many stakeholders across a diverse and complicated market. One challenge that must be overcome is the fact that schools suffer from signficiant deferred maintenance problems. The Berkeley Center for Cities and Schools suggests that schools in California suffer from a structural pattern of under investment in operations and maintenance, yet, effective O&M is critical to success in ZNE.

Given the current state of the market, ZNE may be too ambitious a goal for some school districts today. For these districts, its is about a path to ZNE which is rooted in continual improvement of energy performance in existing schools. This requires benchmarking, where districts measure energy performance and learn to analyze this data in order to make more informed decisions regarding operations and retrofits. Districts are in a position to integrate enegy considerations into their policies, plans and practices, and Program Administrators (PAs) can support efforts that encourage the incorporation of ultra-low energy retrofits and ongoing performance improvements into facility planning and implementation activities. Influencing these policies, plans and practices so that they consider energy is critical on the path to success with ZNE.

ZNE school retrofits are different from business-as-usual. Successful ZNE teams set absolute energy targets and use these targets as a way to organize decisions during design and construction. In ZNE projects, teams first drastically reduce energy consumption using a whole building, integrated approach where more cost effective measures offset less cost effective measures. After achieving energy reductions necessary to meet the target, remaining loads can then be addressed with solar. Finally, ZNE projects actually measure energy outcomes rather than relying on predicted performance estimates.

Energy targets are Energy Use Intensity (EUI) goals for a particular building type in a particular location. Program Adminsitrators can use energy targets and measured performance outcomes in programs, rather than relying on predicted results, as is traditional in the industry. This changes the conversation from a predicted to an actual result and encourages designers, contractors, operators and occupants to understand and support their role in an ultra-low energy result. ZNE requires this transition because these buildings are operated at ZNE, not just designed to ZNE.

The state can help set these absolute energy targets and transition their programs facilitate for the development and implementation of policy, practices and measured performance outcomes for California schools. Decisions made now will impact energy performance in 2030. The actions outlined in this K-14 ZNE Retrofit Readiness Study are required now to achieve California's aggressive climate goals.

APPENDIX A: RESEARCH QUESTIONS, OBJECTIVE AND TOPICS TABLE

The following table outlines where key research questions, objectives and topics are addressed in this report.

Table 17. Research Questions, Objectives and Topics

Research Questions, Objectives & Topics	Short Answer and Location within Report
1. Identify key market actors; drivers (economic, leadership, technology, other market); budgets, funding sources and levels, common business plans and patterns of interactions.	School Boards are the primary decision-makers in local schools. They are advised and influenced by a complex network of professionals and public interest groups. Funding for school retrofits come primarily from state and local bond measures. Energy is typically not considered by school decision makers, and districts need support with continuous energy management. Prop 39 has been successful because it provided a dedicated source of funding for energy efficiency. School Decision-Makers, Programs, Funding and Decision-Making Process in K-14 School Facilities
a. What are key market actor drivers, and how can these be harnessed to advance ZNE retrofit goals?	School boards and other market actors are primarily driven by student educational outcomes. ZNE can be tied to enhanced student performance with high quality daylighting, indoor air quality and acoustic environments. School Decision-Makers
b. Identify key supply chains (technologies and professionals) and opportunities to incorporate (when can ZNE happen? Bonding, seismic, expansion etc.)	Architects, engineers and contractors often focus on schools. Retrofits have also been facilitated by Energy Service Companies. Solar projects have been facilitated by solar developers. ZNE will take a coordinated approach to deep retrofits and solar installation and should leverage all opportunities as they naturally occur in a building's lifecycle (equipment replacement, retrofit, bonds, etc.). This will require influencing policy and practice in California schools. Funding and Decision-Making Process in K-14 School Facilities
2. Identify barriers, challenges and opportunities	Key barriers include lack of awareness, lack of interest in energy efficiency, deferred maintenance, lack of dedicated funds for energy efficiency, tight project timelines and renewable energy barriers. Addressing Market Barriers to ZNE Retrofits
a. What are key barriers, and how can these be overcome, via: program design; regulatory framework updates; market actor engagement, etc.	Strategies to overcome include increasing market awareness of ZNE, facilitating a strategic approach to ZNE, using energy targets and measured performance outcomes. Addressing Market Barriers to ZNE Retrofits
3. Identify leading and lagging geographic regions and market actors	Urban areas and large districts tend to have energy and sustainability plans. Energy Practices in K-12 Schools, Current Status of ZNE in California Schools
4. Identify high priority strategies and partners to advance ZNE retrofits in K-14	Addressing Market Barriers to ZNE Retrofits
a. What is the range of potential savings available, on a sector level and average per building?	Energy modeling in the sensitivity analysis suggests savings of 50% are possible at the building level and 75,730 Million Btu of source savings at the sector level. Range of Potential Savings
b. Where are the key opportunities to develop ZNE retrofits in educational institutions?	Key opportunities to develop retrofits align with where other improvements will be made for educational purposes. Implications

Research Questions, Objectives & Topics	Short Answer and Location within Report
	of Decision Making and Funding on Efforts to Encourage ZNE, Implications for ZNE School Retrofits
c. What are the best strategies and partners to advance ZNE retrofits in K-14?	A comprehensive list of strategies and recommendations to address market barriers is included in this report. Addressing Market Barriers to ZNE Retrofits
d. What lessons can be leveraged to accelerate adoption of ZNE in schools?	Policy and practices that encourage energy targets and measured performance outcomes. **Error! Reference source not found.**
e. What is the range of educational institution and IOU costs for ZNE retrofits?	Transitioning the public K-12 schools to ZNE in California may cost more than $8 billion. Possible Range of Costs for ZNE Retrofits
Research Topics	
1. School Districts and Facilities. A summary of the total California school facilities locations, size and key demographic factors.	Public K-12 Schools and Enrollment
2. Financing Sources and Approaches. Identification of the primary and secondary methods for funding capital improvements.	Funding and Decision-Making Process in K-14 School Facilities
3. Management and Decision Making. A review study of the management approaches and decision making methodology as well as key determinants used for decisions of capital improvements at school districts and community colleges.	California K-14 Schools, Decision-Makers and Financing
4. Current Supporting Programs and Policies. Descriptions of various policies, activities, programs and incentives available to support major energy efficiency retrofits and occupant training toward performance outcomes and ZNE.	Programs
5. Facility Characteristics. Representation of the current building prototypes and typical technologies in various eras and climate zones of buildings.	Technical Approaches to Achieving ZNE
6. Energy Characteristics and Net Zero Potential. Total and comparative energy analysis of the school sector in California and the potential energy savings opportunities through ZNE.	Technical Approaches to Achieving ZNE
7. The Path to All Schools being ZNE Schools. The conclusions and	Addressing Market Barriers to ZNE Retrofits, Conclusion

Research Questions, Objectives & Topics	Short Answer and Location within Report
recommendations for the people + process + market + technology paths to move all existing schools to ZNE.	

APPENDIX B: INTERVIEW GUIDE

K-14 School ZNE Retrofit Readiness Characterization

Project Goal: The goal of the K-14 Zero Net Energy (ZNE) School Retrofit Readiness Characterization is to investigate the challenges and opportunities associated with ZNE retrofits in California public schools. For this study, public schools are defined as kindergarten through twelfth grade (K-12) and community colleges (collectively referred to as "K-14").

Interview Objectives: The objective(s) of these interviews are to help us understand how current school modernization/retrofit projects are financed and delivered, the primary drivers of key decision-makers, ZNE retrofit market opportunities and leading/lagging regions for ZNE schools. We are also interested to learn more about how school operations and deferred maintenance may be barriers to ZNE retrofit of schools. The intent of this interview guide is to help structure our conversation to ensure that we are covering the critical topics related to this research. We expect to interview from 15-29 people across the five groups as shown in Table 18, below. The file named "K-14 School Attachments"' (included separately) will be provided in advance of the interview and will also be shown via gotomeeting during the interview itself.

Table 18: Questions asked of Interviewees by Interview Section

Section	DGS	IOU	Director of O&M /Facility Manager	Design Expert	LEA School Board
Introduction (5 min)	X	X	X	X	X
Project Selection Decision-Making Structure (5 min)	X				X
Project Selection Decision-Making At The State Level (12 min)	X				
Project Selection Decision-Making At The Local School District Level (15 min)	X	X	X	x	X
Modernization Implementation Structure (12 min)		X	X	X	X
School Facility Operations & Maintenance (12 min)			X		X
ZNE Projects (12 min)		X	X	X	
Other Interview Participants (2 min)	X	X	X	X	X
Approximate interview length (minutes)	*39*	*46*	*58*	*46*	*51*

Interview Guide Questions

(All)

Introduction (5 minutes)

1. Name: ______________
2. Company: ______________
3. Title: ______________
4. Primary responsibilities: ______________
5. How long have you been in this position?
6. How many years have you been in your professional field (ask when relevant)?
7. How familiar are you with ZNE?
8. Date of Interview: ______________
9. Interview Start Time: _____________

Project selection decision-making structure (5 minutes)

(DGS, IOU, LEA School Board)

1. We created a graphic which shows our understanding of the main decision-makers involved in State funded K-12 Modernization Projects and sent it to you labeled as <u>Attachment 1: State & Local Decision-Makers Structure for Capital-Funded K-12 Projects (confirm that they received it and ask if they need anything to be clarified)</u>. Given your understanding of the K-12 schools market based on your role in it, please let us know if:
    a. there are any decision makers that appear to be missing from this diagram.
    b. there are any formal or casual relationships that should be represented on this diagram.
    c. The influence arrows make sense or if we are missing arrows that show key relationships

Project selection decision-making at the state level (12 minutes)

(*DGS*)

2. Among the state level decision makers (on the left side of this same graphic), who is the most influential in selecting existing building renovation projects to fund within the School Facility Modernization Program (SFMP) to and why?
3. In your opinion, what are the primary things these influential market actors consider when making decisions on which SFMP projects to fund?
4. Do school retrofit projects happen *without* funding sources from the State? If so, do you have a sense of what percent of projects across the state are implemented without State funding??
5. Is energy consumption in schools considered at any point by the State Allocation Board in determining which projects to fund through SFMP? If so when and how is it addressed?
6. After a funded SFMP project is complete, what, if any, requirements are placed on Local Education Agencies (LEAs)?

a. Probe for requirements to address the ongoing maintenance of buildings that were funded in part by the SFMP?

7. Are you aware of state-level procurement or maintenance activities (for either equipment such as lighting, HVAC, IT equipment or for project delivery like professional services and construction) that schools would find beneficial if they implemented similar approaches?

    a. Probe why they may or may not think these activities might lend themselves to the k-12 sector.

Project selection decision-making at the local school district level (15 minutes)

(DGS, Facility Manager, Design Expert, LEA School Board)

9. Do all LEAs have Long Range Planning Committees?

10. Based on your experience, what role does the Long Range Planning Committee in decision-making for school retrofits.

11. Has your district [facility manager or LEA school board member], a district that you have worked with [DGS or design expert] applied for SFMP funding for a retrofit project from the State? if so, did you/they receive the funding you/they applied for?

12. [ASK IF Yes to above question] Describe the retrofit project selection process at the local level. (i.e. how retrofit projects were selected for SFMP fund applications?)

13. [*Facility managers and design experts:* We created a graphic which shows our understanding of the main decision makers involved in State funded K-12 Modernization Projects and sent it to you labeled as <u>Attachment 1: State & Local Decision-Makers Structure for Capital-Funded K-12 Projects] [</u>*DGS and LEA School Board:* Please look back at the decision maker graphic we had discussed earlier.] Among the local decision-makers (on the right side of the graphic), who is the most influential in selecting existing building renovation projects to pursue and why?

14. What are the primary criteria/factors these influential market actors consider when making decisions on what renovation projects should be pursued?

15. Please rate the level of involvement (high, medium, low, none) of the local school board in the drafting of bonds to pay for school retrofits.

16. Can you provide some examples of school district policies that set goals for building energy performance? (Provide examples if needed: energy performance benchmarking policies, goals to improve the energy performance across the portfolio of schools by some percent, new construction LEED goal policies, Zero Net Energy etc.)

    a. Probe for how have these policies influenced decisions for new construction options and/or selecting retrofit project selection decision-making.

17. What are the key opportunities to develop ZNE Retrofits in K-12 schools?

Modernization Implementation Structure (12 minutes)

(IOU, Facility Manager, Design Expert, LEA School Board)

These next set of questions are around the decisions made after a retrofit project is chosen and before construction starts.

18. We also sent you a graphic which shows our understanding of how retrofit projects are implemented labeled Appendix 2: <u>K-12 Project Implementation Structure</u>. Look at the information under "Local Project

Implementers." Given your understanding of the K-12 schools market, please let us know if any influential group involved in implementing retrofits should be added or removed and where.

19. What are the primary things of these influential market actors consider when making decisions about renovation projects?
    a. Probe for how much energy efficiency or moving to ZNE may be a driver
20. How do school district policies influence retrofit project implementation decision-making?
21. Does the school district [facility manager and LEA School Board] use; Do you typically see [IOU and Design Experts] bulk purchasing agreements for energy using equipment (for example HVAC equipment, lighting equipment, computers, etc.)?
    a. Probe for energy efficiency requirements within the agreements
22. There are different construction project delivery method such as design-bid-build, design-bid, integrated project delivery etc., What method does your school district use? [Facility managers and LEA School Board} have you seen most often? [IOU and Design experts)
23. For new construction, does your school district require [Facility Managers and LEA School Board] have you seen [IOU and Design Experts] energy outcome targets or Energy Use Intensity (EUI) targets? If so what are they.
24. For building renovation, does your school district use [Facility Managers and LEA School Board] have you used; [IOU and Design Experts] energy targets?
    a. Probe for specific energy targets if included or seen.

School Facility Operations & Maintenance (12 minutes)

(Facility Manager, LEA School Board)

Now I want to talk to you about energy use and maintenance at your facilities.

25. Energy consumption information is included in monthly bills.
    a. Does anyone review the bill for the energy use associated with the cost?
    b. If so who and what do they do with the energy information?
26. Does your school district track facility energy consumption?
27. Are facility managers [facility managers and LEA school Districts] aware of the energy performance of their facilities?
28. Does the school district have an automated benchmarking system (such as automatic utility bill input into Energy Star Portfolio Manager or building dashboard system)?
29. Does your school district have any energy reduction target goals?
    a. If so, probe for who is responsible for setting them and ensuring they are met
30. Does your school districts k a list of building characteristics (such as building lighting, HVAC, kitchen equipment, specialty process loads such as shop equipment or swimming pools, plug load and computer equipment)?
    a. If so, probe for format (for example, in a spreadsheet, with papers in a drawer, in a relational database)?

31. Describe how your school prioritized energy using equipment maintenance (such as set points on HVAC systems or checking energy management system software settings) versus other maintenance needs and makes decisions regarding which maintenance items will be completed now versus later.

32. How does your school district keep track of maintenance needs and activities of energy using equipment?

33. School districts often have maintenance needs that are deferred to a later time. What level of this deferred maintenance is within your district's facilities?

    a. Probe for whether they think their school district has lower than average or higher than average deferred maintenance

34. Sustainability Managers wear many hats, among them is developing, supervision and executing projects that save district-wide energy or other resources. In your opinion, what percentage of school districts across the state have a sustainability manager?

    a. If they have some idea, probe for leading/lagging geographic areas are in California?

ZNE projects (12 minutes)

(IOU, Facility Manager, Design Expert)

35. How many ZNE projects have you been involved in on behalf of current or previous employers?

36. How many of those have been schools?

37. Briefly describe your role.

38. How many have been existing building retrofit projects?

ASK THE FOLLOWING QUESTIONS IF Yes to Q35, if not skip to Q43.

39. What is different about implementation of ZNE school project compared to a typical school project?

40. What was the project delivery method used on these projects and how did this impact the ZNE outcome?

41. What were the energy targets on your ZNE school projects?

42. What are the primary lessons learned from your experience with ZNE projects?

43. What is the range of costs for ZNE project(s) and how did the costs compare to a typical project?

44. What are the barriers to ZNE in school retrofits?

45. What geographic areas are leaders/laggards regarding ZNE schools in CA?

    a. Probe for specific districts who are leaders

46. How can school district policies support and encourage the development of ZNE retrofits?

47. How could rate payer energy efficiency funds support ZNE in school retrofits?

Other interview participants (2 minutes)

(All)

48. Given the questions that we have discussed, can you suggest other school district administrators or professionals who might have important insights to share with us for our research? If yes, what is their contact information.

Interview end time: ________________

APPENDIX C: BACKGROUND ON TECHNICAL SENSITIVITY ANALYSIS

California DEER K-14 Educational Building Baseline Prototypes

DEER includes ex ante savings values[35] and prescribed savings estimation methods for the most common energy efficiency measures offered to customers through California's energy efficiency programs. These ex ante savings are based on engineering calculations and computer energy simulation of prototype buildings.[36] The prototypes are defined in the form of individual eQUEST projects, which use the DOE-2.2 hourly building simulation engine. The multiple prototypes represent differences in baseline HVAC system types and other building characteristics. Each building prototype file describes a single site configuration with either one building or multiple buildings served by one or multiple HVAC system types. Of relevance to this study, the database includes savings values for typical building types, including four school building types: primary, secondary, portable and community college, which were the starting point for the sensitivity analysis.

Table 19 describes the basic assumptions regarding the four building types used in this study. Each building type also has a predefined HVAC baseline system type. Table 25 through Table 42 provides detailed assumptions about the prototypes including: space use breakdown, envelope characteristics, internal gains, operation hours, HVAC and building weights. The tables also include the building type, vintage and climate zone specific modeling assumption for the DEER baseline variations.

Table 19: Basic Assumptions of DEER Prototype Models

<table>
<tr><th rowspan="2"></th><th rowspan="2">Primary School</th><th colspan="2">Secondary School</th><th rowspan="2">Relocatable Classroom</th><th rowspan="2">Community College</th></tr>
<tr><th>Educational Building</th><th>Gymnasium</th></tr>
<tr><td>Stories</td><td>1</td><td>2</td><td>1</td><td>1</td><td>3</td></tr>
<tr><td>Total Area (ft2)</td><td>50,000</td><td>127,500</td><td>22,500</td><td>1,920</td><td>300,000</td></tr>
<tr><td>Window-to-Wall Ratio (%)</td><td>21</td><td colspan="2">20</td><td>4</td><td>26</td></tr>
<tr><td>Exterior Walls Construction Type</td><td>Wood frame</td><td colspan="2">Heavy weight</td><td>Metal frame</td><td>Heavy weight</td></tr>
<tr><td>Roof Construction Type</td><td>Built-up flat roof</td><td colspan="2">Built-up flat roof</td><td>Built-up flat roof</td><td>Built-up flat roof</td></tr>
<tr><td>Floor-to-Floor Height (ft2)</td><td>12</td><td>13</td><td>26</td><td>13</td><td>13</td></tr>
</table>

Baseline Variations

The research team divided the sensitivity analysis into two primary modeling groups: (1) baseline conditions and (2) measure packages. Besides the current DEER baselines by prototype, vintage, and climate zone, the team created two other baselines (described below). The modeling process applied each measure package, along with combinations of those measure packages on top of each baseline.

Baseline: DEER with Alternative Operation and Controls

The CPUC's DEER update process has developed operating assumptions included in the DEER models over the past 20 years. These operating assumptions are intended to represent typical operating practices over a

35 The program administrators use ex ante savings values to forecast savings from installed measures.

36 Simulation measure analysis uses the software "MASControl" available from www.deersources.com.

population of buildings. The operating practices in actual buildings will range from poor to nearly perfect and will also vary from the DEER assumptions simply due to higher or lower building utilization and occupancy. CPUC advisors and the research team acknowledge that operating schedules and controls within the DEER might not account for the fact that buildings are not always perfectly operated or reflect extended operating hours. Therefore, an alternate baseline to DEER operating assumptions has been included in the modeling analysis. This alternative baseline includes extended operating hours for lighting, plug loads and HVAC systems as well as sub-optimal control settings for HVAC controls (such as temperature resets and economizer set points) and is explained in

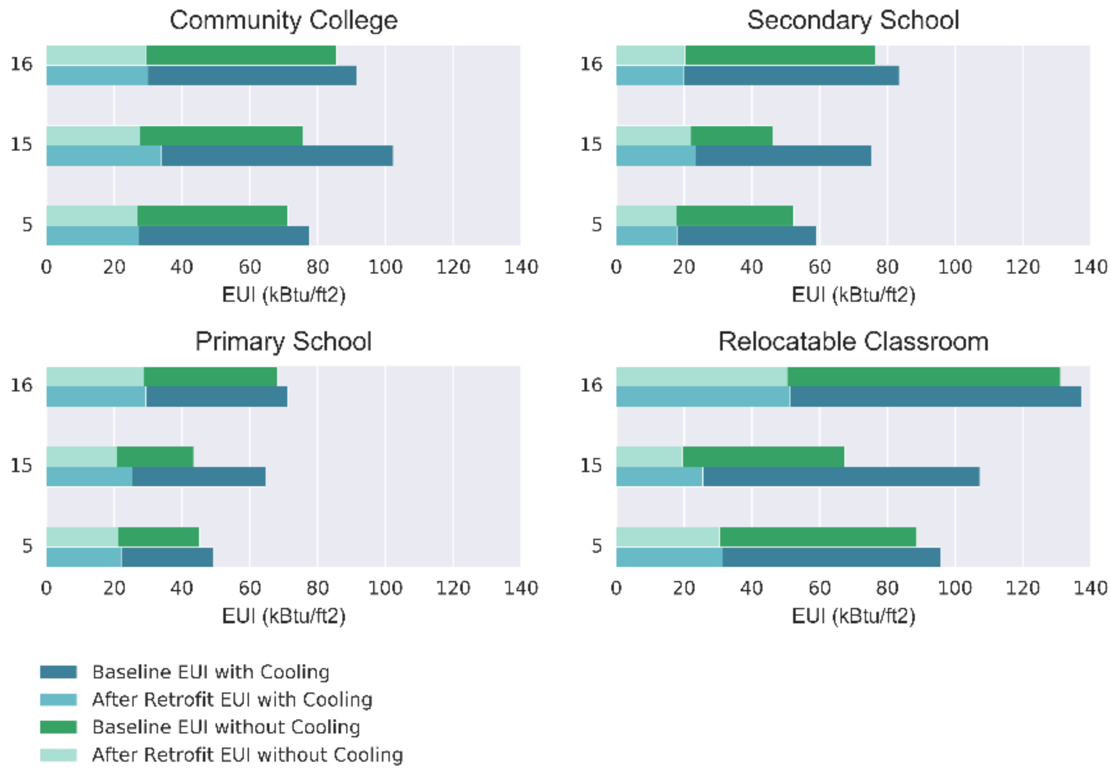
Additionally, the research team analyzed the results of the Commercial Saturation Survey[37] (CSS) to see how the DEER baseline assumptions compared to actual field observations. The comparison of the DEER assumptions and the CSS survey included investigations into factors such as lighting power density and operational schedules. As shown in Table 44 and Table 45, most building types included in this analysis and in the field observations are in line with the DEER assumptions. For some building characteristics, researchers were unable to determine valid comparisons between CSS and DEER for two factors investigated, specifically operational schedules and space make up. This is due to inconsistency in responses among a small CSS sample size. Therefore, no important findings could be reported for these two factors. Comparisons for these are also provided in Table 44 and Table 45.

Baseline: DEER with No Cooling

The team knew that many schools throughout California do not have air conditioning. However, as shown in Table 42 all HVAC systems within the DEER prototypes are modeled with air conditioning. To develop a set of results for prototypical buildings without air conditioning, the research team simply removed the air conditioning end-use energy consumption from all simulation runs and created a new set of results with the air conditioning energy removed. Researchers agreed that this would be a reasonable result for "heated only" buildings without increasing the total number of simulations. Since all DEER prototypes used for this analysis include air conditioning, the fully weighted results reported here consider that all buildings include cooling, even for buildings in cooler climates (such as 1 and 3) where the air conditioning may operate for only a small portion of the year. Figure: Baseline and After Retrofit EUI for Buildings in CZ5 (Mild), CZ 15 (Hot) and CZ 16 (Cold) with and without Cooling for the DEER Vintage Before 1978 shows the comparison of the cooling and non-cooling baseline and results in select climate zones.

37 California Commercial Saturation Survey, Itron, August 26, 2014.

Figure: Baseline and After Retrofit EUI for Buildings in CZ5 (Mild), CZ 15 (Hot) and CZ 16 (Cold) with and without Cooling for the DEER Vintage Before 1978



Note that the researchers did not make any adjustments to the simulation inputs, and this includes the central fan system. Therefore, the fan energy contained in all energy modeling results, including results for heated-only buildings, includes fan energy that would occur if the building included air-conditioning. This is likely an over-estimate of fan energy consumption for heated-only buildings, since the only fan energy that would occur during warmer seasons is the energy needed to provide outside air ventilation for the spaces. This error would tend to be greater in cooling dominated climates where systems have high cooling loads and the fan would often operate at full flow, thus increasing the fan energy.

Energy Efficiency Measure Packages and Modeling Approach

The research team chose to estimate savings for retrofit "packages" rather than for retrofit "measures". Generally, a measure-by-measure analysis does not provide useful guidance for making decisions about the deep retrofits necessary to achieve the significant performance improvements needed in existing buildings to reach ZNE. As such, modelers input bundles of energy efficiency measures rather than single energy efficiency measures. Additionally, the team included only efficiency measures within the bundles that could be explicitly modeled using DOE-2/eQUEST and used no work-arounds.

The team defined and classified the bundled packages according to the three main building system areas that drive energy use of a building: HVAC, envelope and internal gains (which consists of lighting, plug loads and miscellaneous equipment). For each system area, the team included three energy efficiency packages and created each package by logically grouping one or several energy efficiency measures together.

Table 20 describes the energy efficiency packages included in the analysis.

Table 20: Energy Efficiency Packages

HVAC Packages		
1	High Performance VAV	High performance built-up VAV including the following features: Hydronic reheat with condensing gas boiler (thermal efficiency 98%), High performance multistage chiller, with magnetic bearing compressors (two-stage, COP-5), Demand control ventilation, Air economizer, Low supply and return fan power: 0.9 W/cfm, Static pressure reset.
2	Ground Source Heat-Pumps	Ground source heat pump (EER-18[1] and COP-3.7[1]) with a water loop equipped with a variable speed pump, and aided by natural ventilation for cooling operations. Heat recovery installed in outside air ventilation ducts.
3	High Performance Single Zone Units	High performance single zone units with gas heat and DX cooling (EER-13[2], IEER-15.1) with air-economizer. Variable speed supply fan (0.4 W/cfm).
Internal Gains Packages		
4	Lighting Power Density (LPD)	Complete LED retrofit. Reduction of the LPDs from the 2011 DEER vintage level by 50%.
5	Daylighting, Interior Lighting and Plug Load Control	Side and top daylighting control with continuous dimming. Advanced lighting and plug load control (example: occupancy sensors).
6	Both daylighting and LED with improved control	Package 4 and 5 modeled together.
Envelope Packages		
7	Opaque Surfaces and Infiltration Reduction	Opaque Components: Roof: U-0.028[3], Wall: U-0.037[3] (steel-framed), U-0.048[3] (mass), U-0.032[3] (wood-framed). Slab: F-0.434 Infiltration: Infiltration rates used in DEER (0.038 cfm/ft2) reduced by 50% (0.019 cfm/ft2).
8	Fenestration	High performance glazing: highest performing glazing available coupled to a thermally broken frame. Applied to all window orientations.[38]
9	Opaque, Infiltration and Fenestration	Package 7 and 8 modeled together.

Notes:
1. Based on ASHRAE 90.1-2013, Minimum Efficiency Requirements, Table 6.8.1-2
2. Based on best performing unit for the 65k-135kBtu/h capacity range. Approximately 20% better than ASHRAE 90.1-2013, Minimum EER Requirements, Table 6.8.1-2
3. Based on ASHRAE 90.1-2013, Building Envelope Requirements for Climate Zone 8, Table 5

Simulations

After implementing the baselines and measure bundles in the DEER prototypes as described above using the DOE-2 expression language as well as the input macro language, modelers simulated each with an aim of capturing the interactive effects between each energy efficiency package.[39] In total, modelers performed around

38 For climate zone 1 through 5,11, 12 and 16: U-0.36 and SHGC-0.28, for all other climate zones U-0.34 and SHGC-0.15
39 The simulations were run using the latest version of DOE-2.2 (48y) and eQUEST (3.65) and the latest set of typical weather files for California climate zone (created in 2010).

40,000 individual simulations. They performed this high level of simulations using the batch processing capabilities of the eQUEST software.

Researchers interpreted the multiple simulation results by correlating the level of efficiency of each building component to the overall building energy use through a multiple-linear regression. The regression algorithm uses overall building energy use as the dependent variable and the ranking of each bundled package within a simulation as the three independent variables. That is, for a single permutation, we compared the building energy use after implementing each package and then ranked them from highest to lowest use. We included energy use of the baseline as well. These performance indices ranged between 2 (highest use, lowest savings) and 4 (lowest use, highest savings) with 1 being the baseline use. By combining the performance indices into a single regression, we captured the interactive effect between building components.

The regression equation is:

$$(EU) = A + B\ (HVAC) + C\ (IG) + D\ (ENV)$$

Where:
(EU) is the estimated total energy use
(HVAC) is the level of energy efficiency of the HVAC system (range between 1 and 4; 1 being the baseline)
(IG) is the level of energy efficiency of the internal gains (range between 1 and 4; 1 being the baseline)
(ENV) is the level of the energy efficiency of the building envelope (range between 1 and 4; 1 being the baseline)
And A, B, C and D being regression coefficients

The B, C and D coefficients[40] provide an indication of the energy efficiency provided by the retrofit packages for that building component compared to the other packages in the other components. Because each coefficient is negative (showing a reduction in use compared to the baseline), the smaller the coefficient is, the greater impact the component will have on reducing the total energy use. As such, it is possible to identify which end-uses are the primary drivers of building energy use and to observe the impact of different retrofit packages (combined with each other or not) on the consumed building energy.

We evaluated the absolute and relative goodness of fit. We assessed absolute goodness of fit through using the root mean square error and its coefficient of variation and assessed the relative goodness of fit via the adjusted coefficient of determination[41] (R^2). The goodness of fit of the regression models is generally good (values greater than 0.8), except for the primary school prototype where close to 50% of the regression models have an adjusted coefficient of determination lower than 0.7 (see Figure 21).

Figure 20 is an example of a regression of the estimated energy use (that uses the ranking for each of the independent variables) from the multiple-linear regression against the energy use directly from the simulations. As shown in this figure, the coefficient of determination is high which indicates that there is a strong correlation between the results from the simulations and the outcome of the multiple-linear regression.

40 Always negative.
41 The coefficient of determination is an indication of the proportion of the variance in the dependent variable that is predictable from the independent variable. It varies between 0 and 1, 1 corresponding to less variance and therefore a better value.

Figure 20: Regression for community college (CZ 15, vintage 2006 - 2009, with cooling)

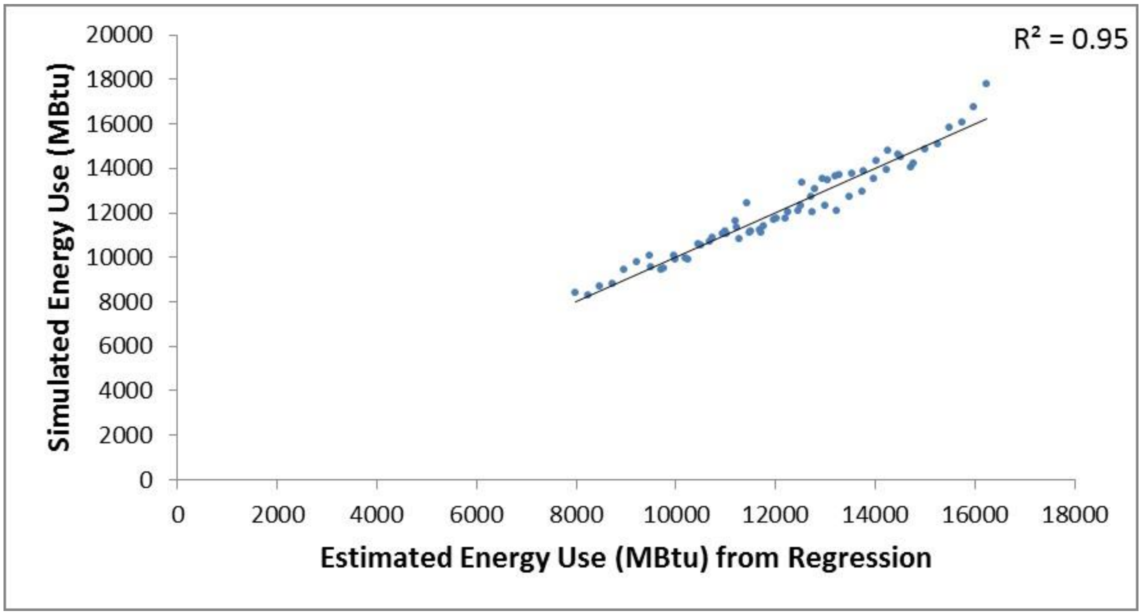
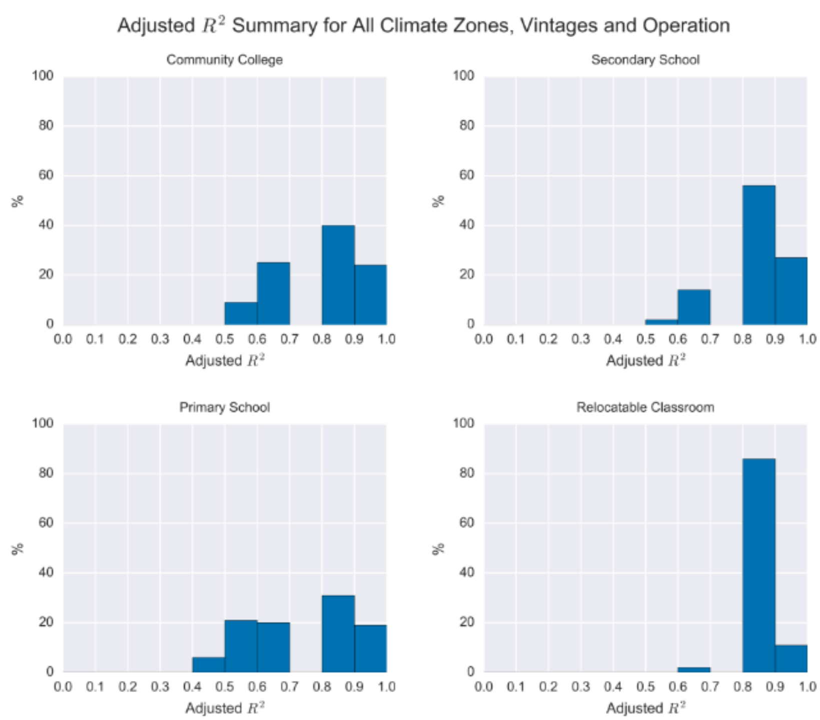


Figure 21 shows all adjusted coefficients of determination by building types, which were generally very good values.

Figure 21: All Adjusted Coefficients of Determination by Building Types



Adjusted R2 values are better when closer to 1.0

Modelers performed regressions for individual cases (i.e., a set of specific building type, climate zone, vintage and baseline) and for results combined and weighted in three ways (by climate zone, by vintage and by both climate zones and vintage). When multiplying results from each individual regression relationship for a particular building type, climate zone and vintage, by its DEER weight and then summed, it creates a weighted result for a particular weight group. (See Table 43 for the DEER building weights.). For example, to develop a result for primary schools in climate zone 8, each result for each vintage is first multiplied by its relative floor space weight for that vintage within climate zone 8. This is done for each of the six vintage results. Since the weights by vintage within a climate zone sum to one, the six individual products of result and vintage weight are then summed to develop a "weighted average" result for primary school within climate zone 8.

Using the Analysis Results

The regression analysis allows:

1) Seeing the impact and tradeoffs of deep retrofit of different level of efficiency on prototypical buildings for a set of input without having to perform building energy simulations
2) Estimating the EUI reduction of deep retrofit if the level of efficiency is known, without having to perform building energy simulations
3) Estimating the level of efficiency needed to achieve a desired EUI reduction

By using the regression models with energy efficiency indices between 1 through 4, analysis can be extended to any retrofit package. To ensure that the results returned by the regression for different retrofit packages are valid estimations, the indices used as input should stay within the bounds we used to perform the regression (i.e., no smaller than 1 or larger than 4).

To estimate the EUI of a combination of retrofit packages for a particular building type in a particular climate zone (or weighted by climate zone) and of a particular vintage (or weighted by vintage) using the regression models, one needs to compare the anticipated performance of each type of packages to the performance indicator provided by the regression model in order to calculate regression indices for each retrofit package. The indicators are the followings:

- HVAC packages: HVAC EUI (kBtu/square foot)
- Internal gains packages: Internal Gains EUI (kBtu/ square foot)
- Envelope packages: HVAC[42] EUI (kBtu/ square foot)

Then, the calculated indices can be plugged into the regression model to obtain a building EUI after retrofit.

<u>Example</u>:
For a secondary school in climate zone 8 built between 1978 and 1992, the regression analysis shows that retrofits having the most impact on the building EUI are HVAC retrofit (56%), followed by internal gains retrofit (24%) and envelope retrofit (20%). The analysis also provides performance indicator values for each level of efficiency of retrofit packages (see Table 20).

The information in Table 21 is the starting point for the next three steps, as follows:

Table 21: Performance Index Provided by the Regression Analysis

Retrofit Type	Level of Efficiency	Performance Indicator Value (kBtu/ft2)

42 We categorize envelope measures as having an impact on the HVAC energy use and hence an HVAC EUI. The envelope itself does not use energy, but primarily causes changes in the HVAC energy use.

HVAC Indicator: HVAC EUI	Baseline (Regression Index 1)	29.9
	Above Average (Regression Index 2)	26.9
	Good (Regression Index 3)	18.2
	Best Available (Regression Index 4)	11.6
Internal Gains Indicator: Int. G. EUI	Baseline (Regression Index 1)	19.0
	Above Average (Regression Index 2)	13.1
	Good (Regression Index 3)	11.6
	Best Available (Regression Index 4)	8.7
Envelope Indicator: HVAC EUI	Baseline (Regression Index 1)	29.9
	Above Average (Regression Index 2)	26.0
	Good (Regression Index 3)	22.4
	Best Available (Regression Index 4)	19.6

1. Define the retrofit packages
   A design team wants to know the building EUI after a deep retrofit that includes a total HVAC retrofit, plug load and lighting reduction and envelope retrofit. Based on their internal analysis, the team expects the proposed HVAC system to have an HVAC EUI in the low twenties (~22 kBtu/ square foot), to reduce the internal gains from plug-loads and lighting by 50% and to reduce the building HVAC loads due to envelope retrofits by 10%.

2. Calculate the regression index
   The anticipated HVAC EUI due to the HVAC retrofit packages would have, according to Table 21 , a level of efficiency between “Above Average” and “Good”. By linear interpolation, the team calculates a regression index of 2.56 for this HVAC retrofit package.

   Reducing the plug-loads and lighting by 50% would results in an internal gains EUI of 9.0 kBtu/ square foot. According to Table 21, the level of efficiency of this retrofit package would be slightly above “Best Available”. By linear interpolation, the team calculates a regression index of 3.90 is calculated for the internal gains retrofit package.

   The anticipated HVAC EUI (27.0 kBtu/ square foot) due to the envelope retrofit package would have, according to Table 21, a level of efficiency between “Baseline” and “Above Average”. By linear interpolation a regression index of 1.74 is calculated for the envelope retrofit package.

3. Regression Model
   For this particular combination of building type, climate zone and vintage the regression model provides the coefficients for each retrofit package category shown in Table 22.

Table 22: Regression Coefficients

Category	Coefficients
HVAC	-831.25
Internal Gains	-363.09
Envelope	-302.71
Constant	8792.47

Using the previously calculated retrofit indices, the design team can estimate the EUI of the proposed deep energy efficiency retrofit.

$$EUI = \frac{8792.47 - 302.71 \times 1.74 - 363.09 \times 3.90 - 831.25 \times 2.56}{150000^{43}} = 34.38\ kBtu/ft^2$$

Service and Domestic Water Heating

The team did not examine water heating systems as part of the simulations, nor in the development of the savings estimator because stand-alone service and domestic water heating systems have little, if any interaction with building HVAC systems. That is, changes in energy use of a water heating system do not result in changes in heating or cooling loads in a building that would affect the energy use of a building HVAC system. Instead, modelers applied a 50% reduction[44] to the total water heating end use consumption in order to show how close to ZNE the prototypical building could get if a reduction in service and domestic hot water use is included. This was added to the ZNE savings potential as discussed in the Range of Potential Savings section.

43 Area of the secondary school prototype model

44 Engineering investigation of the technical potential for water heating savings was not included in the scope of this analysis. However, the NBI/Madison Engineering research team agreed with CPUC staff and its advisors that a 50% reduction in water heating energy use was a reasonable reduction to assume for a ZNE ready goal.

Additional Technical Information

In addition to the standard DEER assumptions, the modeling team used an Alternative Operational and Controls Assumptions to consider "poor operations" and additional plug load savings.

DEER with alternative operation and controls

The intent of modeling an alternative baseline is to compare the impact of energy efficiency upgrades to a building following the DEER prototypical assumptions but that would be poorly maintained or operated. This alternative baseline is identical to the DEER baseline except for the two following items:

- Extended operating hours for lighting, equipment (including miscellaneous plug loads) and HVAC systems
- Less than ideal control settings for economizer set points and operations

Lighting, equipment and miscellaneous plug loads

Figure 22 and Figure 23 show the difference in daily profiles between three scenarios, the DEER baseline, the alternative baseline (DEER with poor controls), and the "advanced controls" energy efficiency packages (package 5 and 6 in Table 20). As shown below, the DEER baseline with poor controls fraction of lighting on during the unoccupied hours has been considerably increased, but kept the same during occupied hours. The "advanced controls" energy efficiency upgrade reduced the fraction of lighting on for both unoccupied and occupied hours. This advanced controls simulation assumes that lighting and equipment control devices such as occupancy sensors are present in the building and hence decrease both occupied and unoccupied hours of operations[45].

45 The "advanced controls" profiles represent the expected operational conditions that are included in the internal gains measure packages.

Figure 22: Lighting Profiles For Linear Fluorescent Lights In A Community College Classroom (Or Shop) For Weekdays During The "Open" Periods

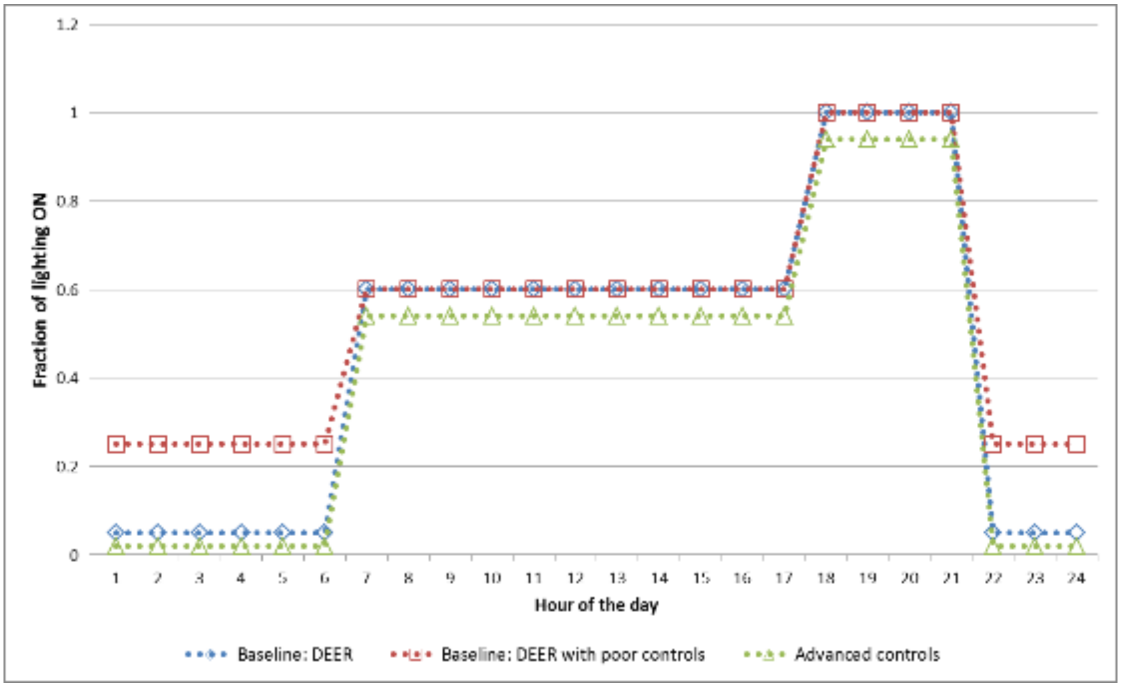
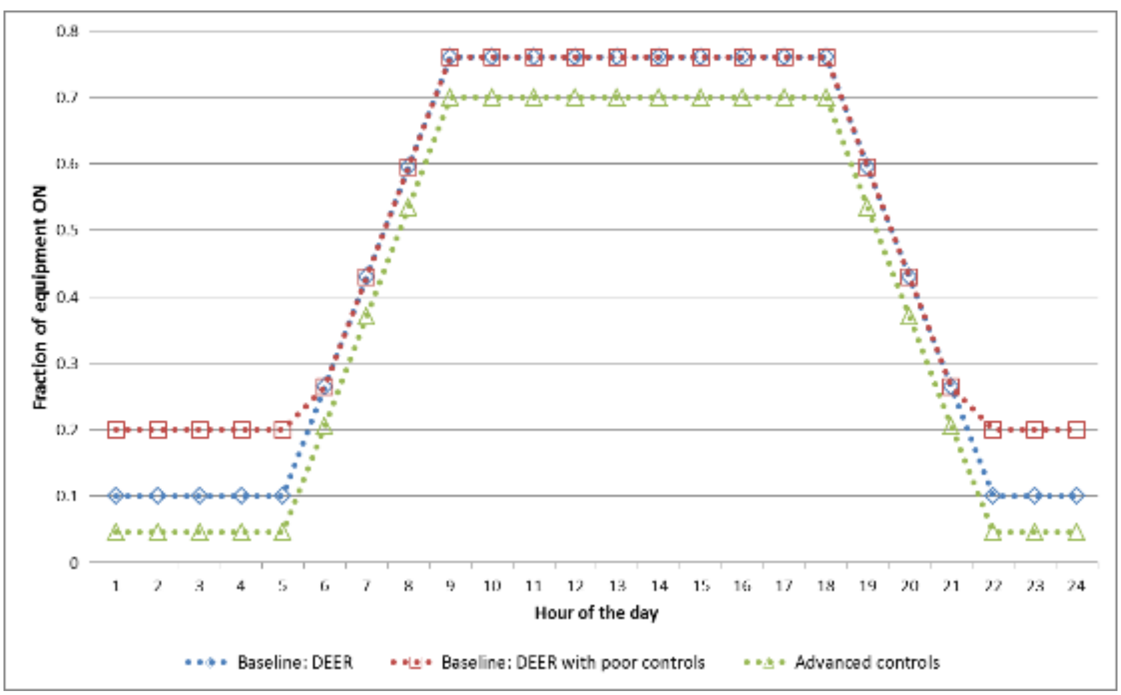


Figure 23: Equipment Profiles For A Community College Classroom (Or Shop) For Weekdays During The "Open" Periods



Economizer set points and operation

The DEER baseline with poor operation and controls has modified economizer set points and operation as shown in Table 23.

Table 23: Modified Economizer Operation

System Type	Operation Type	Economizer Dry bulb Limit (F)	Maximum Outdoor Air Fraction	Minimum Outdoor Air Fraction
Rooftop Gas Pack	Poor Operations	65	0.60	0.25
	DEER	75 for climate zones 2, 11, 13, 14, 15, 16 70 for all others	0.8	0.2
Package VAV with reheat	Poor Operations	Same as DEER	0.90	0.10
	DEER	75 for climate zones 2, 11, 13, 14, 15, 16 70 for all others	1.0	0.0
Built-up VAV with reheat	Poor Operations	Same as DEER	0.90	0.10
	DEER	75 for climate zones 2, 11, 13, 14, 15, 16 70 for all others	1.0	0.0

Preliminary Sensitivity Analysis

The team performed a small-scale assessment to validate the approach to use for the sensitivity analysis before performing an extensive sensitivity analysis.

A multitude of type of sensitivity analysis exists. We evaluated three of them as part of the small scale analysis (listed by increasing level of complexity and computational intensity):

- Morris sensitivity analysis ("one-at-a-time")
- Multiple-linear regression based on Monte Carlo simulations
- Sobol sensitivity analysis (variance-based)

We modeled and simulated a set of twelve individual energy efficiency measures for each analysis, as described next.

Morris Sensitivity Analysis

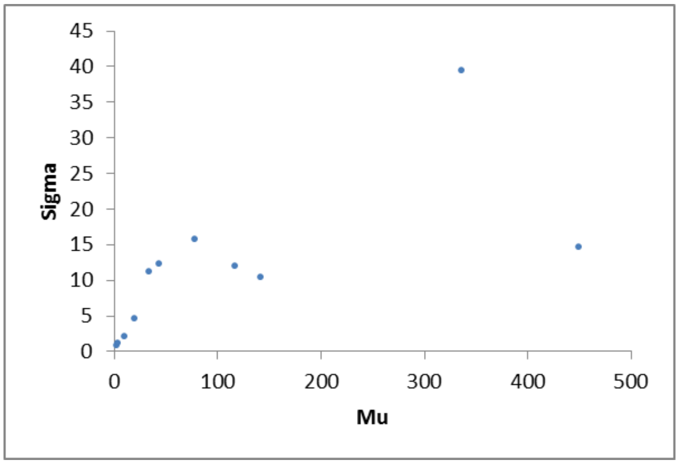
A Morris sensitivity analysis is the quickest analysis as it requires only a couple hundred simulations to generate results. A Morris sensitivity analysis can be performed using a simulation sample made of discrete values but the outcome of the analysis needs to be used with caution, using a discrete value sample will affect the results of the sensitivity analysis.[46]

Figure 24 shows the outcome of a Morris sensitivity analysis for the primary school prototype building for a particular vintage and climate zone. On the figure each data point represents an energy efficiency measure. A higher value for "Mu" shows an important influence on the overall output (energy use). A higher value for "Sigma" shows an important interaction of a particular input with other inputs on the overall output. In this

46 The simulation for such type of sensitivity analysis is typically made from continuous parameters. However, this study evaluates the impact of energy efficiency measures which cannot always be represented by continuous values.

example, the highest value of sigma corresponds to a cooling efficiency measure which should only have an impact on the overall output but no interaction with other inputs. The same results have been observed for different building types. Based on these results it was decided to reject the Morris method as the type of sensitivity analysis to use for this study.

Figure 24: Results Of A Morris Sensitivity Analysis For The Primary School Prototype For A Particular Vintage And Particular Climate Zone



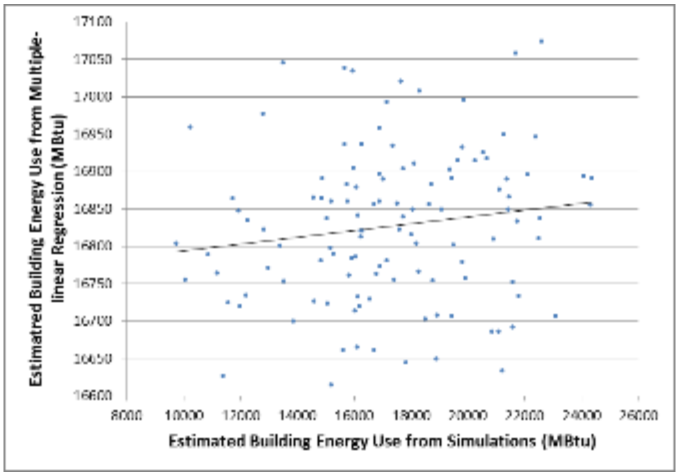
Multiple-linear Regression based on Monte Carlo simulations

The second method we investigated was a multiple-linear regression based on the outcome of Monte Carlo simulations. We assigned an index to each level of performance of each energy efficiency measure. We randomly generated sets of indices for particular baseline parameters (vintage and climate zone) in order to create 10,000 individual simulation runs.

We performed a multiple-linear regression for each set of simulation results to gage which measure type contributed the most to the reduction in energy use. We used the indices that defined each individual simulation run and the total energy use from the simulation. The objective of such regression was to correlate each type of measure to an estimated energy use. The computed value of the regression coefficient would highlight which energy efficiency measures are driving the energy use of the building down.

Figure 25 shows the results obtained from a multiple-linear regression plotted against the actual results from the simulation for a particular set of runs. The figure shows that there is no correlation, meaning that the results from the multiple-linear regression cannot be used as an estimated of the actual energy use from the simulations.

Figure 25: Estimated Building Energy Use From Simulations Against The Estimated Energy Use From A Multiple-Linear Regression For The Community College Prototype For A Particular Vintage And Climate Zone



With this method the total number of individual runs possible can become very large. In order to improve the results of the multiple-linear regression one could increase the number of simulation runs.

This method is computationally speaking more intensive as it requires a larger number of simulations than the Morris method to give good results. Regardless of the method, 10,000 simulations for a particular baseline (set of building type, climate zone and vintage) is an important number of simulations even if DOE-2, the simulation software used for the simulations, is relatively fast compared to other available hourly building energy simulation software. the ability to quickly restart the analysis when modification the modeling process is necessary. Therefore, if we had tried to increase the number of simulations to improve the results of the multiple-linear regression, the time required to simulate every individual run would have slowed down the analysis. For these reasons, we did not choose this as our study method.

Sobol Sensitivity Analysis

As opposed to the Morris method, the Sobol method can be used for discrete scenarios. It however requires more computational resources as the number of simulation to be performed can be large. The size of the sample depends on the number of parameters and the number of evaluations for estimating each individual effect.

We performed an initial assessment of the Sobol sensitivity analysis method for each building type and for a set of a particular vintage and climate zone using 192 estimations and the set of 12 energy efficiency measures as parameters, resulting in 4,992 individual simulation runs for each building type, each climate zone and each vintage.

Table 24 shows an example of results of the total and first order Sobol indices for the primary school prototype for a particular vintage and a particular climate zone. The confidence intervals for the total order Sobol indices are acceptable, however, the confidence interval computed for the first order Sobol indices are too high to be accepted. The results could be certainly improved by increasing the number of estimations.

Table 24: First Order Sobol Indices For The Primary School Prototype For A Particular Vintage And A Particular Climate Zone

	Total Order Sobol Indices[47]	Confidence Interval	First Order Sobol Indices[48]	Confidence Interval
HVAC System Type	0.8451	0.1213	0.773	1.182
Heating Efficiency	0.0009	0.0005	-0.004	0.034
Cooling Efficiency	0.0428	0.0145	0.002	0.228
Outdoor Air	0.0118	0.0032	0.037	0.123
HVAC Fan Power	0.0219	0.0053	0.028	0.167
Lighting Power Density	0.1143	0.0261	0.148	0.401
Infiltration	0.0001	0.0000	0.002	0.008
Wall U-Value	0.0003	0.0001	0.004	0.025
Roof U-Value	0.0000	0.0000	0.003	0.016
Fen U-Factor and SHGC	0.0092	0.0024	0.009	0.114
DHW Demand	0.0103	0.0021	0.007	0.125
Water Heater Efficiency	0.0014	0.0003	0.003	0.045

The outcome and conclusion of the assessment of this method is similar to the multiple-linear regression approach. The Sobol indices method requires a lot of computational resources as over 5,000 simulations would be required to get acceptable results for each building type, vintage and climate zone (not including alternative baselines).

Conclusion

Both the multiple-linear regression approach and the Sobol sensitivity analysis showed that a large number of runs would be required to obtain acceptable results. Additionally, the results presented were simulated for a particular vintage and a particular climate zone, thus, the number total of simulations to be performed would have to be multiplied by the number of climate zone (16) and the number of vintages (6) which is equivalent to multiply the number of runs required to obtain acceptable results by 96, which if more than 10,000 simulations are required for a case (particular vintage and climate zone), over a millions of simulations would have to be run. This scenario would require a huge amount of computational resources in order to provide results in timely fashion.

Since none of these three approaches were judged acceptable for this study, the team developed a different method. The focus of the approach was to reduce the number of input parameters by grouping energy efficiency measures in upgrade packages and reduce the amount of simulation runs while still achieving the goal of identifying the big contributors to the energy use reduction of the educational building stock. The chosen packages (for HVAC, Internal Gains, and Envelope) are described above in Table 20.

47 Total indices measure the contribution to the output variance of the variables including all variance caused by its interactions.
48 First order indices measure the effect of varying the variable alone but averaged over variations in other input parameters.

Table 25: DEER Baseline Wall U-Vales

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Community College	Mass	Before 1978	25.5%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Community College	Mass	1978 - 1992	25.5%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Community College	Mass	1993 - 2001	25.5%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Community College	Mass	2002 - 2005	25.5%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Community College	Mass	2006 - 2009	25.5%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Community College	Mass	2010 - 2013	25.5%	0.253	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.184	0.253	0.211	0.184	0.184	0.160
Primary School	Wood Frame	Before 1978	21.0%	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Primary School	Wood Frame	1978 - 1992	21.0%	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.088
Primary School	Wood Frame	1993 - 2001	21.0%	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.080	0.088	0.088	0.080	0.080	0.080	0.080	0.080	0.080
Primary School	Wood Frame	2002 - 2005	21.0%	0.080	0.080	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Primary School	Wood Frame	2006 - 2009	21.0%	0.080	0.080	0.088	0.088	0.088	0.088	0.088	0.088	0.088	0.080	0.080	0.080	0.080	0.080	0.080	0.080
Primary School	Wood Frame	2010 - 2013	21.0%	0.080	0.059	0.088	0.059	0.088	0.088	0.088	0.088	0.059	0.059	0.059	0.059	0.059	0.059	0.042	0.059
Secondary School	Mass	Before 1978	20.2%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Secondary School	Mass	1978 - 1992	20.2%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Secondary School	Mass	1993 - 2001	20.2%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Secondary School	Mass	2002 - 2005	20.2%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Secondary School	Mass	2006 - 2009	20.2%	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262
Secondary School	Mass	2010 - 2013	20.2%	0.253	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.262	0.184	0.253	0.211	0.184	0.184	0.160
Relocatable Classroom	Metal Frame	Before 1978	4.2%	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265	0.265
Relocatable Classroom	Metal Frame	1978 - 1992	4.2%	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
Relocatable Classroom	Metal Frame	1993 - 2001	4.2%	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.165
Relocatable Classroom	Metal Frame	2002 - 2005	4.2%	0.152	0.152	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.152	0.152	0.152	0.152	0.152	0.152	0.152
Relocatable Classroom	Metal Frame	2006 - 2009	4.2%	0.152	0.152	0.165	0.165	0.165	0.165	0.165	0.165	0.165	0.152	0.152	0.152	0.152	0.152	0.152	0.152
Relocatable Classroom	Metal Frame	2010 - 2013	4.2%	0.098	0.062	0.062	0.062	0.062	0.098	0.098	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062

Table 26: DEER Baseline Roof U-Values

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Community College	Mass	Before 1978	25.5%	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Community College	Mass	1978 - 1992	25.5%	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Community College	Mass	1993 - 2001	25.5%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050
Community College	Mass	2002 - 2005	25.5%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Community College	Mass	2006 - 2009	25.5%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Community College	Mass	2010 - 2013	25.5%	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Primary School	Wood Frame	Before 1978	21.0%	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Primary School	Wood Frame	1978 - 1992	21.0%	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057

Primary School	Wood Frame	1993 - 2001	21.0%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050
Primary School	Wood Frame	2002 - 2005	21.0%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Primary School	Wood Frame	2006 - 2009	21.0%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Primary School	Wood Frame	2010 - 2013	21.0%	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Secondary School	Mass	Before 1978	20.2%	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063	0.063
Secondary School	Mass	1978 - 1992	20.2%	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
Secondary School	Mass	1993 - 2001	20.2%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050
Secondary School	Mass	2002 - 2005	20.2%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Secondary School	Mass	2006 - 2009	20.2%	0.050	0.050	0.050	0.050	0.050	0.078	0.078	0.078	0.057	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Secondary School	Mass	2010 - 2013	20.2%	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
Relocatable Classroom	Metal Frame	Before 1978	4.2%	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
Relocatable Classroom	Metal Frame	1978 - 1992	4.2%	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116	0.116
Relocatable Classroom	Metal Frame	1993 - 2001	4.2%	0.094	0.094	0.094	0.094	0.094	0.116	0.116	0.116	0.116	0.116	0.094	0.094	0.094	0.094	0.094	0.094
Relocatable Classroom	Metal Frame	2002 - 2005	4.2%	0.094	0.094	0.094	0.094	0.094	0.116	0.116	0.116	0.116	0.094	0.094	0.094	0.094	0.094	0.094	0.094
Relocatable Classroom	Metal Frame	2006 - 2009	4.2%	0.066	0.066	0.066	0.066	0.066	0.076	0.076	0.076	0.076	0.066	0.066	0.066	0.066	0.066	0.066	0.066
Relocatable Classroom	Metal Frame	2010 - 2013	4.2%	0.049	0.039	0.039	0.039	0.049	0.075	0.067	0.067	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039

Table 27: DEER Baseline Window U-Factor

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Community College	Mass	Before 1978	25.5%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Community College	Mass	1978 - 1992	25.5%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Community College	Mass	1993 - 2001	25.5%	0.770	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	0.770	0.770	0.770	0.770	0.770	0.770
Community College	Mass	2002 - 2005	25.5%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Community College	Mass	2006 - 2009	25.5%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Community College	Mass	2010 - 2013	25.5%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	Before 1978	21.0%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Primary School	Wood Frame	1978 - 1992	21.0%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Primary School	Wood Frame	1993 - 2001	21.0%	0.770	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	0.770	0.770	0.770	0.770	0.770	0.770
Primary School	Wood Frame	2002 - 2005	21.0%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	2006 - 2009	21.0%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	2010 - 2013	21.0%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Secondary School	Mass	Before 1978	20.2%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Secondary School	Mass	1978 - 1992	20.2%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Secondary School	Mass	1993 - 2001	20.2%	0.770	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	0.770	0.770	0.770	0.770	0.770	0.770
Secondary School	Mass	2002 - 2005	20.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Secondary School	Mass	2006 - 2009	20.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Secondary School	Mass	2010 - 2013	20.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Relocatable Classroom	Metal Frame	Before 1978	4.2%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Relocatable Classroom	Metal Frame	1978 - 1992	4.2%	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230
Relocatable Classroom	Metal Frame	1993 - 2001	4.2%	0.770	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	1.230	0.770	0.770	0.770	0.770	0.770	0.770
Relocatable Classroom	Metal Frame	2002 - 2005	4.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Relocatable Classroom	Metal Frame	2006 - 2009	4.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Relocatable Classroom	Metal Frame	2010 - 2013	4.2%	0.470	0.470	0.770	0.770	0.770	0.770	0.770	0.770	0.770	0.470	0.470	0.470	0.470	0.470	0.470	0.470

Table 28: DEER Baseline Window SHGC for NON-North Facing Windows

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Community College	Mass	Before 1978	25.5%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Community College	Mass	1978 - 1992	25.5%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Community College	Mass	1993 - 2001	25.5%	0.500	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.500	0.500	0.500	0.500	0.500	0.500
Community College	Mass	2002 - 2005	25.5%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Community College	Mass	2006 - 2009	25.5%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Community College	Mass	2010 - 2013	25.5%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Primary School	Wood Frame	Before 1978	21.0%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Primary School	Wood Frame	1978 - 1992	21.0%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Primary School	Wood Frame	1993 - 2001	21.0%	0.500	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.500	0.500	0.500	0.500	0.500	0.500
Primary School	Wood Frame	2002 - 2005	21.0%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Primary School	Wood Frame	2006 - 2009	21.0%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Primary School	Wood Frame	2010 - 2013	21.0%	0.430	0.360	0.410	0.410	0.410	0.390	0.390	0.390	0.390	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Secondary School	Mass	Before 1978	20.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Secondary School	Mass	1978 - 1992	20.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Secondary School	Mass	1993 - 2001	20.2%	0.500	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.500	0.500	0.500	0.500	0.500	0.500
Secondary School	Mass	2002 - 2005	20.2%	0.430	0.360	0.550	0.550	0.550	0.610	0.610	0.610	0.610	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Secondary School	Mass	2006 - 2009	20.2%	0.430	0.360	0.550	0.550	0.550	0.610	0.610	0.610	0.610	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Secondary School	Mass	2010 - 2013	20.2%	0.430	0.360	0.550	0.550	0.550	0.610	0.610	0.610	0.610	0.360	0.360	0.360	0.360	0.360	0.360	0.430
Relocatable Classroom	Metal Frame	Before 1978	4.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Relocatable Classroom	Metal Frame	1978 - 1992	4.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Relocatable Classroom	Metal Frame	1993 - 2001	4.2%	0.500	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.620	0.500	0.500	0.500	0.500	0.500	0.500
Relocatable Classroom	Metal Frame	2002 - 2005	4.2%	0.490	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.460	0.460	0.490
Relocatable Classroom	Metal Frame	2006 - 2009	4.2%	0.490	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.460	0.460	0.490
Relocatable Classroom	Metal Frame	2010 - 2013	4.2%	0.490	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.460	0.460	0.490

Table 29: DEER Baseline Window SHGC for North Facing Windows

Building Type	Construction Type	Vintage	Window-to Wall Ratio	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Community College	Mass	Before 1978	25.5%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Community College	Mass	1978 - 1992	25.5%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Community College	Mass	1993 - 2001	25.5%	0.770	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.770	0.770	0.770	0.500	0.500	0.770
Community College	Mass	2002 - 2005	25.5%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Community College	Mass	2006 - 2009	25.5%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Community College	Mass	2010 - 2013	25.5%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	Before 1978	21.0%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Primary School	Wood Frame	1978 - 1992	21.0%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Primary School	Wood Frame	1993 - 2001	21.0%	0.770	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.770	0.770	0.770	0.500	0.500	0.770
Primary School	Wood Frame	2002 - 2005	21.0%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	2006 - 2009	21.0%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Primary School	Wood Frame	2010 - 2013	21.0%	0.470	0.470	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.470	0.470	0.470	0.470	0.470	0.470	0.470
Secondary School	Mass	Before 1978	20.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Secondary School	Mass	1978 - 1992	20.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Secondary School	Mass	1993 - 2001	20.2%	0.770	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.770	0.770	0.770	0.500	0.500	0.770
Secondary School	Mass	2002 - 2005	20.2%	0.490	0.510	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.510	0.510	0.510	0.510	0.510	0.510	0.490
Secondary School	Mass	2006 - 2009	20.2%	0.490	0.510	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.510	0.510	0.510	0.510	0.510	0.510	0.490
Secondary School	Mass	2010 - 2013	20.2%	0.490	0.510	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.510	0.510	0.510	0.510	0.510	0.510	0.490
Relocatable Classroom	Metal Frame	Before 1978	4.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Relocatable Classroom	Metal Frame	1978 - 1992	4.2%	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
Relocatable Classroom	Metal Frame	1993 - 2001	4.2%	0.770	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.770	0.770	0.770	0.500	0.500	0.770
Relocatable Classroom	Metal Frame	2002 - 2005	4.2%	0.720	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.720
Relocatable Classroom	Metal Frame	2006 - 2009	4.2%	0.720	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.720
Relocatable Classroom	Metal Frame	2010 - 2013	4.2%	0.720	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.610	0.720

Table 30: DEER Lighting Power (Before 1978)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.6	50.4	46.5	3.4	0.3	0.3
	Cafeteria	7,500	15	1.5	11.3	10.4	0.8	0.1	0.1
	Gymnasium	7,500	15	1.2	9.0	8.3	0.6	0.0	0.1
	Kitchen	3,500	7	1.7	6.0	5.5	0.4	0.0	0.0
	Total	**50,000**		**1.5**	**76.6**	**70.6**	**5.1**	**0.4**	**0.5**
Secondary School	Classroom	88,200	59	1.6	141.1	123.5	11.7	5.2	0.6
	Computer Room	3,082	2	1.6	4.9	4.3	0.4	0.2	0.0
	Cafeteria	22,500	15	1.5	33.8	29.5	2.8	1.2	0.1
	Gymnasium	22,500	15	1.2	27.0	23.6	2.2	1.0	0.1
	Kitchen	10,500	7	1.7	17.9	15.6	1.5	0.7	0.1
	Office	3,218	2	1.3	4.2	3.7	0.3	0.2	0.0
	Total	**150,000**		**1.5**	**228.8**	**200.2**	**19.0**	**8.5**	**0.9**
Community College	Classroom	150,825	50	1.6	241.3	213.6	20.3	7.0	0.6
	Computer Room	9,625	3	1.6	15.4	13.6	1.3	0.4	0.0
	Workshop	37,500	12	1.8	67.5	59.7	5.7	2.0	0.2
	Cafeteria	26,250	9	1.5	39.4	34.8	3.3	1.1	0.1
	Kitchen	5,625	2	1.7	9.6	8.5	0.8	0.3	0.0
	Office	70,175	23	1.3	91.2	80.7	7.7	2.6	0.2
	Total	**300,000**		**1.5**	**464.4**	**411.0**	**39.0**	**13.5**	**1.2**
Relocatable Classroom	Classroom	**1,920**	100	**1.6**	**3.1**	**0.3**	**0.0**	**0.0**	**0.0**

Table 31: DEER Lighting Power (1978 - 1992)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.6	50.4	46.5	3.4	0.3	0.3
	Cafeteria	7,500	15	1.5	11.3	10.4	0.8	0.1	0.1
	Gymnasium	7,500	15	1.2	9.0	8.3	0.6	0.0	0.1
	Kitchen	3,500	7	1.7	6.0	5.5	0.4	0.0	0.0
	Total	**50,000**		**1.5**	**76.6**	**70.6**	**5.1**	**0.4**	**0.5**
Secondary School	Classroom	88,200	59	1.6	141.1	123.5	11.7	5.2	0.6
	Computer Room	3,082	2	1.6	4.9	4.3	0.4	0.2	0.0
	Cafeteria	22,500	15	1.5	33.8	29.5	2.8	1.2	0.1
	Gymnasium	22,500	15	1.2	27.0	23.6	2.2	1.0	0.1
	Kitchen	10,500	7	1.7	17.9	15.6	1.5	0.7	0.1
	Office	3,218	2	1.3	4.2	3.7	0.3	0.2	0.0
	Total	**150,000**		**1.5**	**228.8**	**200.2**	**19.0**	**8.5**	**0.9**
Community College	Classroom	150,825	50	1.6	241.3	213.6	20.3	7.0	0.6
	Computer Room	9,625	3	1.6	15.4	13.6	1.3	0.4	0.0
	Workshop	37,500	12	1.8	67.5	59.7	5.7	2.0	0.2
	Cafeteria	26,250	9	1.5	39.4	34.8	3.3	1.1	0.1
	Kitchen	5,625	2	1.7	9.6	8.5	0.8	0.3	0.0
	Office	70,175	23	1.3	91.2	80.7	7.7	2.6	0.2
	Total	**300,000**		**1.5**	**464.4**	**411.0**	**39.0**	**13.5**	**1.2**
Relocatable Classroom	Classroom	**1,920**	100	**1.6**	**3.1**	**0.3**	**0.0**	**0.0**	**0.0**

Table 32: DEER Lighting Power (1993 - 2001)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.6	50.4	46.5	3.4	0.3	0.3
	Cafeteria	7,500	15	1.3	9.8	9.0	0.7	0.0	0.1
	Gymnasium	7,500	15	1.0	7.5	6.9	0.5	0.0	0.1
	Kitchen	3,500	7	1.7	6.0	5.5	0.4	0.0	0.0
	Total	**50,000**		**1.5**	**73.6**	**67.9**	**4.9**	**0.4**	**0.5**
Secondary School	Classroom	88,200	59	1.6	141.1	123.5	11.7	5.2	0.6
	Computer Room	3,082	2	1.6	4.9	4.3	0.4	0.2	0.0
	Cafeteria	22,500	15	1.3	29.3	25.6	2.4	1.1	0.1
	Gymnasium	22,500	15	1.0	22.5	19.7	1.9	0.8	0.1
	Kitchen	10,500	7	1.7	17.9	15.6	1.5	0.7	0.1
	Office	3,218	2	1.3	4.2	3.7	0.3	0.2	0.0
	Total	**150,000**		**1.5**	**219.8**	**192.4**	**18.2**	**8.1**	**0.9**
Community College	Classroom	150,825	50	1.6	241.3	213.6	20.3	7.0	0.6
	Computer Room	9,625	3	1.6	15.4	13.6	1.3	0.4	0.0
	Workshop	37,500	12	1.2	45.0	39.8	3.8	1.3	0.1
	Cafeteria	26,250	9	1.3	34.1	30.2	2.9	1.0	0.1
	Kitchen	5,625	2	1.7	9.6	8.5	0.8	0.3	0.0
	Office	70,175	23	1.3	91.2	80.7	7.7	2.6	0.2
	Total	**300,000**		**1.5**	**436.6**	**386.4**	**36.7**	**12.7**	**1.1**
Relocatable Classroom	Classroom	**1,920**	100	**1.2**	**2.3**	**0.2**	**0.0**	**0.0**	**0.0**

Table 33: DEER Lighting Power (2002 - 2005)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.2	37.8	34.9	2.5	0.2	0.3
	Cafeteria	7,500	15	1.3	9.8	9.0	0.7	0.0	0.1
	Gymnasium	7,500	15	1.0	7.5	6.9	0.5	0.0	0.1
	Kitchen	3,500	7	1.7	6.0	5.5	0.4	0.0	0.0
	Total	**50,000**		**1.2**	**61.0**	**56.2**	**4.1**	**0.3**	**0.4**
Secondary School	Classroom	88,200	59	1.2	105.8	92.6	8.8	3.9	0.4
	Computer Room	3,082	2	1.6	4.9	4.3	0.4	0.2	0.0
	Cafeteria	22,500	15	1.3	29.3	25.6	2.4	1.1	0.1
	Gymnasium	22,500	15	1.0	22.5	19.7	1.9	0.8	0.1
	Kitchen	10,500	7	1.7	17.9	15.6	1.5	0.7	0.1
	Office	3,218	2	1.3	4.2	3.7	0.3	0.2	0.0
	Total	**150,000**		**1.2**	**184.6**	**161.5**	**15.3**	**6.8**	**0.7**
Community College	Classroom	150,825	50	1.2	181.0	160.2	15.2	5.2	0.5
	Computer Room	9,625	3	1.6	15.4	13.6	1.3	0.4	0.0
	Workshop	37,500	12	1.2	45.0	39.8	3.8	1.3	0.1
	Cafeteria	26,250	9	1.3	34.1	30.2	2.9	1.0	0.1
	Kitchen	5,625	2	1.7	9.6	8.5	0.8	0.3	0.0
	Office	70,175	23	1.3	91.2	80.7	7.7	2.6	0.2
	Total	**300,000**		**1.3**	**376.3**	**333.0**	**31.6**	**10.9**	**0.9**
Relocatable Classroom	Classroom	**1,920**	100	**1.2**	**2.3**	**0.2**	**0.0**	**0.0**	**0.0**

Table 34: DEER Lighting Power (2006 - 2009)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.2	37.8	34.9	2.5	0.2	0.3
	Cafeteria	7,500	15	1.3	9.8	9.0	0.7	0.0	0.1
	Gymnasium	7,500	15	1.0	7.5	6.9	0.5	0.0	0.1
	Kitchen	3,500	7	1.6	5.6	5.2	0.4	0.0	0.0
	Total	**50,000**		**1.2**	**60.7**	**55.9**	**4.1**	**0.3**	**0.4**
Secondary School	Classroom	88,200	59	1.2	105.8	92.6	8.8	3.9	0.4
	Computer Room	3,082	2	1.2	3.7	3.2	0.3	0.1	0.0
	Cafeteria	22,500	15	1.3	29.3	25.6	2.4	1.1	0.1
	Gymnasium	22,500	15	1.0	22.5	19.7	1.9	0.8	0.1
	Kitchen	10,500	7	1.6	16.8	14.7	1.4	0.6	0.1
	Office	3,218	2	1.3	4.2	3.7	0.3	0.2	0.0
	Total	**150,000**		**1.2**	**182.3**	**159.5**	**15.1**	**6.7**	**0.7**
Community College	Classroom	150,825	50	1.2	181.0	160.2	15.2	5.2	0.5
	Computer Room	9,625	3	1.2	11.6	10.2	1.0	0.3	0.0
	Workshop	37,500	12	1.2	45.0	39.8	3.8	1.3	0.1
	Cafeteria	26,250	9	1.3	34.1	30.2	2.9	1.0	0.1
	Kitchen	5,625	2	1.6	9.0	8.0	0.8	0.3	0.0
	Office	70,175	23	1.3	91.2	80.7	7.7	2.6	0.2
	Total	**300,000**		**1.2**	**371.9**	**329.1**	**31.2**	**10.8**	**0.9**
Relocatable Classroom	Classroom	**1,920**	100	**1.2**	**2.3**	**0.2**	**0.0**	**0.0**	**0.0**

Table 35: DEER Lighting Power (2010 - 2013)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Total Power (kW)	Linear Fluorescent Power (kW)	CFL Power (kW)	Other Power (kW)	Exit Signs Power (kW)
Primary School	Classroom	31,500	63	1.2	37.8	34.9	2.5	0.2	0.3
	Cafeteria	7,500	15	1.3	9.8	9.0	0.7	0.0	0.1
	Gymnasium	7,500	15	1.0	7.5	6.9	0.5	0.0	0.1
	Kitchen	3,500	7	1.6	5.6	5.2	0.4	0.0	0.0
	Total	**50,000**		**1.2**	**60.7**	**55.9**	**4.1**	**0.3**	**0.4**
Secondary School	Classroom	88,200	59	1.2	105.8	92.6	8.8	3.9	0.4
	Computer Room	3,082	2	1.2	3.7	3.2	0.3	0.1	0.0
	Cafeteria	22,500	15	1.3	29.3	25.6	2.4	1.1	0.1
	Gymnasium	22,500	15	1.0	22.5	19.7	1.9	0.8	0.1
	Kitchen	10,500	7	1.6	16.8	14.7	1.4	0.6	0.1
	Office	3,218	2	1.1	3.4	3.0	0.3	0.1	0.0
	Total	**150,000**		**1.2**	**181.5**	**158.8**	**15.1**	**6.7**	**0.7**
Community College	Classroom	150,825	50	1.2	181.0	160.2	15.2	5.2	0.5
	Computer Room	9,625	3	1.2	11.6	10.2	1.0	0.3	0.0
	Workshop	37,500	12	1.1	41.3	36.5	3.5	1.2	0.1
	Cafeteria	26,250	9	1.3	34.1	30.2	2.9	1.0	0.1
	Kitchen	5,625	2	1.6	9.0	8.0	0.8	0.3	0.0
	Office	70,175	23	1.1	73.7	65.2	6.2	2.1	0.2
	Total	**300,000**		**1.2**	**350.6**	**310.3**	**29.5**	**10.2**	**0.9**
Relocatable Classroom	Classroom	**1,920**	100	**1.2**	**2.3**	**0.2**	**0.0**	**0.0**	**0.0**

Table 36: DEER Equipment Power (Before 1978)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.2	1.2	1.4	43.5
	Cafeteria	7,500	15	0.6	1.2	0.7	5.2
	Gymnasium	7,500	15	0.6	1.2	0.7	5.2
	Kitchen	3,500	7	1.7	1.2	2.1	7.2
	Total	**50,000**		**1.0**	1.2	**1.2**	**61.1**
Secondary School	Classroom	88,200	59	1.2	1.0	1.1	98.4
	Computer Room	3,082	2	5.8	1.0	5.6	17.2
	Cafeteria	22,500	15	0.6	1.0	0.6	12.5
	Gymnasium	22,500	15	0.6	1.0	0.6	12.5
	Kitchen	10,500	7	1.7	1.0	1.7	17.6
	Office	3,218	2	1.7	1.0	1.7	5.4
	Total	**150,000**		**1.1**	1.0	**1.1**	**163.6**
Community College	Classroom	150,825	50	1.2	1.3	1.4	216.8
	Computer Room	9,625	3	5.8	1.3	7.2	69.2
	Workshop	37,500	12	1.2	1.3	1.4	53.9
	Cafeteria	26,250	9	0.6	1.3	0.7	18.9
	Kitchen	5,625	2	1.7	1.3	2.2	12.1
	Office	70,175	23	1.7	1.3	2.2	151.3
	Total	**300,000**		**1.4**	1.3	**1.7**	**522.2**
Relocatable Classroom	Classroom	**1,920**	100	1.2	1.0	1.2	**2.2**

Table 37: DEER Equipment Power (1978 - 1992)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.1	1.2	1.3	41.6
	Cafeteria	7,500	15	0.6	1.2	0.7	5.0
	Gymnasium	7,500	15	0.6	1.2	0.7	5.0
	Kitchen	3,500	7	1.7	1.2	2.0	6.9
	Total	**50,000**		**1.0**	1.2	**1.2**	**58.4**
Secondary School	Classroom	88,200	59	1.1	1.0	1.1	94.1
	Computer Room	3,082	2	5.5	1.0	5.3	16.4
	Cafeteria	22,500	15	0.6	1.0	0.5	12.0
	Gymnasium	22,500	15	0.6	1.0	0.5	12.0
	Kitchen	10,500	7	1.7	1.0	1.6	16.8
	Office	3,218	2	1.7	1.0	1.6	5.2
	Total	**150,000**		**1.1**	1.0	**1.0**	**156.5**
Community College	Classroom	150,825	50	1.1	1.3	1.4	207.4
	Computer Room	9,625	3	5.5	1.3	6.9	66.2
	Workshop	37,500	12	1.1	1.3	1.4	51.6
	Cafeteria	26,250	9	0.6	1.3	0.7	18.0
	Kitchen	5,625	2	1.7	1.3	2.1	11.6
	Office	70,175	23	1.7	1.3	2.1	144.7
	Total	**300,000**		**1.3**	1.3	**1.7**	**499.5**
Relocatable Classroom	Classroom	**1,920**	100	1.1	1.0	1.1	**2.1**

Table 38: DEER Equipment Power (1993 - 2001)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.1	1.2	1.3	39.7
	Cafeteria	7,500	15	0.5	1.2	0.6	4.7
	Gymnasium	7,500	15	0.5	1.2	0.6	4.7
	Kitchen	3,500	7	1.6	1.2	1.9	6.6
	Total	**50,000**		**0.9**	1.2	**1.1**	**55.8**
Secondary School	Classroom	88,200	59	1.1	1.0	1.0	89.8
	Computer Room	3,082	2	5.3	1.0	5.1	15.7
	Cafeteria	22,500	15	0.5	1.0	0.5	11.5
	Gymnasium	22,500	15	0.5	1.0	0.5	11.5
	Kitchen	10,500	7	1.6	1.0	1.5	16.0
	Office	3,218	2	1.6	1.0	1.5	4.9
	Total	**150,000**		**1.0**	1.0	**1.0**	**149.4**
Community College	Classroom	150,825	50	1.1	1.3	1.3	198.0
	Computer Room	9,625	3	5.3	1.3	6.6	63.2
	Workshop	37,500	12	1.1	1.3	1.3	49.2
	Cafeteria	26,250	9	0.5	1.3	0.7	17.2
	Kitchen	5,625	2	1.6	1.3	2.0	11.1
	Office	70,175	23	1.6	1.3	2.0	138.2
	Total	**300,000**		**1.3**	1.3	**1.6**	**476.8**
Relocatable Classroom	Classroom	**1,920**	100	1.1	1.0	1.1	**2.0**

Table 39: DEER Equipment Power (2002 - 2005)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.0	1.2	1.2	37.8
	Cafeteria	7,500	15	0.5	1.2	0.6	4.5
	Gymnasium	7,500	15	0.5	1.2	0.6	4.5
	Kitchen	3,500	7	1.5	1.2	1.8	6.3
	Total	**50,000**		**0.9**	1.2	**1.1**	**53.1**
Secondary School	Classroom	88,200	59	1.0	1.0	1.0	85.6
	Computer Room	3,082	2	5.0	1.0	4.9	14.9
	Cafeteria	22,500	15	0.5	1.0	0.5	10.9
	Gymnasium	22,500	15	0.5	1.0	0.5	10.9
	Kitchen	10,500	7	1.5	1.0	1.5	15.3
	Office	3,218	2	1.5	1.0	1.5	4.7
	Total	**150,000**		**1.0**	1.0	**0.9**	**142.3**
Community College	Classroom	150,825	50	1.0	1.3	1.3	188.5
	Computer Room	9,625	3	5.0	1.3	6.3	60.2
	Workshop	37,500	12	1.0	1.3	1.3	46.9
	Cafeteria	26,250	9	0.5	1.3	0.6	16.4
	Kitchen	5,625	2	1.5	1.3	1.9	10.5
	Office	70,175	23	1.5	1.3	1.9	131.6
	Total	**300,000**		**1.2**	1.3	**1.5**	**454.1**
Relocatable Classroom	Classroom	**1,920**	100	1.0	1.0	1.0	**1.9**

Table 40: DEER Equipment Power (2006 - 2009)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.0	1.2	1.2	36.2
	Cafeteria	7,500	15	0.5	1.2	0.6	4.3
	Gymnasium	7,500	15	0.5	1.2	0.6	4.3
	Kitchen	3,500	7	1.5	1.2	1.7	6.0
	Total	**50,000**		**0.9**	1.2	**1.0**	**50.9**
Secondary School	Classroom	88,200	59	1.0	0.9	0.9	81.1
	Computer Room	3,082	2	5.0	0.9	4.6	14.2
	Cafeteria	22,500	15	0.5	0.9	0.5	10.4
	Gymnasium	22,500	15	0.5	0.9	0.5	10.4
	Kitchen	10,500	7	1.5	0.9	1.4	14.5
	Office	3,218	2	1.5	0.9	1.4	4.4
	Total	**150,000**		**1.0**	0.9	**0.9**	**135.0**
Community College	Classroom	150,825	50	1.0	1.2	1.2	181.0
	Computer Room	9,625	3	5.0	1.2	6.0	57.8
	Workshop	37,500	12	1.0	1.2	1.2	45.0
	Cafeteria	26,250	9	0.5	1.2	0.6	15.8
	Kitchen	5,625	2	1.5	1.2	1.8	10.1
	Office	70,175	23	1.5	1.2	1.8	126.3
	Total	**300,000**		**1.2**	1.2	**1.5**	**435.9**
Relocatable Classroom	Classroom	**1,920**	100	1.0	1.0	1.0	**1.9**

Table 41: DEER Equipment Power (2010 - 2013)

Building Type	Activity Areas	Area	% Area	Overall Power Density (W/ft2)	Adjustment Factor	Adjusted Overall Power Density (W/ft2)	Total Power (kW)
Primary School	Classroom	31,500	63	1.0	1.2	1.2	36.2
	Cafeteria	7,500	15	0.5	1.2	0.6	4.3
	Gymnasium	7,500	15	0.5	1.2	0.6	4.3
	Kitchen	3,500	7	1.5	1.2	1.7	6.0
	Total	**50,000**		**0.9**	1.2	**1.0**	**50.9**
Secondary School	Classroom	88,200	59	1.0	0.9	0.9	81.1
	Computer Room	3,082	2	5.0	0.9	4.6	14.2
	Cafeteria	22,500	15	0.5	0.9	0.5	10.4
	Gymnasium	22,500	15	0.5	0.9	0.5	10.4
	Kitchen	10,500	7	1.5	0.9	1.4	14.5
	Office	3,218	2	1.5	0.9	1.4	4.4
	Total	**150,000**		**1.0**	0.9	**0.9**	**135.0**
Community College	Classroom	150,825	50	1.0	1.2	1.2	181.0
	Computer Room	9,625	3	5.0	1.2	6.0	57.8
	Workshop	37,500	12	1.0	1.2	1.2	45.0
	Cafeteria	26,250	9	0.5	1.2	0.6	15.8
	Kitchen	5,625	2	1.5	1.2	1.8	10.1
	Office	70,175	23	1.5	1.2	1.8	126.3
	Total	**300,000**		**1.2**	1.2	**1.5**	**435.9**
Relocatable Classroom	Classroom	**1,920**	100	1.0	1.0	1.0	**1.9**

Table 42: DEER HVAC Characteristics

Building Type	Total Area	Vintage (years)	Area Served (sqft)	Area Served (descrip)	System Type (type)	Cooling Type (type)	# Chlrs	Heating Type (type)
Primary School	50,000	Before 1978	50,000	all	Rooftop Gas Pack	DX	n/a	Gas Furnace
		1978 - 1992	50,000		Rooftop Gas Pack	DX	n/a	Gas Furnace
		1993 - 2001	50,000		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2002 - 2005	50,000		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2006 - 2009	50,000		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2010 - 2012	50,000		Rooftop Gas Pack	DX	n/a	Gas Furnace
Secondary School	150,000	Before 1978	115,270	class/admin	Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		1978 - 1992	115,270		Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		1993 - 2001	115,270		Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		2002 - 2005	115,270		Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		2006 - 2009	115,270		Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		2010 - 2012	115,270		Pack VAV-reheat	A/C Recip Chiller	2	Boiler
		Before 1978	34,730	kitch/gym/comp	Rooftop Gas Pack	DX	n/a	Gas Furnace
		1978 - 1992	34,730		Rooftop Gas Pack	DX	n/a	Gas Furnace
		1993 - 2001	34,730		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2002 - 2005	34,730		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2006 - 2009	34,730		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2010 - 2012	34,730		Rooftop Gas Pack	DX	n/a	Gas Furnace
Community College	300,000	Before 1978	287,780	class/admin	Blt-Up VAV-reheat	W/C Cent Chiller	2	Boiler
		1978 - 1992	287,780		Blt-Up VAV-reheat	W/C Cent Chiller	2	Boiler
		1993 - 2001	287,780		Blt-Up VAV-reheat	W/C Cent Chiller	2	Boiler
		2002 - 2005	287,780		Blt-Up VAV-reheat	W/C Cent Chiller	3	Boiler
		2006 - 2009	287,780		Blt-Up VAV-reheat	W/C Cent Chiller	3	Boiler
		2010 - 2012	287,780		Blt-Up VAV-reheat	W/C Cent Chiller	3	Boiler
		Before 1978	12,220	kitch/comp	Rooftop Gas Pack	DX	n/a	Gas Furnace
		1978 - 1992	12,220		Rooftop Gas Pack	DX	n/a	Gas Furnace
		1993 - 2001	12,220		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2002 - 2005	12,220		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2006 - 2009	12,220		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2010 - 2012	12,220		Rooftop Gas Pack	DX	n/a	Gas Furnace
Relocatable Classroom	1,920	Before 1978	1,920	all	Rooftop Gas Pack	DX	n/a	Gas Furnace
		1978 - 1992	1,920		Rooftop Gas Pack	DX	n/a	Gas Furnace
		1993 - 2001	1,920		Rooftop Gas Pack	DX	n/a	Gas Furnace
		2002 - 2005	1,920		Rooftop Gas Pack	DX	n/a	Gas Furnace

	2006 - 2009	1,920	Rooftop Gas Pack	DX	n/a	Gas Furnace
	2010 - 2012	1,920	Rooftop Gas Pack	DX	n/a	Gas Furnace

Building Type	Vintage (years)	Area Served (sqft)	Area Served (descrip)	Economizer (type)	Cool Reset (y/n)	Heat Reset (y/n)	CHW Control Type (type)	HW Control Type (type)	Fan Control (type)	Design Duct DT (deltaT, F°)
Primary School	Before 1978	50,000	all	n/a	n/a	n/a	n/a	n/a	CV	3
	1978 - 1992	50,000		DB	n/a	n/a	n/a	n/a	CV	2
	1993 - 2001	50,000		DB	n/a	n/a	n/a	n/a	CV	1
	2002 - 2005	50,000		DB	n/a	n/a	n/a	n/a	CV	1
	2006 - 2009	50,000		DB	n/a	n/a	n/a	n/a	CV	1
	2010 - 2012	50,000		DB	n/a	n/a	n/a	n/a	CV	1
Secondary School	Before 1978	115,270	class/admin	n/a	no	no	Constant	Constant	CV	6
	1978 - 1992	115,270		DB	yes	yes	Constant	Constant	Inlet	4
	1993 - 2001	115,270		DB	yes	yes	Constant	Constant	Inlet	2
	2002 - 2005	115,270		DB	yes	yes	Constant	Constant	VSD	1
	2006 - 2009	115,270		DB	yes	yes	Variable w/ VSD	Variable w/ VSD	VSD	1
	2010 - 2012	115,270		DB	yes	yes	Variable w/ VSD	Variable w/ VSD	VSD	1
	Before 1978	34,730	kitch/gym/comp	n/a	n/a	n/a	n/a	n/a	CV	3
	1978 - 1992	34,730		DB	n/a	n/a	n/a	n/a	CV	2
	1993 - 2001	34,730		DB	n/a	n/a	n/a	n/a	CV	1
	2002 - 2005	34,730		DB	n/a	n/a	n/a	n/a	CV	1
	2006 - 2009	34,730		DB	n/a	n/a	n/a	n/a	CV	1
	2010 - 2012	34,730		DB	n/a	n/a	n/a	n/a	CV	1
Community College	Before 1978	287,780	class/admin	DB	no	no	Constant	Constant	CV	6
	1978 - 1992	287,780		DB	yes	yes	Constant	Constant	Inlet	4
	1993 - 2001	287,780		DB	yes	yes	Constant	Constant	Inlet	2
	2002 - 2005	287,780		DB	yes	yes	Constant	Constant	VSD	1
	2006 - 2009	287,780		DB	yes	yes	Variable w/ VSD	Variable w/ VSD	VSD	1
	2010 - 2012	287,780		DB	yes	yes	Variable w/ VSD	Variable w/ VSD	VSD	1
	Before 1978	12,220	kitch/comp	n/a	n/a	n/a	n/a	n/a	CV	3
	1978 - 1992	12,220		DB	n/a	n/a	n/a	n/a	CV	2
	1993 - 2001	12,220		DB	n/a	n/a	n/a	n/a	CV	1
	2002 - 2005	12,220		DB	n/a	n/a	n/a	n/a	CV	1
	2006 - 2009	12,220		DB	n/a	n/a	n/a	n/a	CV	1
	2010 - 2012	12,220		DB	n/a	n/a	n/a	n/a	CV	1
Relocatable Classroom	Before 1978	1,920	all	n/a	n/a	n/a	n/a	n/a	CV	3
	1978 - 1992	1,920		n/a	n/a	n/a	n/a	n/a	CV	2

	1993 - 2001	1,920		n/a	n/a	n/a	n/a	n/a	CV	1
	2002 - 2005	1,920		n/a	n/a	n/a	n/a	n/a	CV	1
	2006 - 2009	1,920		n/a	n/a	n/a	n/a	n/a	CV	1
	2010 - 2012	1,920		n/a	n/a	n/a	n/a	n/a	CV	1

Abbreviations:

- Rooftop Gas Pack: Packaged rooftop direct expansion cooling system with natural gas heating. Serves a single thermal zone.
- Blt-Up VAV-reheat: Built-up chilled water cooling system. A single duct distribution system serves multiple zones. Each zone has a standard variable air volume terminal unit with hot water reheat. The fan variable flow method varies by vintage. Chilled water is supplied by a water-cooled centrifugal or air-cooled reciprocating chiller.
- Pack VAV-reheat: Packaged, rooftop, direct expansion cooling system. A single duct distribution system serves multiple zones. Each zone has a standard variable air volume terminal unit with hot water reheat. The fan variable flow method varies by vintage.
- W/C Cent Chiller: Water cooled centrifugal chiller.
- A/C Recip Chiller: Air cooled reciprocating chiller.
- DX: Direct expansion.
- CV: Constant volume fan.
- Inlet: Inlet damper.
- VSD: Fan equipped with a variable speed drive.

Table 43: DEER Weights

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Primary School	Before 1978	0.6301	0.0028	0.0018
Primary School	1978 - 1992	0.1647	0.0047	0.0005
Primary School	1993 - 2001	0.0847	0.0023	0.0002
Primary School	2002 - 2005	0.069	0.0023	0.0002
Primary School	2006-2009	0.0258	0.003	0.0001
Primary School	2010-2013	0.0258	0.003	0.0001
Secondary School	Before 1978	0.6301	0.0028	0.0018
Secondary School	1978 - 1992	0.1647	0.0047	0.0005
Secondary School	1993 - 2001	0.0847	0.0023	0.0002
Secondary School	2002 - 2005	0.069	0.0023	0.0002
Secondary School	2006-2009	0.0258	0.003	0.0001
Secondary School	2010-2013	0.0258	0.003	0.0001
Community College	Before 1978	0.7375	0.0112	0.0062
Community College	1978 - 1992	0.1342	0.0067	0.0011
Community College	1993 - 2001	0.0676	0.0049	0.0006
Community College	2002 - 2005	0.0245	0.0022	0.0002
Community College	2006-2009	0.0181	0.0041	0.0002
Community College	2010-2013	0.0181	0.0041	0.0002
Relocatable Classroom	Before 1978	0.6301	0.0028	0.0018
Relocatable Classroom	1978 - 1992	0.1647	0.0047	0.0005
Relocatable Classroom	1993 - 2001	0.0847	0.0023	0.0002
Relocatable Classroom	2002 - 2005	0.069	0.0023	0.0002
Relocatable Classroom	2006-2009	0.0258	0.003	0.0001
Relocatable Classroom	2010-2013	0.0258	0.003	0.0001
Primary School	Before 1978	0.7018	0.0233	0.0152
Primary School	1978 - 1992	0.0892	0.019	0.0019
Primary School	1993 - 2001	0.1016	0.0205	0.0022
Primary School	2002 - 2005	0.0659	0.0166	0.0014

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Primary School	2006-2009	0.0207	0.018	0.0004
Primary School	2010-2013	0.0207	0.018	0.0004
Secondary School	Before 1978	0.7018	0.0233	0.0152
Secondary School	1978 - 1992	0.0892	0.019	0.0019
Secondary School	1993 - 2001	0.1016	0.0205	0.0022
Secondary School	2002 - 2005	0.0659	0.0166	0.0014
Secondary School	2006-2009	0.0207	0.018	0.0004
Secondary School	2010-2013	0.0207	0.018	0.0004
Community College	Before 1978	0.6171	0.0245	0.0135
Community College	1978 - 1992	0.1482	0.0195	0.0032
Community College	1993 - 2001	0.0858	0.0162	0.0019
Community College	2002 - 2005	0.0838	0.0201	0.0018
Community College	2006-2009	0.0326	0.0193	0.0007
Community College	2010-2013	0.0326	0.0193	0.0007
Relocatable Classroom	Before 1978	0.7018	0.0233	0.0152
Relocatable Classroom	1978 - 1992	0.0892	0.019	0.0019
Relocatable Classroom	1993 - 2001	0.1016	0.0205	0.0022
Relocatable Classroom	2002 - 2005	0.0659	0.0166	0.0014
Relocatable Classroom	2006-2009	0.0207	0.018	0.0004
Relocatable Classroom	2010-2013	0.0207	0.018	0.0004
Primary School	Before 1978	0.7781	0.099	0.0647
Primary School	1978 - 1992	0.057	0.0465	0.0047
Primary School	1993 - 2001	0.0831	0.064	0.0069
Primary School	2002 - 2005	0.0495	0.0476	0.0041
Primary School	2006-2009	0.0162	0.0539	0.0013
Primary School	2010-2013	0.0162	0.0539	0.0013
Secondary School	Before 1978	0.7781	0.099	0.0647
Secondary School	1978 - 1992	0.057	0.0465	0.0047
Secondary School	1993 - 2001	0.0831	0.064	0.0069
Secondary School	2002 - 2005	0.0495	0.0476	0.0041

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Secondary School	2006-2009	0.0162	0.0539	0.0013
Secondary School	2010-2013	0.0162	0.0539	0.0013
Community College	Before 1978	0.6743	0.134	0.074
Community College	1978 - 1992	0.115	0.0757	0.0126
Community College	1993 - 2001	0.09	0.0851	0.0099
Community College	2002 - 2005	0.071	0.0854	0.0078
Community College	2006-2009	0.0248	0.0735	0.0027
Community College	2010-2013	0.0248	0.0735	0.0027
Relocatable Classroom	Before 1978	0.7781	0.099	0.0647
Relocatable Classroom	1978 - 1992	0.057	0.0465	0.0047
Relocatable Classroom	1993 - 2001	0.0831	0.064	0.0069
Relocatable Classroom	2002 - 2005	0.0495	0.0476	0.0041
Relocatable Classroom	2006-2009	0.0162	0.0539	0.0013
Relocatable Classroom	2010-2013	0.0162	0.0539	0.0013
Primary School	Before 1978	0.6867	0.0446	0.0291
Primary School	1978 - 1992	0.0823	0.0343	0.0035
Primary School	1993 - 2001	0.1155	0.0454	0.0049
Primary School	2002 - 2005	0.0728	0.0358	0.0031
Primary School	2006-2009	0.0214	0.0363	0.0009
Primary School	2010-2013	0.0214	0.0363	0.0009
Secondary School	Before 1978	0.6867	0.0446	0.0291
Secondary School	1978 - 1992	0.0823	0.0343	0.0035
Secondary School	1993 - 2001	0.1155	0.0454	0.0049
Secondary School	2002 - 2005	0.0728	0.0358	0.0031
Secondary School	2006-2009	0.0214	0.0363	0.0009
Secondary School	2010-2013	0.0214	0.0363	0.0009
Community College	Before 1978	0.5956	0.0294	0.0162
Community College	1978 - 1992	0.1543	0.0252	0.0042
Community College	1993 - 2001	0.0873	0.0205	0.0024
Community College	2002 - 2005	0.0923	0.0275	0.0025

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Community College	2006-2009	0.0353	0.0259	0.001
Community College	2010-2013	0.0353	0.0259	0.001
Relocatable Classroom	Before 1978	0.6867	0.0446	0.0291
Relocatable Classroom	1978 - 1992	0.0823	0.0343	0.0035
Relocatable Classroom	1993 - 2001	0.1155	0.0454	0.0049
Relocatable Classroom	2002 - 2005	0.0728	0.0358	0.0031
Relocatable Classroom	2006-2009	0.0214	0.0363	0.0009
Relocatable Classroom	2010-2013	0.0214	0.0363	0.0009
Primary School	Before 1978	0.6913	0.0068	0.0045
Primary School	1978 - 1992	0.0829	0.0052	0.0005
Primary School	1993 - 2001	0.1122	0.0067	0.0007
Primary School	2002 - 2005	0.0716	0.0053	0.0005
Primary School	2006-2009	0.021	0.0054	0.0001
Primary School	2010-2013	0.021	0.0054	0.0001
Secondary School	Before 1978	0.6913	0.0068	0.0045
Secondary School	1978 - 1992	0.0829	0.0052	0.0005
Secondary School	1993 - 2001	0.1122	0.0067	0.0007
Secondary School	2002 - 2005	0.0716	0.0053	0.0005
Secondary School	2006-2009	0.021	0.0054	0.0001
Secondary School	2010-2013	0.021	0.0054	0.0001
Community College	Before 1978	0.5953	0.0223	0.0123
Community College	1978 - 1992	0.1545	0.0192	0.0032
Community College	1993 - 2001	0.0875	0.0156	0.0018
Community College	2002 - 2005	0.0921	0.0209	0.0019
Community College	2006-2009	0.0353	0.0197	0.0007
Community College	2010-2013	0.0353	0.0197	0.0007
Relocatable Classroom	Before 1978	0.6913	0.0068	0.0045
Relocatable Classroom	1978 - 1992	0.0829	0.0052	0.0005
Relocatable Classroom	1993 - 2001	0.1122	0.0067	0.0007
Relocatable Classroom	2002 - 2005	0.0716	0.0053	0.0005

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Relocatable Classroom	2006-2009	0.021	0.0054	0.0001
Relocatable Classroom	2010-2013	0.021	0.0054	0.0001
Primary School	Before 1978	0.7502	0.1291	0.0844
Primary School	1978 - 1992	0.0839	0.0927	0.0094
Primary School	1993 - 2001	0.0741	0.0773	0.0083
Primary School	2002 - 2005	0.0578	0.0752	0.0065
Primary School	2006-2009	0.017	0.0767	0.0019
Primary School	2010-2013	0.017	0.0767	0.0019
Secondary School	Before 1978	0.7502	0.1291	0.0844
Secondary School	1978 - 1992	0.0839	0.0927	0.0094
Secondary School	1993 - 2001	0.0741	0.0773	0.0083
Secondary School	2002 - 2005	0.0578	0.0752	0.0065
Secondary School	2006-2009	0.017	0.0767	0.0019
Secondary School	2010-2013	0.017	0.0767	0.0019
Community College	Before 1978	0.5633	0.139	0.0767
Community College	1978 - 1992	0.1798	0.1469	0.0245
Community College	1993 - 2001	0.1221	0.1432	0.0166
Community College	2002 - 2005	0.0716	0.1068	0.0097
Community College	2006-2009	0.0316	0.1163	0.0043
Community College	2010-2013	0.0316	0.1163	0.0043
Relocatable Classroom	Before 1978	0.7502	0.1291	0.0844
Relocatable Classroom	1978 - 1992	0.0839	0.0927	0.0094
Relocatable Classroom	1993 - 2001	0.0741	0.0773	0.0083
Relocatable Classroom	2002 - 2005	0.0578	0.0752	0.0065
Relocatable Classroom	2006-2009	0.017	0.0767	0.0019
Relocatable Classroom	2010-2013	0.017	0.0767	0.0019
Primary School	Before 1978	0.553	0.0294	0.0192
Primary School	1978 - 1992	0.1435	0.0489	0.005
Primary School	1993 - 2001	0.1476	0.0475	0.0051
Primary School	2002 - 2005	0.1081	0.0435	0.0038

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Primary School	2006-2009	0.0239	0.0333	0.0008
Primary School	2010-2013	0.0239	0.0333	0.0008
Secondary School	Before 1978	0.553	0.0294	0.0192
Secondary School	1978 - 1992	0.1435	0.0489	0.005
Secondary School	1993 - 2001	0.1476	0.0475	0.0051
Secondary School	2002 - 2005	0.1081	0.0435	0.0038
Secondary School	2006-2009	0.0239	0.0333	0.0008
Secondary School	2010-2013	0.0239	0.0333	0.0008
Community College	Before 1978	0.3262	0.0311	0.0171
Community College	1978 - 1992	0.2842	0.0896	0.0149
Community College	1993 - 2001	0.1616	0.0732	0.0085
Community College	2002 - 2005	0.1428	0.0823	0.0075
Community College	2006-2009	0.0426	0.0605	0.0022
Community College	2010-2013	0.0426	0.0605	0.0022
Relocatable Classroom	Before 1978	0.553	0.0294	0.0192
Relocatable Classroom	1978 - 1992	0.1435	0.0489	0.005
Relocatable Classroom	1993 - 2001	0.1476	0.0475	0.0051
Relocatable Classroom	2002 - 2005	0.1081	0.0435	0.0038
Relocatable Classroom	2006-2009	0.0239	0.0333	0.0008
Relocatable Classroom	2010-2013	0.0239	0.0333	0.0008
Primary School	Before 1978	0.75	0.2247	0.1469
Primary School	1978 - 1992	0.0827	0.159	0.0162
Primary School	1993 - 2001	0.0735	0.1335	0.0144
Primary School	2002 - 2005	0.0594	0.1346	0.0116
Primary School	2006-2009	0.0172	0.135	0.0034
Primary School	2010-2013	0.0172	0.135	0.0034
Secondary School	Before 1978	0.75	0.2247	0.1469
Secondary School	1978 - 1992	0.0827	0.159	0.0162
Secondary School	1993 - 2001	0.0735	0.1335	0.0144
Secondary School	2002 - 2005	0.0594	0.1346	0.0116

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Secondary School	2006-2009	0.0172	0.135	0.0034
Secondary School	2010-2013	0.0172	0.135	0.0034
Community College	Before 1978	0.5712	0.2319	0.128
Community College	1978 - 1992	0.1791	0.2408	0.0402
Community College	1993 - 2001	0.1188	0.2295	0.0266
Community College	2002 - 2005	0.0694	0.1705	0.0155
Community College	2006-2009	0.0308	0.1865	0.0069
Community College	2010-2013	0.0308	0.1865	0.0069
Relocatable Classroom	Before 1978	0.75	0.2247	0.1469
Relocatable Classroom	1978 - 1992	0.0827	0.159	0.0162
Relocatable Classroom	1993 - 2001	0.0735	0.1335	0.0144
Relocatable Classroom	2002 - 2005	0.0594	0.1346	0.0116
Relocatable Classroom	2006-2009	0.0172	0.135	0.0034
Relocatable Classroom	2010-2013	0.0172	0.135	0.0034
Primary School	Before 1978	0.763	0.1676	0.1096
Primary School	1978 - 1992	0.0696	0.0981	0.01
Primary School	1993 - 2001	0.0673	0.0896	0.0097
Primary School	2002 - 2005	0.0667	0.1109	0.0096
Primary School	2006-2009	0.0167	0.0962	0.0024
Primary School	2010-2013	0.0167	0.0962	0.0024
Secondary School	Before 1978	0.763	0.1676	0.1096
Secondary School	1978 - 1992	0.0696	0.0981	0.01
Secondary School	1993 - 2001	0.0673	0.0896	0.0097
Secondary School	2002 - 2005	0.0667	0.1109	0.0096
Secondary School	2006-2009	0.0167	0.0962	0.0024
Secondary School	2010-2013	0.0167	0.0962	0.0024
Community College	Before 1978	0.6746	0.153	0.0844
Community College	1978 - 1992	0.1174	0.0882	0.0147
Community College	1993 - 2001	0.0984	0.1062	0.0123
Community College	2002 - 2005	0.0603	0.0827	0.0075

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Community College	2006-2009	0.0246	0.0833	0.0031
Community College	2010-2013	0.0246	0.0833	0.0031
Relocatable Classroom	Before 1978	0.763	0.1676	0.1096
Relocatable Classroom	1978 - 1992	0.0696	0.0981	0.01
Relocatable Classroom	1993 - 2001	0.0673	0.0896	0.0097
Relocatable Classroom	2002 - 2005	0.0667	0.1109	0.0096
Relocatable Classroom	2006-2009	0.0167	0.0962	0.0024
Relocatable Classroom	2010-2013	0.0167	0.0962	0.0024
Primary School	Before 1978	0.4268	0.0907	0.0593
Primary School	1978 - 1992	0.1692	0.2306	0.0235
Primary School	1993 - 2001	0.1719	0.2213	0.0239
Primary School	2002 - 2005	0.1547	0.2488	0.0215
Primary School	2006-2009	0.0387	0.2152	0.0054
Primary School	2010-2013	0.0387	0.2152	0.0054
Secondary School	Before 1978	0.4268	0.0907	0.0593
Secondary School	1978 - 1992	0.1692	0.2306	0.0235
Secondary School	1993 - 2001	0.1719	0.2213	0.0239
Secondary School	2002 - 2005	0.1547	0.2488	0.0215
Secondary School	2006-2009	0.0387	0.2152	0.0054
Secondary School	2010-2013	0.0387	0.2152	0.0054
Community College	Before 1978	0.3443	0.0479	0.0264
Community College	1978 - 1992	0.2277	0.1049	0.0175
Community College	1993 - 2001	0.1502	0.0994	0.0115
Community College	2002 - 2005	0.1554	0.1309	0.0119
Community College	2006-2009	0.0612	0.1271	0.0047
Community College	2010-2013	0.0612	0.1271	0.0047
Relocatable Classroom	Before 1978	0.4268	0.0907	0.0593
Relocatable Classroom	1978 - 1992	0.1692	0.2306	0.0235
Relocatable Classroom	1993 - 2001	0.1719	0.2213	0.0239
Relocatable Classroom	2002 - 2005	0.1547	0.2488	0.0215

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Relocatable Classroom	2006-2009	0.0387	0.2152	0.0054
Relocatable Classroom	2010-2013	0.0387	0.2152	0.0054
Primary School	Before 1978	0.5549	0.0158	0.0103
Primary School	1978 - 1992	0.1217	0.0223	0.0023
Primary School	1993 - 2001	0.1365	0.0236	0.0025
Primary School	2002 - 2005	0.1066	0.023	0.002
Primary School	2006-2009	0.0401	0.0299	0.0007
Primary School	2010-2013	0.0401	0.0299	0.0007
Secondary School	Before 1978	0.5549	0.0158	0.0103
Secondary School	1978 - 1992	0.1217	0.0223	0.0023
Secondary School	1993 - 2001	0.1365	0.0236	0.0025
Secondary School	2002 - 2005	0.1066	0.023	0.002
Secondary School	2006-2009	0.0401	0.0299	0.0007
Secondary School	2010-2013	0.0401	0.0299	0.0007
Community College	Before 1978	0.6176	0.03	0.0166
Community College	1978 - 1992	0.0997	0.016	0.0027
Community College	1993 - 2001	0.1022	0.0236	0.0027
Community College	2002 - 2005	0.0982	0.0289	0.0026
Community College	2006-2009	0.0411	0.0298	0.0011
Community College	2010-2013	0.0411	0.0298	0.0011
Relocatable Classroom	Before 1978	0.5549	0.0158	0.0103
Relocatable Classroom	1978 - 1992	0.1217	0.0223	0.0023
Relocatable Classroom	1993 - 2001	0.1365	0.0236	0.0025
Relocatable Classroom	2002 - 2005	0.1066	0.023	0.002
Relocatable Classroom	2006-2009	0.0401	0.0299	0.0007
Relocatable Classroom	2010-2013	0.0401	0.0299	0.0007
Primary School	Before 1978	0.6006	0.06	0.0393
Primary School	1978 - 1992	0.1014	0.065	0.0066
Primary School	1993 - 2001	0.1204	0.0729	0.0079
Primary School	2002 - 2005	0.1072	0.0811	0.007

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Primary School	2006-2009	0.0352	0.092	0.0023
Primary School	2010-2013	0.0352	0.092	0.0023
Secondary School	Before 1978	0.6006	0.06	0.0393
Secondary School	1978 - 1992	0.1014	0.065	0.0066
Secondary School	1993 - 2001	0.1204	0.0729	0.0079
Secondary School	2002 - 2005	0.1072	0.0811	0.007
Secondary School	2006-2009	0.0352	0.092	0.0023
Secondary School	2010-2013	0.0352	0.092	0.0023
Community College	Before 1978	0.6036	0.0417	0.023
Community College	1978 - 1992	0.1214	0.0278	0.0046
Community College	1993 - 2001	0.0967	0.0318	0.0037
Community College	2002 - 2005	0.0993	0.0415	0.0038
Community College	2006-2009	0.0395	0.0408	0.0015
Community College	2010-2013	0.0395	0.0408	0.0015
Relocatable Classroom	Before 1978	0.6006	0.06	0.0393
Relocatable Classroom	1978 - 1992	0.1014	0.065	0.0066
Relocatable Classroom	1993 - 2001	0.1204	0.0729	0.0079
Relocatable Classroom	2002 - 2005	0.1072	0.0811	0.007
Relocatable Classroom	2006-2009	0.0352	0.092	0.0023
Relocatable Classroom	2010-2013	0.0352	0.092	0.0023
Primary School	Before 1978	0.5547	0.0628	0.041
Primary School	1978 - 1992	0.1165	0.0846	0.0086
Primary School	1993 - 2001	0.1593	0.1093	0.0118
Primary School	2002 - 2005	0.0916	0.0785	0.0068
Primary School	2006-2009	0.0389	0.1154	0.0029
Primary School	2010-2013	0.0389	0.1154	0.0029
Secondary School	Before 1978	0.5547	0.0628	0.041
Secondary School	1978 - 1992	0.1165	0.0846	0.0086
Secondary School	1993 - 2001	0.1593	0.1093	0.0118
Secondary School	2002 - 2005	0.0916	0.0785	0.0068

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Secondary School	2006-2009	0.0389	0.1154	0.0029
Secondary School	2010-2013	0.0389	0.1154	0.0029
Community College	Before 1978	0.5482	0.0527	0.0291
Community College	1978 - 1992	0.1255	0.04	0.0067
Community College	1993 - 2001	0.1113	0.0509	0.0059
Community College	2002 - 2005	0.1124	0.0655	0.006
Community College	2006-2009	0.0513	0.0736	0.0027
Community College	2010-2013	0.0513	0.0736	0.0027
Relocatable Classroom	Before 1978	0.5547	0.0628	0.041
Relocatable Classroom	1978 - 1992	0.1165	0.0846	0.0086
Relocatable Classroom	1993 - 2001	0.1593	0.1093	0.0118
Relocatable Classroom	2002 - 2005	0.0916	0.0785	0.0068
Relocatable Classroom	2006-2009	0.0389	0.1154	0.0029
Relocatable Classroom	2010-2013	0.0389	0.1154	0.0029
Primary School	Before 1978	0.4978	0.024	0.0157
Primary School	1978 - 1992	0.146	0.0452	0.0046
Primary School	1993 - 2001	0.1487	0.0435	0.0047
Primary School	2002 - 2005	0.1365	0.0499	0.0043
Primary School	2006-2009	0.0355	0.0448	0.0011
Primary School	2010-2013	0.0355	0.0448	0.0011
Secondary School	Before 1978	0.4978	0.024	0.0157
Secondary School	1978 - 1992	0.146	0.0452	0.0046
Secondary School	1993 - 2001	0.1487	0.0435	0.0047
Secondary School	2002 - 2005	0.1365	0.0499	0.0043
Secondary School	2006-2009	0.0355	0.0448	0.0011
Secondary School	2010-2013	0.0355	0.0448	0.0011
Community College	Before 1978	0.3677	0.0144	0.0079
Community College	1978 - 1992	0.2092	0.027	0.0045
Community College	1993 - 2001	0.1476	0.0274	0.0032
Community College	2002 - 2005	0.1503	0.0355	0.0032

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Community College	2006-2009	0.0626	0.0365	0.0013
Community College	2010-2013	0.0626	0.0365	0.0013
Relocatable Classroom	Before 1978	0.4978	0.024	0.0157
Relocatable Classroom	1978 - 1992	0.146	0.0452	0.0046
Relocatable Classroom	1993 - 2001	0.1487	0.0435	0.0047
Relocatable Classroom	2002 - 2005	0.1365	0.0499	0.0043
Relocatable Classroom	2006-2009	0.0355	0.0448	0.0011
Relocatable Classroom	2010-2013	0.0355	0.0448	0.0011
Primary School	Before 1978	0.4073	0.0067	0.0044
Primary School	1978 - 1992	0.1731	0.0182	0.0019
Primary School	1993 - 2001	0.1757	0.0175	0.0019
Primary School	2002 - 2005	0.1619	0.0201	0.0017
Primary School	2006-2009	0.041	0.0176	0.0004
Primary School	2010-2013	0.041	0.0176	0.0004
Secondary School	Before 1978	0.4073	0.0067	0.0044
Secondary School	1978 - 1992	0.1731	0.0182	0.0019
Secondary School	1993 - 2001	0.1757	0.0175	0.0019
Secondary School	2002 - 2005	0.1619	0.0201	0.0017
Secondary School	2006-2009	0.041	0.0176	0.0004
Secondary School	2010-2013	0.041	0.0176	0.0004
Community College	Before 1978	0.3493	0.0111	0.0061
Community College	1978 - 1992	0.2122	0.0223	0.0037
Community College	1993 - 2001	0.147	0.0222	0.0026
Community College	2002 - 2005	0.1588	0.0305	0.0028
Community College	2006-2009	0.0663	0.0314	0.0012
Community College	2010-2013	0.0663	0.0314	0.0012
Relocatable Classroom	Before 1978	0.4073	0.0067	0.0044
Relocatable Classroom	1978 - 1992	0.1731	0.0182	0.0019
Relocatable Classroom	1993 - 2001	0.1757	0.0175	0.0019
Relocatable Classroom	2002 - 2005	0.1619	0.0201	0.0017

Building Type	Vintage	Vintage Weights	Climate Zone Weights	Combined Climate Zone and Vintage Weights
Relocatable Classroom	2006-2009	0.041	0.0176	0.0004
Relocatable Classroom	2010-2013	0.041	0.0176	0.0004
Primary School	Before 1978	0.4791	0.0127	0.0083
Primary School	1978 - 1992	0.1513	0.0257	0.0026
Primary School	1993 - 2001	0.1568	0.0252	0.0027
Primary School	2002 - 2005	0.1341	0.0269	0.0023
Primary School	2006-2009	0.0394	0.0273	0.0007
Primary School	2010-2013	0.0394	0.0273	0.0007
Secondary School	Before 1978	0.4791	0.0127	0.0083
Secondary School	1978 - 1992	0.1513	0.0257	0.0026
Secondary School	1993 - 2001	0.1568	0.0252	0.0027
Secondary School	2002 - 2005	0.1341	0.0269	0.0023
Secondary School	2006-2009	0.0394	0.0273	0.0007
Secondary School	2010-2013	0.0394	0.0273	0.0007
Community College	Before 1978	0.357	0.0259	0.0143
Community College	1978 - 1992	0.2089	0.0501	0.0084
Community College	1993 - 2001	0.1456	0.0502	0.0058
Community College	2002 - 2005	0.1561	0.0685	0.0062
Community College	2006-2009	0.0662	0.0716	0.0027
Community College	2010-2013	0.0662	0.0716	0.0027
Relocatable Classroom	Before 1978	0.4791	0.0127	0.0083
Relocatable Classroom	1978 - 1992	0.1513	0.0257	0.0026
Relocatable Classroom	1993 - 2001	0.1568	0.0252	0.0027
Relocatable Classroom	2002 - 2005	0.1341	0.0269	0.0023
Relocatable Classroom	2006-2009	0.0394	0.0273	0.0007
Relocatable Classroom	2010-2013	0.0394	0.0273	0.0007

Table 44: Lighting Power Density: CSS vs DEER

	Commercial Saturation Survey (CSS) Weighted Findings				Overall LPDs						
Building Type	Activity Area	Weighted Area (ft2)	% Total Weighted area	DEER Activity Area	CSS	DEER (Before 1978)	DEER (1978 - 1992)	DEER (1993 - 2001)	DEER (2002 - 2005)	DEER (2006 - 2009)	DEER (2010 - 2013)
Community College	Classroom/Lecture	1,194,674	13%	Classroom	0.59	1.60	1.60	1.60	1.20	1.20	1.20
	Office (General)	1,525,728	16%	Office	1.13	1.30	1.30	1.30	1.30	1.30	1.10
	Office (Executive/Private)	1,483,248	16%	Office	0.59	1.30	1.30	1.30	1.30	1.30	1.10
	Office (Open Plan)	1,434,921	15%	Office	1.97	1.30	1.30	1.30	1.30	1.30	1.10
	Hallways/Corridors/Stairways	966,506	10%	n/a	2.76	n/a	n/a	n/a	n/a	n/a	n/a
	Restrooms	675,537	7%	n/a	1.14	n/a	n/a	n/a	n/a	n/a	n/a
	Conference Room	688,710	7%	n/a	2.99	n/a	n/a	n/a	n/a	n/a	n/a
	Kitchen/Break room and Food Preparation	371,728	4%	Kitchen	2.87	1.70	1.70	1.70	1.70	1.60	1.60
	Lobby (Office Reception/Waiting)	57,458	1%	n/a	11.29	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Conditioned)	46,491	0%	n/a	1.39	n/a	n/a	n/a	n/a	n/a	n/a
	Copy Room	132,618	1%	n/a	4.06	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Unconditioned)	125,548	1%	n/a	0.55	n/a	n/a	n/a	n/a	n/a	n/a
	Computer Room	122,720	1%	Computer Room	0.37	1.60	1.60	1.60	1.60	1.20	1.20
	Medical Offices and Exam Rooms	102,789	1%	n/a	0.08	n/a	n/a	n/a	n/a	n/a	n/a
	Computer (Network Room/Server Room	91,058	1%	n/a	2.96	n/a	n/a	n/a	n/a	n/a	n/a
	Lobby (Main Entry and Assembly)	37,555	0%	n/a	0.13	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Refrigerated/Freezer), Walk-in	24,351	0%	n/a	0.39	n/a	n/a	n/a	n/a	n/a	n/a
	Elevators	1,592	0%	n/a	3.19	n/a	n/a	n/a	n/a	n/a	n/a
	Total	**9,083,232**	**96%**	n/a	**1.58**	**1.50**	**1.50**	**1.50**	**1.30**	**1.20**	**1.20**

	Commercial Saturation Survey (CSS) Weighted Findings				Overall LPDs						
Building Type	Activity Area	Weighted Area (ft2)	% Total Weighted area	DEER Activity Area	CSS	DEER (Before 1978)	DEER (1978 - 1992)	DEER (1993 - 2001)	DEER (2002 - 2005)	DEER (2006 - 2009)	DEER (2010 - 2013)
Primary School	Classroom/Lecture	102,322,866	55%	Classroom	1.61	1.60	1.60	1.60	1.20	1.20	1.20
	Auditorium	8,233,174	4%	n/a	0.43	n/a	n/a	n/a	n/a	n/a	n/a
	Kitchen/Break room and Food Preparation	9,654,259	5%	Kitchen	1.80	1.70	1.70	1.70	1.70	1.60	1.60
	Restrooms	9,705,343	5%	n/a	1.54	n/a	n/a	n/a	n/a	n/a	n/a
	Library	7,202,665	4%	n/a	2.98	n/a	n/a	n/a	n/a	n/a	n/a
	Office (General)	4,749,537	3%	Office	2.48	n/a	n/a	n/a	n/a	n/a	n/a
	Hallways/Corridors/Stairways	8,049,491	4%	n/a	1.37	n/a	n/a	n/a	n/a	n/a	n/a
	Dining Area	5,602,399	3%	Cafeteria	0.86	1.50	1.50	1.30	1.30	1.30	1.30
	Office (Executive/Private)	3,823,273	2%	Office	1.62	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Unconditioned)	3,563,734	2%	n/a	0.89	n/a	n/a	n/a	n/a	n/a	n/a
	Office (Open Plan)	2,284,279	1%	Office	1.90	n/a	n/a	n/a	n/a	n/a	n/a
	Computer Room	3,126,742	2%	Computer Room	1.87	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Conditioned)	2,351,987	1%	n/a	1.65	n/a	n/a	n/a	n/a	n/a	n/a
	Exercise Centers/Gymnasium	3,287,086	2%	Gymnasium	0.01	1.20	1.20	1.00	1.00	1.00	1.00
	Lobby (Office Reception/Waiting)	1,331,490	1%	n/a	1.37	n/a	n/a	n/a	n/a	n/a	n/a
	Auto Repair Workshop	1,666,140	1%	n/a	0.13	n/a	n/a	n/a	n/a	n/a	n/a
	Lobby (Main Entry and Assembly)	1,662,425	1%	n/a	1.35	n/a	n/a	n/a	n/a	n/a	n/a
	Copy Room	1,271,909	1%	n/a	2.36	n/a	n/a	n/a	n/a	n/a	n/a
	Mechanical/Electrical Room	1,297,511	1%	n/a	0.47	n/a	n/a	n/a	n/a	n/a	n/a
	Conference Room	641,966	0%	n/a	2.36	n/a	n/a	n/a	n/a	n/a	n/a
	Medical Offices and Exam Rooms	800,880	0%	n/a	0.41	n/a	n/a	n/a	n/a	n/a	n/a

	Commercial Saturation Survey (CSS) Weighted Findings				Overall LPDs						
Building Type	Activity Area	Weighted Area (ft2)	% Total Weighted area	DEER Activity Area	CSS	DEER (Before 1978)	DEER (1978 - 1992)	DEER (1993 - 2001)	DEER (2002 - 2005)	DEER (2006 - 2009)	DEER (2010 - 2013)
	Storage (Refrigerated/Freezer), Walk-in	730,541	0%	n/a	0.35	n/a	n/a	n/a	n/a	n/a	n/a
	Locker and Dressing Room	657,234	0%	n/a	1.40	n/a	n/a	n/a	n/a	n/a	n/a
	Theater (Performance)	638,111	0%	n/a	4.18	n/a	n/a	n/a	n/a	n/a	n/a
	Stairwells (not stairways/hallways)	763,363	0%	n/a	0.33	n/a	n/a	n/a	n/a	n/a	n/a
	Religious Worship	392,253	0%	n/a	0.75	n/a	n/a	n/a	n/a	n/a	n/a
	Convention and Meeting Center	465,739	0%	n/a	0.35	n/a	n/a	n/a	n/a	n/a	n/a
	Other Unlisted Activity Types	232,874	0%	n/a	2.14	n/a	n/a	n/a	n/a	n/a	n/a
	Computer (Network Room/Server Room	268,211	0%	n/a	1.11	n/a	n/a	n/a	n/a	n/a	n/a
	Casino/Gaming	285,795	0%	n/a	1.14	n/a	n/a	n/a	n/a	n/a	n/a
	Laundry	80,321	0%	n/a	2.72	n/a	n/a	n/a	n/a	n/a	n/a
	Elevators	61,184	0%	n/a	0.15	n/a	n/a	n/a	n/a	n/a	n/a
	Patient Rooms	58,359	0%	n/a	0.77	n/a	n/a	n/a	n/a	n/a	n/a
	Laboratory	35,928	0%	n/a	1.67	n/a	n/a	n/a	n/a	n/a	n/a
	Vacant (Unconditioned)	29,944	0%	n/a	1.00	n/a	n/a	n/a	n/a	n/a	n/a
	Vacant (Conditioned)	28,579	0%	n/a	2.54	n/a	n/a	n/a	n/a	n/a	n/a
	Total	**187,357,592**	**100%**	n/a	**1.54**	**1.50**	**1.50**	**1.50**	**1.20**	**1.20**	**1.20**
Relocatable Classroom	Classrooms (Portable)	50,561,797	0.988	Classroom	1.52	1.60	1.60	1.20	1.20	1.20	1.20
	Vacant Classrooms (Portable)	615,384	0.012	Classroom	0.14	1.60	1.60	1.20	1.20	1.20	1.20
	Total	**51,177,181**	**100%**	n/a	**1.50**	**1.60**	**1.60**	**1.20**	**1.20**	**1.20**	**1.20**
Secondary School	Classroom/Lecture	92,580,058	39%	Classroom	1.14	1.60	1.60	1.60	1.20	1.20	1.20
	Auditorium	15,711,134	7%	n/a	0.52	n/a	n/a	n/a	n/a	n/a	n/a

	Commercial Saturation Survey (CSS) Weighted Findings				Overall LPDs						
Building Type	Activity Area	Weighted Area (ft2)	% Total Weighted area	DEER Activity Area	CSS	DEER (Before 1978)	DEER (1978 - 1992)	DEER (1993 - 2001)	DEER (2002 - 2005)	DEER (2006 - 2009)	DEER (2010 - 2013)
	Library	11,334,068	5%	n/a	1.54	n/a	n/a	n/a	n/a	n/a	n/a
	Exercise Centers/Gymnasium	9,276,675	4%	Gymnasium	0.33	1.20	1.20	1.00	1.00	1.00	1.00
	Hallways/Corridors/Stairways	8,842,440	4%	n/a	0.84	n/a	n/a	n/a	n/a	n/a	n/a
	Kitchen/Break room and Food Preparation	10,151,136	4%	Kitchen	1.08	1.70	1.70	1.70	1.70	1.60	1.60
	Restrooms	9,137,849	4%	n/a	0.82	n/a	n/a	n/a	n/a	n/a	n/a
	Locker and Dressing Room	6,391,850	3%	n/a	1.17	n/a	n/a	n/a	n/a	n/a	n/a
	Office (Executive/Private)	6,215,400	3%	Office	0.87	1.30	1.30	1.30	1.30	1.30	1.10
	Dining Area	7,392,443	3%	Cafeteria	0.79	1.50	1.50	1.30	1.30	1.30	1.30
	Office (General)	6,295,220	3%	Office	1.28	1.30	1.30	1.30	1.30	1.30	1.10
	Computer Room	5,486,211	2%	Computer Room	1.65	1.60	1.60	1.60	1.60	1.20	1.20
	Theater (Performance)	4,004,430	2%	n/a	0.74	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Unconditioned)	4,240,914	2%	n/a	0.66	n/a	n/a	n/a	n/a	n/a	n/a
	Office (Open Plan)	2,811,920	1%	Office	1.46	1.30	1.30	1.30	1.30	1.30	1.10
	Storage (Conditioned)	3,294,166	1%	n/a	1.70	n/a	n/a	n/a	n/a	n/a	n/a
	Other Unlisted Activity Types	3,207,403	1%	n/a	0.12	n/a	n/a	n/a	n/a	n/a	n/a
	Lobby (Main Entry and Assembly)	2,534,031	1%	n/a	0.63	n/a	n/a	n/a	n/a	n/a	n/a
	Religious Worship	2,723,631	1%	n/a	1.41	n/a	n/a	n/a	n/a	n/a	n/a
	Comm/Ind Work (General Low Bay)	2,366,407	1%	Workshop	0.82	n/a	n/a	n/a	n/a	n/a	n/a
	Conference Room	1,629,462	1%	n/a	1.68	n/a	n/a	n/a	n/a	n/a	n/a
	Mechanical/Electrical Room	1,001,183	0%	n/a	1.50	n/a	n/a	n/a	n/a	n/a	n/a
	Lobby (Office Reception/Waiting)	1,450,560	1%	n/a	1.33	n/a	n/a	n/a	n/a	n/a	n/a

	Commercial Saturation Survey (CSS) Weighted Findings				Overall LPDs						
Building Type	Activity Area	Weighted Area (ft2)	% Total Weighted area	DEER Activity Area	CSS	DEER (Before 1978)	DEER (1978 - 1992)	DEER (1993 - 2001)	DEER (2002 - 2005)	DEER (2006 - 2009)	DEER (2010 - 2013)
	Comm/Ind Work (General High Bay)	1,228,800	1%	Workshop	0.34	n/a	n/a	n/a	n/a	n/a	n/a
	Auto Repair Workshop	352,734	0%	n/a	1.70	n/a	n/a	n/a	n/a	n/a	n/a
	Stairwells (not stairways/hallways)	502,206	0%	n/a	1.06	n/a	n/a	n/a	n/a	n/a	n/a
	Storage (Refrigerated/Freezer), Walk-in	649,882	0%	n/a	0.59	n/a	n/a	n/a	n/a	n/a	n/a
	Convention and Meeting Center	479,520	0%	n/a	0.68	n/a	n/a	n/a	n/a	n/a	n/a
	Vacant Classroom/Lecture	222,977	0%	n/a	3.32	n/a	n/a	n/a	n/a	n/a	n/a
	Medical Offices and Exam Rooms	662,279	0%	n/a	2.03	n/a	n/a	n/a	n/a	n/a	n/a
	Copy Room	419,270	0%	n/a	2.54	n/a	n/a	n/a	n/a	n/a	n/a
	Laboratory	456,776	0%	n/a	1.26	n/a	n/a	n/a	n/a	n/a	n/a
	Theater (Motion Picture)	464,163	0%	n/a	0.10	n/a	n/a	n/a	n/a	n/a	n/a
	Computer (Network Room/Server Room	148,443	0%	n/a	1.51	n/a	n/a	n/a	n/a	n/a	n/a
	Retail Sales/Showroom	115,847	0%	n/a	0.47	n/a	n/a	n/a	n/a	n/a	n/a
	Laundry	67,481	0%	n/a	1.73	n/a	n/a	n/a	n/a	n/a	n/a
	Elevators	67,268	0%	n/a	0.14	n/a	n/a	n/a	n/a	n/a	n/a
	Patient Rooms	15,011	0%	n/a	1.35	n/a	n/a	n/a	n/a	n/a	n/a
	Total	**223,931,248**	**95%**	n/a	**1.03**	**1.50**	**1.50**	**1.50**	**1.20**	**1.20**	**1.20**

Table 45: Space Use: CSS vs DEER

		DEER Prototype (% Area)	CSS (%Area)
Primary School	Classroom	63%	55%
	Cafeteria	15%	3%
	Gymnasium	15%	2%

	Kitchen	7%	5%
Secondary School	Classroom	59%	39%
	Computer Room	2%	2%
	Cafeteria	15%	3%
	Gymnasium	15%	4%
	Kitchen	7%	4%
	Office	2%	6%
Community College	Classroom	50%	13%
	Computer Room	3%	1%
	Workshop	12%	0%
	Cafeteria	9%	0%
	Kitchen	2%	4%
	Office	23%	47%

Baseline and Improved Energy End Use

Baseline and Improved Energy End Use shows all baseline and improved energy end use distributions that show significant reductions in heating, cooling, and lighting energy as a percentage of total building load, and a shift to loads driven by internal gains from lights and equipment. The most significant change is in the proportion of building energy represented by miscellaneous equipment. This category includes computers, printers, lab equipment, and other equipment categories that generally have more to do with building operation and occupant program needs than with building design features. In other words, as the pie shrinks and “regulated” loads (envelope, lighting and HVAC loads) get smaller, the percent of the pie from operation and occupant driven loads increases.

The significant relative increase in these loads means that in high performing buildings, tracking and managing these loads becomes much more important to overall building performance than it was before the upgrade. This has implications on how these buildings will need to be managed and maintained to achieve the performance levels targeted. Similar results are seen in the changing components of the pie chart in the other building prototypes.

APPENDIX D: CALIFORNIA IOU LESSONS LEARNED FROM THE ZNE SCHOOLS RETROFIT PILOT

The Prop 39 ZNE Pilot projects have been ongoing during the course of this research. During the public review process, researchers received comments from the IOU staff implementing the Prop 39 pilot. These are included below for documentation and reference.

Peter Turnbull of PG&E provided the following comments regarding the Prop 39 ZNE pilot and considerations about the program moving forward:

> I have about five main points about the retrofit projects and how your report should address/incorporate them.
>
> 1. The ZNE Pilot program for schools is working. All or nearly all of the retrofit projects are on a path to succeed in achieving ZNE. For the seven I'm familiar with in PG&E's territory, there is a great deal of enthusiasm and excitement about the projects among the teams involved at each school. Although it's possible we may end up with one or two dropouts, we fully expect to demonstrate the basic technical feasibility of retrofitting to ZNE at every site (or nearly every site). Since the projects were not screened to select only the "best candidates" or "easiest targets" technically, this is a big deal. I believe we can conclude that it is broadly feasible on a technical basis to retrofit schools to ZNE. However, this finding is not yet widely accepted and has certainly not been widely disseminated.
>
> Starting with the Executive Summary of the report, this success around technical feasibility should be mentioned prominently. Although it is true that this Pilot, at ~$8.5 million over four years, is small in comparison to the overall Prop 39 effort, it is nonetheless, to my knowledge, the largest program of its kind in the school market in the US.
>
> 2. Part and parcel of the improved energy performance of the schools is the fact that the improvements enabling ZNE also make the schools (1) better learning environments for the students as well as (2) healthier places. At one participating site, the staff was particularly pleased with an HVAC retrofit of a package heat pump—that classroom is now adequately ventilated, it meets temperature requirements and it's far quieter with the new unit. Without adequate ventilation, we know CO2 levels can rise to levels that can lead to drowsy, sleepy students. Noise from the package heat pumps (which are ubiquitous in the public school system) is a well-known problem and major distraction to the learning process. The staff at this school insisted we visit the classroom where it was installed—they were thrilled with the result. So, this retrofit, which could be repeated thousands of times across the state, contributes to a healthier classroom which is now a better learning environment: in the bargain, it saves a lot of energy.
>
> 3. The story is similar with daylighting. When we looked, we noticed that all of the schools we visited had originally installed daylighting measures which were subsequently "defeated" to a substantial degree in various ways. In all (or nearly all) of the projects, thoughtful addition of daylighting together with advanced LED systems and controls is being implemented. As has been demonstrated, daylighting not only saves significant amounts of energy, but likewise contributes to a better learning environment (see Lisa Heschong's work from 1999-2000, among that of others).
>
> Both 2 and 3 may represent opportunities for highly leveraged statewide or regional purchasing and installation programs—these and other opportunities should be considered in the school market going forward.
>
> 4. Cost is an issue: One of the important perceptions we've gained from ZNE is the whole building perspective—to meet ZNE, it's important to set an energy target per square foot and then meet that target

(including the renewable sizing). However, this issue also brings into relief the fact that energy costs are in the $2/sf/year range—but major renovations cost many, many times that. Holding the expectation that whole building renovations to zero can be "financed" through energy savings alone is simply not a viable expectation "at scale" (in a few isolated cases this may work, but not "on average"). This is why it is so important that the additional benefits of the renovations—the better learning environment, the healthier place to occupy—be recognized and encouraged.

A corollary in this area is cost effectiveness under current metrics to evaluate C/E: although I understand that there is resistance to identifying C/E as a "barrier," I think it is highly unrealistic not to recognize this issue: failure to acknowledge it means that possible solutions will not receive emphasis. How is it useful to not acknowledge and address this very substantial barrier?

5. Getting to scale. Although we have learned a great deal and we are having success with the projects, my view is that we need a 4x-8x increase in scale of these demonstrations to leverage the ZNE feasibility/value message adequately. (The cost increase would not be linear; rather it would be more like 2x-4x to increase 4x-8x.) It is clear that retrofitting a dozen schools to ZNE is not sufficient in scale to really generate the interest and visibility needed to get things to happen more broadly in the school environment. Such an expansion would yield 50-100 schools retrofit to ZNE. It may be that there are other approaches to be tried out in this area (e.g., bulk purchasing/installation). The non-project efforts like training, education and recognition should also be continued, but these would not require major increases in cost/funding and are not high-cost items in the first place.

In addition, the following are excerpts of meeting notes from a Prop 39 ZNE Pilot IOU implementation team meeting documenting lessons learned thus far in the pilot:

Below are lessons learned and input from Southern California Edison and Southern California Gas:

- Projects do undergo funding shifts causing projects to be postponed/cancelled, i.e. Peters Elementary School funds had to be transferred to another school that had no air-conditioning at the site.
- School does not have a qualified champion to run the project, no support Consultants to assist, either person is new to the school, or no prior experience on Prop 39.
- For Community Colleges, barriers to direct interaction with the Customer. Account representative always a layer in between discussions with the School and ZNE Pilot stakeholders.
- School wants the money and requests for items to be paid that are not really incremental costs above T24 Code.
- Some schools cannot meet the 16-22 kBtu/square foot per year metric due to different operation; i.e. Kitchen.
- School may be cautious in adopting a measure since they will need to pay a portion of it or it will affect their current construction schedule.
- Contract Agreement difference in policies; i.e. Public School does not want Limitation of Liability clause in the Contract. IOU requires Limitation of Liability clause in the Contract.
- Candidate screening tool should have a question on staff manpower availability.
- Candidate screening tool should require construction timetable to be provided and cross checked with ZNE Pilot schedule.
- Current ZNE projects have one site master meter, for electricity and gas. Challenge to get monitoring data for a specific building. More challenging for gas monitoring since installation of gas monitoring equipment involves plumbing piping rework.
- Tubular daylighting may be susceptible to leaks and installation will need to be monitored during construction.

- Public school, due to lack of skilled maintenance personnel, are hesitant to adopt “cutting edge” technologies or to “push the envelope” with energy efficiency measures.
- M&V monitoring labor if from out of state will need to be paid California prevailing wage which will increase cost.