Newcastle Elementary School
Zero Net Energy Study

April 6 , 2016

Prepared for:
PG&E
&
Newcastle Elementary School

Prepared by:

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PROJECT DESCRIPTION AND EXISTING CONDITIONS

1.1 Goal of the Prop 39 ZNE Schools Pilot Program

Fostering the state of California's larger goal of bringing greenhouse gas emissions down to sustainable levels, PG&E aims to lead the market with exemplary ZNE projects. PG&E has established the ZNE Schools Pilot Program to encourage schools using California Prop 39 funding to achieve zero net energy.

The incentives in place for standard building retrofit projects encourage Energy Service Companies to perform energy efficiency measures that achieve the fastest, largest, most cost-effective savings. The intention of this ZNE effort, by contrast, is to foster deeper, greener measures, starting with passive strategies such as building envelope efficiency and daylighting, as part of a more comprehensive package for reducing building energy use more dramatically. The relatively smaller amount of remaining energy needs can then be provided with 100% photovoltaics, or other renewable energy. PG&E's goal is to demonstrate and incentivize the market to move beyond the standard retrofit toward the ZNE retrofit. Utility company assistance can encourage the market to address the more comprehensive energy efficiency measures, starting with passive measures first.

Point Energy/Stok is one of the design teams that PG&E has enlisted to assist schools in evaluating strategies for getting to zero net energy as described above, and implementing a chosen strategy that will work for the school on many levels, particularly comfort, school performance, economics, maintainability, and durability.

1.2 Definition of ZNE

In the *2013 Integrated Energy Policy Report (IEPR)*, the California Energy Commission (CEC) adopted a definition for ZNE Code Buildings, developed in collaboration with the California Public Utilities Commission (CPUC). This ZNE definition calls for a building to be energy efficient and include on-site renewable energy generation that offsets the time-dependent value of the energy used in the building, per the following definition:

> *A ZNE Code Building is one where the value of the net amount of energy produced by on-site renewable energy resources is equal to the value of the energy consumed annually by the building, at the level of a single "project" seeking development entitlements and building code permits, measured using the California Energy Commission's Time Dependent Valuation metric. A ZNE Code Building meets an Energy Use Intensity value designated in the Building Energy Efficiency Standards by building type and climate zone that reflect best practices for highly efficient buildings.*

1.3 School Description and Existing Conditions

The Newcastle Elementary / Charter School District is in the foothills northeast of Sacramento, California. The school operates a dependent charter at the elementary school site. The school site is of the 1950's vintage with some slight architectural modifications over time. This Newcastle Elementary School site has just over 31,536 square feet total, including two permanent learning structures, a few portables and a permanent multi use building. This does not include the Harvest Ridge Charter School, which is located on the site but is not part of the study.

Location:

Newcastle Elementary School
450 Main St, Newcastle, CA 95658
Lat (deg N): 38.67 (McClellan AFLD, CA)
Long (deg W): 121.40 (McClellan AFLD, CA)
Elev (m): 75 ft (McClellan AFLD, CA)

Outside Design Conditions:
Winter 99.6% Heating DB: 31.1 °F
Summer 0.4% Cooling DB: 102 °F / MCWB: 70.2°F

The school is in a mild climate and is relatively efficient, despite its single pane glass and likely quite low levels of insulation, based on reports following a recent re-roofing project. It has a relatively new “cool white” roof (which should be providing a considerable advantage in reducing cooling loads). The school HVAC system consists of rooftop air conditioning units with natural gas heating, supplied via ceiling mounted ductwork. Existing interior lighting is T8 fluorescent fixtures throughout. Classrooms have three independently switched lighting circuits. Outdoor lighting includes High Pressure Sodium Wallpacks and Metal Halide parking lot lighting.

The school was originally designed with clerestory windows, which would have provided daylighting, but these high windows were painted over years ago. Currently some of them are broken or boarded. Large “light shelves” front the windows, mostly loaded with ductwork. Exterior overhangs extend out about five feet, in the plane of the interior light shelves.

Other conditions pertinent to this study include an HVAC rooftop unit on the gymnasium that is in current need of replacement.

1.4 Baseline Energy Performance

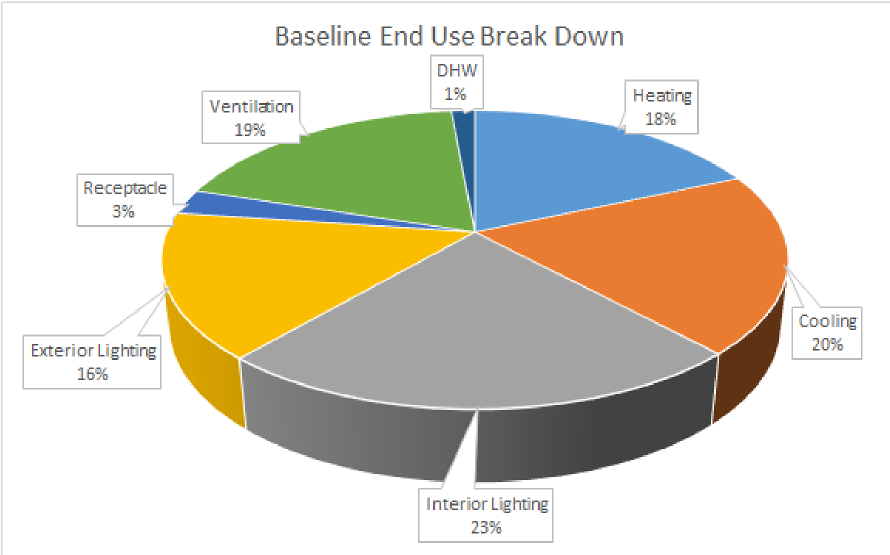
Based on interval electric and gas data from PG&E, Newcastle Elementary has an existing Energy Use Intensity (EUI) ranging from 21 kBtu/sf/yr (for the most recent 12 months) to 25 kBtu/sf/yr (for 2014), delineated as follows:

- Annual electricity usage ranged from
  - 167,786 kWh (for the most recent 12 months) to
  - 200,003 kWh (for 2014, with an associated annual cost of $31,818)
- Annual gas usage ranged from
  - 1,173 Therms to
  - 1,457 Therms (for 2014, with an associated annual cost of $971)
- Annual total energy usage ranged from
  - 689,787 kBtu (most recent 12 months) to
  - 828,110 kBtu (for 2014)

ZNE INVESTIGATION

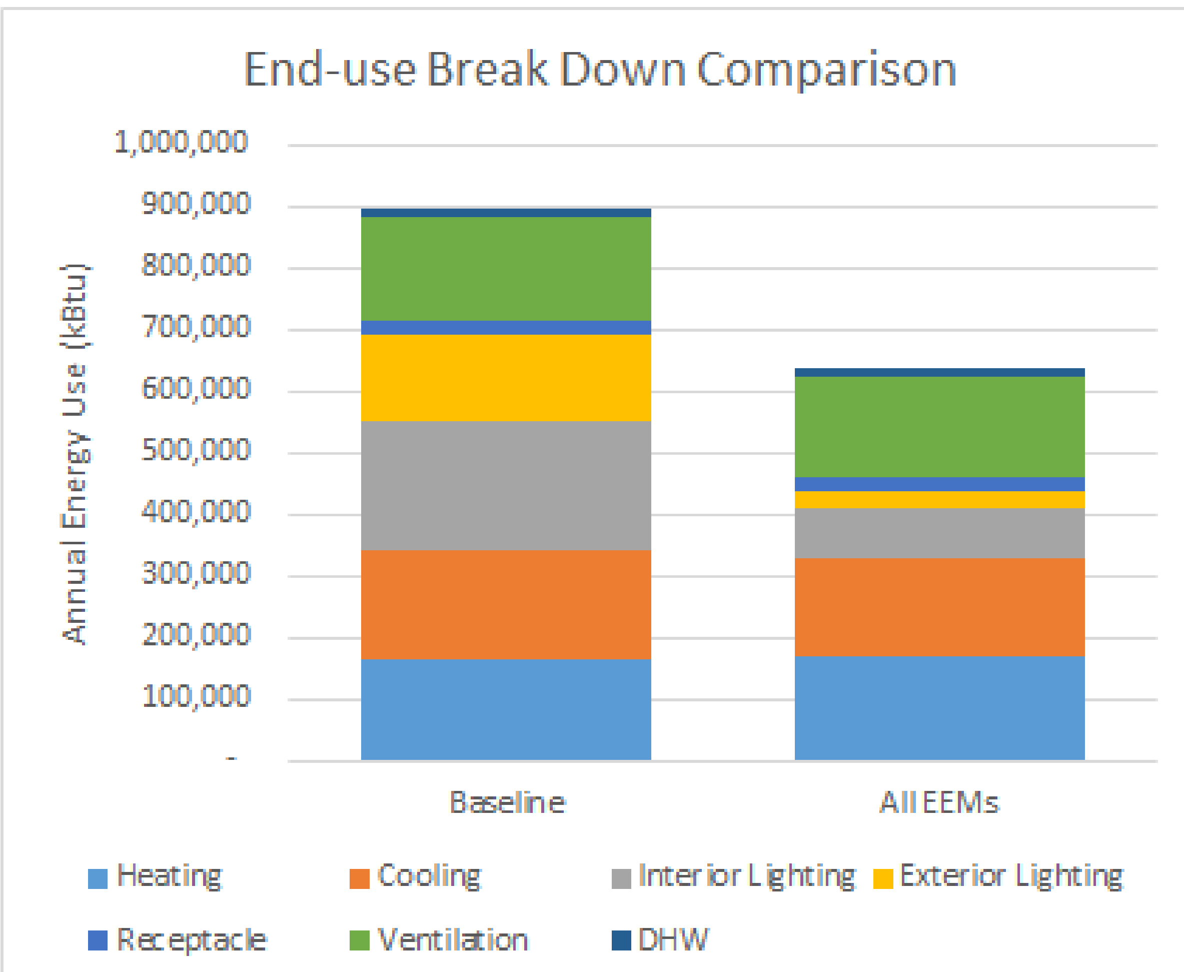
2.1 Modeled Energy Performance

In order to predict the impact of the various energy efficiency measures (EEMs) investigated for Newcastle Elementary, the PEI/Stok team developed an energy model. Due to the inherently variable



nature of model inputs such as weather and human behavior, models are typically calibrated to be within +/- 10% of metered energy use on an annual basis. The baseline model, based on the school's existing construction, was calibrated within 8% of the actual annual utility usage, predicting an annual total energy use of 895,400 kBtu with an energy end use breakdown depicted here.

The model indicates that the EEMs analyzed, if all are employed, will affect the energy end use as follows.



2.2 Energy Efficiency Measures (EEMs)

For a deep green, ZNE retrofit, important considerations are lifecycle cost-effectiveness and benefits beyond energy cost savings, such as durability, comfort, healthfulness, and maintainability. The approach best aligned with these considerations starts by first assessing the building envelope and identifying any potentially effective passive energy efficiency measures. The next step is to assess mechanical systems and finally, to address the "low-hanging fruit" measures such as adjusting schedules and setpoints and installing PV. Using this framework, the following efficiency measures were deemed the most beneficial:

- **Sealing and Caulking:** Seal and caulk around windows, doors, electrical and plumbing penetrations and any other locations identified as leaky, using a standard blower door test. This measure would be done by maintenance staff at no additional program cost. Its effect was not simulated because existing leakiness has not been measured, but it would slightly enhance the modeled results.
- **Classroom Daylighting:** Provide combined Clerestory + Skylight daylighting in the classrooms as follows:
    - Install clear glass in place of painted or boarded windows in clerestory window walls that adjoin the outdoors (23 window walls)
    - Clean ducts and shelves
    - The following tasks are recommended to enhance the outcome but can be deferred to reduce upfront costs:
        - Paint top of ducts white with zero-VOC paint, where ducts are not already white; alternatively light-redirecting film can be applied to the inside of the clerestory glazing (see #8, below)
        - Remove the following four entire light shelf structures: Room 100-North side, Room 101-North side, Room 300-North side, Room 301-North side
        - Remove the following four vertical "turn-up" parts of the light shelf structures: Room 100-South side, Room 101-South side, Room 203-West side, Room 209-East side
    - Add 18 Solatubes (locate per PEI) in permanent classrooms, as follows (classrooms not listed have sufficient daylighting without Solatubes):
        - Room 202: 4 Solatubes
        - Room 208: 2 Solatubes
        - Room 204: 2 Solatubes
        - Room 210: 4 Solatubes
        - Room 207 (Library): 4 Solatubes
        - Room 304: 2 Solatubes
- **Gym Daylighting:** In the Gym/Multipurpose room, add Solatubes to brighten the wall surfaces, thereby enhancing the existing skylighting and eliminating the need for artificial light most of the time.
- **Exterior Lighting:** Replace all exterior HPS wall packs and MH parking lot lighting with LED fixtures.
- **Interior Lighting:** Replace all existing interior fluorescent tubes with LEDs, reducing the wattage from 32 watts to 17 watts per bulb. Note: If California Conservation Corps grant, and a rebate for new lighting fixtures can both be acquired, then interior fixtures can be replaced with dimmable LED fixtures instead of just replacing bulbs. Otherwise fixture replacement costs $200K more than tube replacement, without guaranteeing much greater savings, making it beyond the

reasonable economic metrics (considering that bulb replacement delivers similar energy savings). This is yet to be determined.

- **Gym HVAC:** Replace Gym/Multipurpose HVAC rooftop unit with high efficiency unit.
- **Building Management System**: Install a campuswide Building Management System (BMS), which will save energy by automatically turning equipment off when not needed.
- **Bard HVAC Units:** Replace five EER-8.7 BARD HVAC units with EER-14.5 BARD HVAC units, which also have Bard's quietest sound rating.

The following additional EEMs were evaluated but were not cost-effective enough for recommendation, compared to the alternatives above:

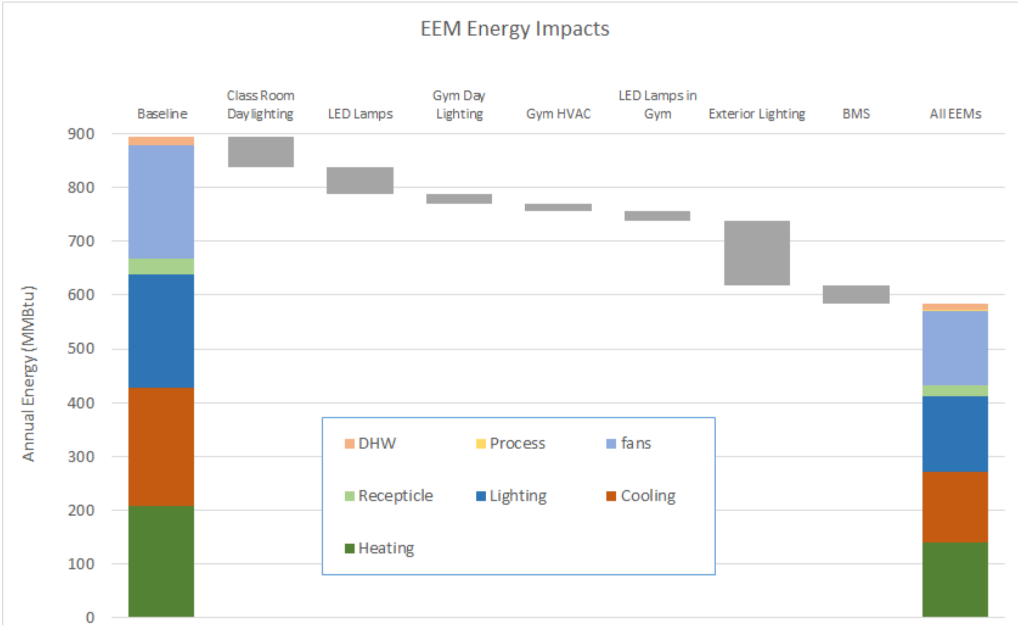
- Replace interior fixtures with LED fixtures with dimmable ballasts (see note above). $272,00 for interior fixtures (excludes outdoor fixtures).
- Add Serralux daylight redirecting film to help redirect light onto the ceiling if the remediated light shelves do not prove effective enough (involves replacing single pane glass with double) .
- Add Solatubes to permanent classrooms without remediating clerestory windows. In a classroom with view glass on just one wall, provide six Solatubes to allow electric lights to be turned off during sunny conditions. Classrooms with two walls of view windows require fewer Solatubes to daylight the space.
- Use Solatubes to daylight the portable classrooms, which do not have clerestories. Six Solatubes would typically be needed per portable classroom.
- Provide natural ventilation in the Gym by raising the existing skylights and adding louvers.
- Replace existing Bard units on portable classrooms with new high efficiency heat pump units. See appendix for analysis results.

2.3 Energy Savings Associated with Potential EEMs

Described in the chart below are the results of the energy efficiency measures on predicted energy use. As depicted, each EEM subtracts a predicted amount of saved energy (in MMBtus) from the original baseline.

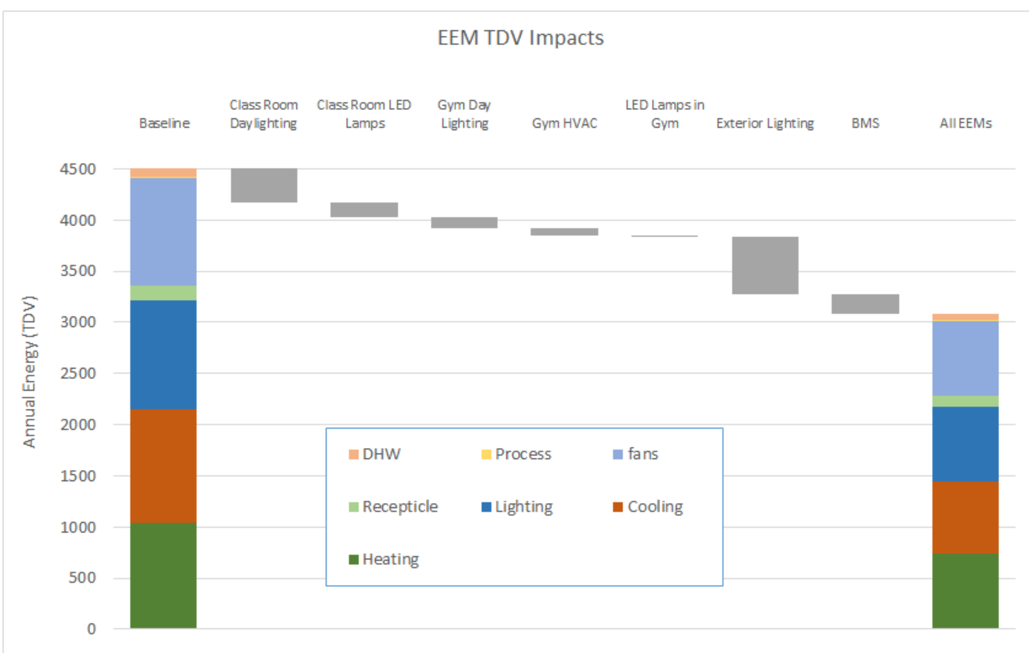
Results of EEMs on the Predicted Annual Site Energy Use (Actual Gas & Electricity Consumption)
The following graph shows a 35% total reduction in annual site energy use, compared to the baseline. This would result in the EUI being reduced from 21-25 kBtu/sf-yr (baseline) to 13-16 kBtu/sf-yr.

Note: Caulking was not modeled because pre- and post-EEM leakiness was not tested. Also, the effect of the BMS is an estimate based on general experience, also not modeled, and the analysis team believes that this is a conservative estimate of potential savings.



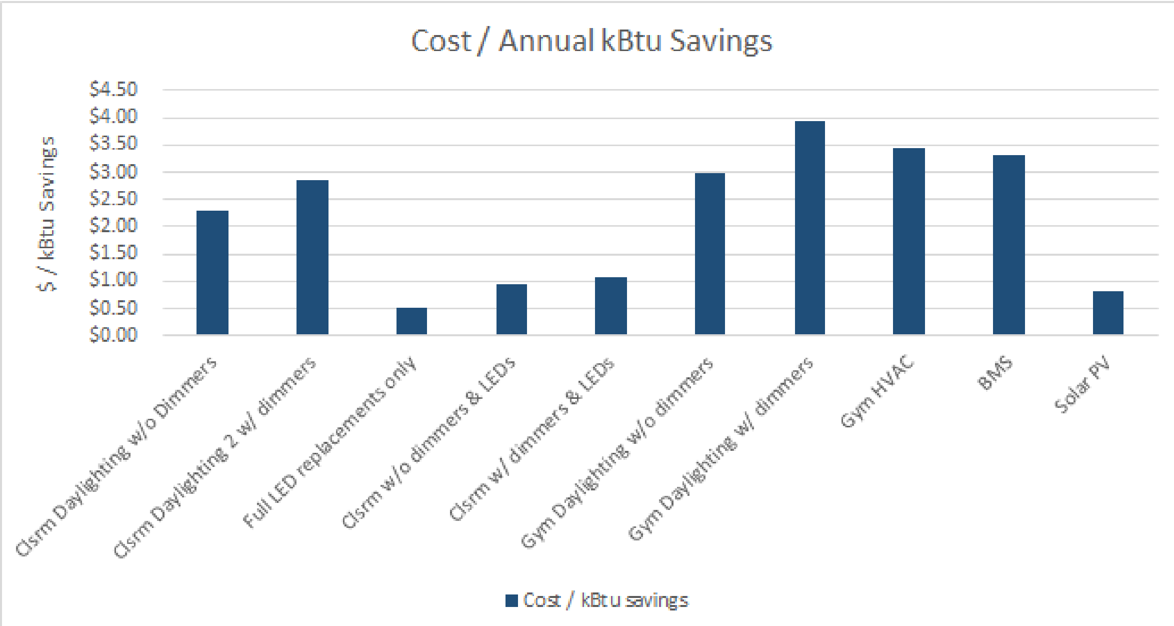
Results of Package 1 (All EEMs) on the Annual Energy Use TDV

The chart below converts the result of the energy efficiency measures above into the time dependent value (TDV) of predicted energy use. The resulting bar is what would have to be provided by onsite renewable energy (PV in this case) to achieve ZNE by the CPUC definition. The effect of the BMS is not included in TDV calculations because we are not able to predict the time-dependent behavioral “errors” that the BMS system will correct. The following graph shows a 32% total reduction in the annual energy (gas & electricity) TDV, compared to the baseline.



2.4 Financial Analysis of EEMs

Cost Effectiveness of Individual EEMs (Cost per Unit of Energy Savings)
The following chart illustrates the cost-effectiveness of each measure, based on its associated energy savings, the shorter the bar, the less it costs per unit of energy saved (or energy produced, for PV)



Capital Costs and Operational Savings Associated with EEMs
The following chart describes the EEMs' associated upfront capital costs, operational energy savings in total kBtu (gas & electricity), electrical savings only, in kWh, net present value (NPV) and savings to investment ratio (SIR). California Proposition 39, which funds school energy retrofits, requires that the SIR be equal to or greater than 1.05.

EEM #	Energy Efficiency Measure (EEM)	Cost	kBtu svgs/yr	kWh svgs/yr	20-yr NPV	SIR
1	Classroom daylighting (clerestories + Solatubes without dimmers)	$126,855	62,200	18,100	($51,900)	0.58
2	Classroom daylighting (clerestories + Solatubes with dimmers	$168,407	62,200	18,100	($92,600)	0.44
3	Replace all interior T8 lamp tubes with LEDs	$42,010	71,660	25,550	$84,400	3.05
4	Replace all exterior fixtures with LED fixtures	$31,330	130,160	38,150	$122,100	4.98
5	LED lighting replacements (includes both interior & exterior LEDs)	$73,340	201,820	63,700	$206,500	3.87
6	Combined classroom daylighting (no dimmers) and interior/exterior LEDs	$200,195	252,200	73,900	$121,600	1.62
6a	Classroom Daylighting w/out dim (Energy savings reduced to account for LED retrofit)	$126,855	50,800	14,908	($64,700)	0.48
6b	Interior LED replacement (Energy savings reduced to account for Daylighting retrofit)	$42,010	71,200	20,900	$64,200	2.56

6c	Exterior LED replacement (Energy savings unaffected by daylighting retrofit)	$31,330	130,200	38,150	$122,100	4.98
7	Combined classroom daylighting (with dimmers) and interior/exterior LEDs	$241,747	252,200	73,900	$80,900	1.34
7a	Classroom Daylighting w/ dim (Energy savings reduced to account for LED retrofit)	$168,407	50,800	14,900	($105,500)	0.36
7b	Interior LED replacement (Energy savings reduced to account for Daylighting retrofit)	$42,010	71,200	20,900	$64,200	2.56
7c	Exterior LED replacement (Energy savings unaffected by daylighting retrofit)	$31,330	130,200	38,100	$122,100	4.98
8	Solatube daylighting in Gym (no dimmers)	$55,800	18,700	5,500	($32,800)	0.40
9	Solatube daylighting in Gym with dimmers	$73,600	18,700	5,500	($50,300)	0.30
10	High efficiency HVAC for gym*	$52,200	15,100	4,100	$1,700	1.03
11	Building Energy Management System (BMS) (savings estimated not modeled)	$129,900	39,100	11,500	($81,400)	0.36
12	Sealing and Caulking (savings not modeled)	$0	>0	>0	>0	>0
13	Replace five EER-8.7 BARD HVAC units with EER-14.5 BARD HVAC units*	$73,145	10,577	3,100	($11,200)	0.84

* existing unit(s) to be replaced at 5 years regardless

2.5 Alternate Retrofit Package Recommendations

The goal of the ZNE program is to offset the TDV of the annual energy use. The school has a larger goal, offsetting the total site electricity use. As noted above, the school's existing energy use has ranged recently from 689,787 kBtu to 828,110 kBtu, and electricity use has ranged from 167,786 kWh to 200,003 kWh (the latter associated with an annual cost of $31,818.) These annual kBtu and kWh savings are approximate, based on energy model predictions, and solar PV is based on production estimates.

Package 1: All Recommended EEMs, with 106 kW PV to offset 100% of Annual Site Electricity

EEM #	Energy Efficiency Measure (EEM)	Cost	kBtu svgs/yr	kWh svgs/yr	20-yr NPV	SIR
6	Combined classroom daylighting (no dimmers) and interior/exterior LEDs	$200,195	252,200	73,900	$121,600	1.62
6a	Classroom Daylighting w/out dim (Energy savings reduced to account for LED retrofit)	$126,855	50,800	14,908	($64,750)	0.48
6b	Interior LED replacement (Energy savings reduced to account for Daylighting retrofit)	$42,010	71,200	20,900	$64,222	2.56
6c	Exterior LED replacement (Energy savings unaffected by daylighting retrofit)	$31,330	130,200	38,150	$122,128	4.98
8	Solatube daylighting in Gym without dimmers	$55,800	18,700	5,500	($32,800)	0.4
10	High efficiency HVAC for gym	$52,200	15,100	4,100	$1,700	1.03

11	Building Energy Management System (BMS) (savings estimated not modeled)	$129,900	39,100	11,500	-$81,400	0.36
12	Sealing and Caulking (savings not modeled)	$0	>0	>0	>0	>0
13	Replace five EER-8.7 BARD HVAC units with EER-14.5 BARD HVAC units*	$73,145	10,600	3,100	($11,200)	0.84
	Totals	**$511,240**	**335,700**	**98,100**	**($2,100)**	**1.00**
	Solar PV (106 kW array producing 147,700 kWh/yr; incl. 20% safety factor)	$403,713	503,875	144,577	$118,597	1.29
P1	Package 1 with Solar PV	$914,953	839,575	242,677	$116,497	1.13

Package 1A: Alternatively, to just meet TDV ZNE requirements, install just 96 kW PV for $365,626 and a lower total upfront cost of $876,866, but a less beneficial 20-year NPV.

Package 2: Selected EEMs, with 108 kW PV to offset 100% of Annual Site Electricity
This is the PEI/Stok recommended package, as discussed below

EEM #	Energy Efficiency Measure (EEM)	Cost	kBtu svgs/yr	kWh svgs/yr	20-yr NPV	SIR
6	Combined classroom daylighting (no dimmers) and interior/exterior LEDs	$200,195	252,200	73,900	$121,600	1.62
6a	Classroom Daylighting w/out dim (Energy savings reduced to account for LED retrofit)	$126,855	50,800	14,908	($64,750)	0.48
6b	Interior LED replacement (Energy savings reduced to account for Daylighting retrofit)	$42,010	71,200	20,900	$64,222	2.56
6c	Exterior LED replacement (Energy savings unaffected by daylighting retrofit)	$31,330	130,200	38,150	$122,128	4.98
10	High efficiency HVAC for gym	$52,200	15,062	4,092	$1,687	1.03
11	Building Energy Management System (BMS) (savings estimated not modeled)	$129,900	39,100	11,500	($81,400)	0.36
12	Sealing and Caulking (savings not modeled)	$0	>0	>0	>0	>0
13	Replace five EER-8.7 BARD HVAC units with EER-14.5 BARD HVAC units	$73,145	8,817	3,100	($11,231)	0.84
	Totals	**$455,440**	**315,179**	**92,592**	**$30,656**	**1.07**
	Solar PV (108 kW array producing 150,400 kWh/yr; incl. 20% safety factor)	$411,331	503,875	147,677	$122,258	1.30
P2	Package 2 with Solar PV	$866,771	819,054	240,269	$152,914	1.18

Package 2A: Alternatively, to just meet TDV ZNE requirements, install just 101 kW PV for $377,053 and a lower total upfront cost of $832,493, but a less beneficial 20-yr NPV.

Package 3: Selected EEMs, with 118 kW PV to offset 100% of Annual Site Electricity

EEM #	Energy Efficiency Measure (EEM)	Cost	kBtu svgs/yr	kWh svgs/yr	20-yr NPV	SIR
6	Combined classroom daylighting (no dimmers) and interior/exterior LEDs	$200,195	252,200	73,900	$121,629	1.62
6a	Classroom Daylighting w/out dim (Energy savings reduced to account for LED retrofit)	$126,855	50,800	14,908	($64,721)	0.48
6b	Interior LED replacement (Energy savings reduced to account for Daylighting retrofit)	$42,010	71,200	20,900	$64,222	2.56
6c	Exterior LED replacement (Energy savings unaffected by daylighting retrofit)	$31,330	130,200	38,150	$122,128	4.98
10	High efficiency HVAC for gym	$52,200	15,062	4,092	$1,687	1.03
12	Sealing and Caulking (savings not modeled)	$0	>0	>0	>0	>0
	Totals	**$252,395**	**267,262**	**77,992**	**$123,316**	**1.50**
	Solar PV (118 kW array producing 161,300 kWh/yr; incl. 20% safety factor)	$449,417	550,530	161,300	$133,384	1.30
P3	Package 3 with Solar PV	$701,812	817,792	239,292	$256,700	1.37

Package 3A: Alternatively, to just meet TDV ZNE requirements, install just 107 kW PV for $406,500 and a lower total upfront cost of $693,300, but a less beneficial 20-yr NPV.

Package 4: Selected EEMs, with 125 kW PV to offset 100% of Annual Site Electricity

EEM #	Energy Efficiency Measure (EEM)	Cost	kBtu svgs/yr	kWh svgs/yr	20-yr NPV	SIR
3	Replace all interior T8 lamp tubes with LEDs	$42,010	71,660	25,550	$84,366	3.05
4	Replace all exterior fixtures with LED fixtures	$31,330	130,160	38,150	$122,128	4.98
10	High efficiency HVAC for gym	$52,200	15,062	4,092	$1,687	1.03
12	Sealing and Caulking (savings not modeled)	$0	>0	>0	>0	>0
	Totals	**$125,540**	**216,882**	**67,792**	**$208,181**	**2.69**
	Solar PV (125 kW array producing 171,500 kWh/yr; incl. 20% safety factor)	$476,077	583,189	171,500	$143,714	1.30
P4	Package 4 with Solar PV	$601,617	800,071	239,292	$351,895	1.59

Package 4A: Alternatively, to just meet TDV ZNE requirements, install just 115 kW PV for $438,000 and a lower total upfront cost of $563,500, but a less beneficial 20-yr NPV.

2.6 Comparative Paths to Achieving ZNE

PV Required to Offset Total Site Electricity, and to Achieve ZNE
A roof-mounted PV array of various sizes was analyzed, factoring in actual shading conditions. Without implementing any energy efficiency measures, a 143 kW PV array would be needed to offset current baseline total energy use, at TDV rates, or a 187 kW array would be required to offset total annual site electricity use. Employing all the recommended EEMs, reduces those PV array sizes to 98 kW for ZNE at TDV rates or 108 kW to offset total site electricity use, without overproducing, for maximum reduction in the school's electricity bills. All PV arrays referenced in this report have been sized with a safety factor of 20% to ensure the achievement of ZNE.

The following chart shows the effect of various EEMs and combinations of EEMs on PV sizing.

	Annual Site Energy Savings from Baseline				**TDV of Annual Energy Usage**		
Modeled Case	Gas & Electricity Annual **Savings (kBtu)**	Electricity Only Annual **Savings (kWh)**	PV Size (kW) to offset kWh +20% safety factor	**PV Cost ($)**	**TDV** of Annual Gas & Electricity Use	**PV Size (kW) for ZNE** (offsets Gas & Electricity TDV)	**PV Cost ($)**
Baseline Use	895,400	212,700	187	$710,900	4,502,100	143	$543,900
Replace All Int. Lamps	71,600	25,500	164	$625,700	4,022,900	128	$486,000
Daylighting Classrooms Only	62,100	18,100	171	$650,400	4,157,800	132	$502,300
Daylighting Gym Only	18,700	5,500	182	$692,500	4,395,300	139	$531,000
Gym Roof Top Unit	15,000	4,100	183	$697,200	4,424,400	140	$534,500
BMS	39,100	5,500	182	$692,500	4,305,500	137	$520,100
Exterior Lighting	130,100	38,100	153	$583,600	3,929,500	125	$474,700
5 New High Effic BARDs	10,577	3,100	185	$703,300	4,448,900	140	$538,100
Package 1: All EEMs	312,300	90,100	106	$409,800	3,079,800	98	$372,000
Package 2 EEMs	301,600	87,000	108	$420,100	3,168,800	101	$382,800
Package 3 EEMs	262,500	78,000	118	$450,200	3,365,400	107	$406,500
Package 4 EEMs	216,882	67,800	125	$476,100	3,565,300	115	$438,000

Discussion of Recommended Path to ZNE

The Newcastle Elementary School complex can achieve zero net energy and we recommend it do so. It is already a relatively efficient school, and with key additional energy efficiency measures and enough solar PV on the building roofs, the school will produce enough energy to meet the time dependent value of its energy use. However, we recommend Newcastle install the additional PV to produce enough electricity to offset its total electricity use, which would minimize its utility bills, saving the school the most money in the long run.

The most *cost*-effective way to get to zero net energy based on energy savings alone would be to simply upgrade the interior and exterior lighting to LED lamps, replace the gym rooftop HVAC unit, and then to provide the remaining energy with rooftop PV (Package 4). However, certain other energy efficiency measures, while not returning a positive net present value for energy and maintenance savings alone, should provide additional benefits *beyond energy cost savings,* based on industry research and case studies. Therefore, ***we recommend Package 2*** as the preferable package. It contains:

- Comprehensive interior and exterior LED lighting retrofit
- Comprehensive classroom daylighting with clerestory retrofits and Solatubes without dimmers. Dimming can be provided later if necessary, with electric shut-off shades on the Solatube or with suspended acrylic panels (see Appendix).
- High efficiency HVAC for gym
- Sealing and caulking (ongoing maintenance)
- BMS system
- Five high efficiency BARD HVAC unit replacements (the 6th will serve as a baseline comparison

Daylighting is an exemplary measure that provides productivity and health benefits, not just energy cost savings. Enhanced daylighting and views have been shown to improve learning and test scores in schools [see CEC Daylighting Report]. Other studies link daylighting and views to health, well-being and performance for office workers. Uncovering the clerestory windows and adding skylights would arguably improve the look and feel of the school as well.

Another measure that has additional value beyond the estimated energy savings is the Building Management System or BMS. A BMS not only overcomes human error, for instance turning down HVAC equipment when rooms are not in use, but it can also monitor remote equipment and identify issues without a maintenance person having to physically inspect the equipment, saving staff time and allowing problems to be fixed early. A BMS also helps enable measurement and verification of energy savings results. Therefore, we recommend the school opt for Package 2 (including the BMS) over Package 1, if budget permits.

Finally, replacing the inefficient and very loud BARD HVAC units in the modular classrooms with quiet, efficient units, will not only save energy, but will also allow students and teachers to concentrate better without the loud, distracting HVAC noise.

Package 1 adds the final recommended EEM, Solatubes in the gym that would augment the existing skylights to allow 100% daylighting. Because the gym already has some skylights providing daylighting benefits, this measure is less of a priority than classroom daylighting. It should be considered if budget allows.

With all four packages, we advise providing the maximum PV array to offset total annual kWh, rather than just the minimum array to achieve the TDV zero net energy requirement. Unless budgets dictate the lower upfront cost, maximizing the solar PV will be a long-term economic benefit for the school, with higher life cycle savings. Solar PV is the second-most cost-effective measure after LED lighting, and its associated NPV increases with additional PV array size, up to the point where total annual kWh usage is met (after which point, electricity overproduction would not be compensated at retail electricity rates)

2.7 Conclusion

Based on energy- and cost-optimization *and benefits beyond energy-cost savings*, we recommend a package of classroom daylighting, interior and exterior LED lighting retrofits, gym HVAC optimization, which is timed to align with required end-of-life HVAC replacement, a BMS system, efficient and quiet BARD unit replacements, and caulking and sealing as a maintenance staff task. Additional daylighting in the gym should be included as budgets allow. The school can achieve the Time Dependent Value (TDV) of Zero Net Energy (ZNE) with any of the four packages described above, leveraging the school's projected Prop 39 funding, which can be used for EEMs with SIR of 1.05 or higher, to the allowable funding allowance for the school. PG&E may also "buy down" the incremental cost of certain EEM packages. The retrofit will also enhance comfort and school performance by providing daylighting, the LED lighting will have lower maintenance/replacement costs, and the BMS will help optimize efficient operations, saving both time and cost. Meanwhile, the school's utility bills will be reduced dramatically.

By accomplishing this ZNE retrofit, the school will be an exemplary early win for the Zero Net Energy Schools Pilot, demonstrating to its students, parents, and staff, the achievability and benefits of offsetting all energy use with renewable energy. Newcastle will leave a legacy for generations to come, while gaining momentum toward California's bold goals to be increasingly powered by clean renewable energy, ultimately meeting the 2030 Challenge.

APPENDIX A: EEM DETAILS

Portable Classroom Heat Pump Replacement
The team examined the possibility of replacing the existing through wall heat pump units in the six portable classrooms that fall within the scope of this study. The following characteristics were used in the analysis:

- Predicted heat pump service life: 15 years
- Age of current equipment: 10 Years
- Typical Heating and Cooling performance of current equipment: 3.0 COP / 9.0 EER

For the proposed system, the following equipment efficiencies and costs were used:

1. Peak Performance Bard replacement
    a. EER: 14.5
    b. Cost: $89,851

Given that the current Bard units are nearing the end of their service life, it was assumed that they would be replaced in five years with units with the following characteristics:

1. Replacement Bard unit
    a. EER: 11
    b. Cost: $73,408

Under this scenario it was not found that energy cost savings alone could justify replacing the units before the end of their service life. The analysis shows an NPV of negative $18,500 over the 15 year service life of the unit, which translates roughly into an SIR of 0.79.

While replacement before the end of service life is not shown here to be justifiable from a financial perspective alone, the much quieter replacement units provide benefits in addition to the energy efficiency that can justify replacing the units early. But if this option is not selected, it is recommended that the existing units are replaced with high efficiency and quiet units when the current equipment fails.

LED tube replacements
LEDs not only use 1/3 less power for similar light levels on the desk surface, but they also last longer than fluorescents, reducing replacement and maintenance costs. LEDs don't flicker or hum, have good color rendition, and do not contain mercury (as do fluorescents, requiring them to be disposed of as hazardous waste).

High Efficiency HVAC
This measure is simply replacement of existing equipment with more efficient equipment and has no disadvantage assuming the equipment being replaced has reach the end of its service life or no longer meets school's needs.

Daylighting
Daylighting provides a cost-effective reduction in energy use, *if lights are turned off during daylit conditions.* It is imperative to note that automatic daylight dimmers are not included in the EEMs for cost considerations, (unless grants enable fixture replacement with dimmable LEDs to be adopted). Lights would have to be physically turned off, and this may require ongoing education or training, particularly as new teachers come on board. On cloudy days, or after a presentation has ended, the blinds should be

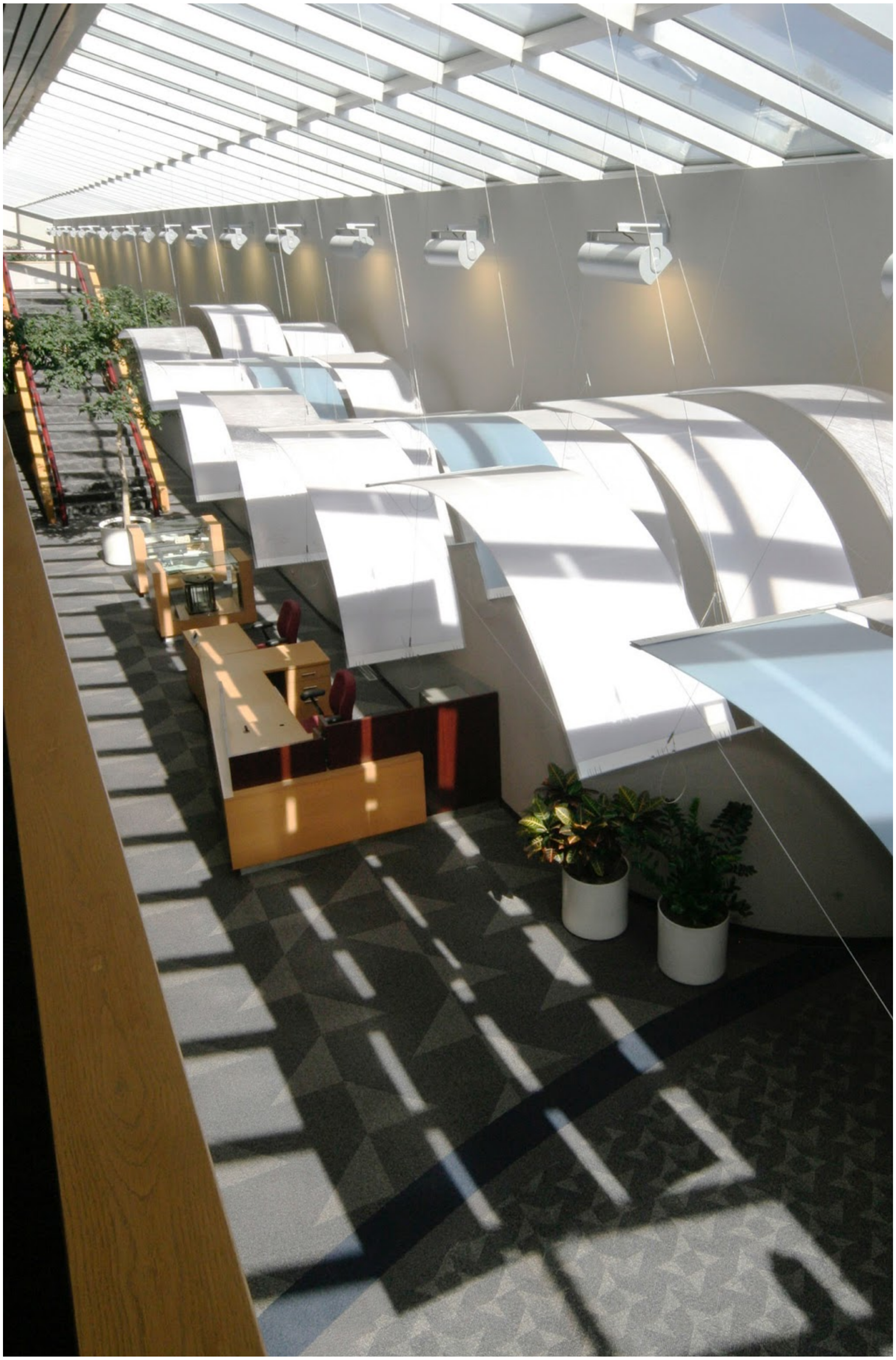
raised and the lights turned to the level they were previously, but this may not happen in practice without costly automation, and thus, savings may be lower than predicted.

Newcastle School, CA, with clerestories painted over and light shelves ineffective

Olani School, Hawaii, with light shelves and lights off

Room with Serralux Daylight Redirecting Film (left) / Room with Standard Glazing (right)

Skylight shading system using Armstrong suspended acrylic panels, reducing the intensity of the skylights and redirecting the light onto the ceiling, eliminating glare.



Skylight shading system using Armstrong suspended acrylic panels, reducing the intensity of the skylights and redirecting the light onto the ceiling, eliminating glare.

While daylighting can be a more complicated retrofit, it provides other benefits. According to a CEC Reanalysis of a Heshong Mahone Group study [see CEC Daylighting Report] students progressed 20-26% faster on test scores when learning in daylit classrooms with views*. Daylight and views are also associated with fewer sick days and better health outcomes in various studies (including offices, hospitals, etc.) With clear clerestory glazing, Newcastle Elementary could capitalize on some of these benefits, while providing better visual acuity, better color rendition and more pleasant lighting. Solatubes and clerestories could be equipped with blinds/louvers to darken them during slide shows and films.

While heat gain associated with replacing painted clerestory windows with clear ones will negatively affect peak cooling loads, it will produce an overall annual energy savings. This is because the overall annual energy advantage of letting more heat in in the winter outweighs the disadvantage of adding heat in the summer. The model shows the peak cooling loads increasing 2-3% due to stripping the paint from the clerestories, which we assume the existing HVAC equipment will be able to handle (this should be verified by the mechanical contractor). Note that the white roof retrofit reduced the peak cooling load approximately 3%, according to our model.

Perform a Mockup

To better evaluate the daylighting options, we recommend performing a demo. Replace the clerestory windows in one classroom and see the effect (measure the light levels) with and without SerraLux light-redirecting film. The SerraLux company was willing to perform a free demonstration. Test the Solatubes without dimmers to see their acceptability for teachers. Dimming is recommended by Solatube for classroom environments, and, based on case studies, is preferred. The project should budget for a dimming solution if non-dimmable Solatubes prove unacceptable.

APPENDIX B: LESSONS LEARNED

Some valuable insights were gained during the implementation of this project that can inform other ongoing projects and are discussed below.

Daylighting

Many schools were originally built with daylighting systems that were removed for various reasons. Through discussions with lighting experts and school personnel, we have learned that these reasons may include, perception during the 1970's that covering up windows would save energy, perception that windows were distracting to students in class, and the experience of glare and heat coming into classrooms, due to lack of appropriate window shading. We now know that proper daylighting has many benefits, as described above, and that we can design the daylighting system to avoid the potential negative factors (such as glare). Uncovering original daylighting systems may be more cost effective than providing new daylighting systems (or it can reduce the amount of new daylighting required), but this needs to be evaluated on a case by case basis.

Adding new tubular skylights is expensive. Our team sought ways to reduce the cost of this measure and make it more replicable across the state. One feature that has additional cost is the motorized skylight dimmer. Our feedback from school districts is that teachers prefer to have the ability to dim their skylights for presentations, but we are piloting non-dimming skylights to see if this lower cost option is acceptable with today's better projectors (dimming feature can be added later).

Behavioral concerns (not realizing energy savings if teachers disregard daylighting systems and turn lights on anyway) led us to research the effectiveness of other daylighting installations. We learned that with a Solatube daylighting solution that provides 100% of the required light levels, the Sacramento Independent School District teachers do leave their lights off and "love the skylights." Savings have been realized. Of particular note, the maintenance staff prefers *not* having dimming controls, stating that this is another feature that can break, and noted that the "on/off" switch solution is working great in Sacramento.

Retrofits that Trigger Department of State Architect (DSA) Review or Title 24 Upgrades

Some retrofits may become prohibitively costly and time consuming when they trigger a DSA review, which is one reason why Energy Service Companies and other retrofit contractors prefer "like for like" retrofits. We learned that a more efficient rooftop HVAC unit that weighs more than the existing unit will trigger a DSA review, as will a mini-split heat pump that might be selected to replace an existing through-wall "Bard" unit. In this project, we were able to work with the equipment manufacturer of the high efficiency rooftop unit to shed weight in the mounting system to keep the unit within the original weight class, avoiding the DSA review, saving the EEM from being eliminated.

We also learned that changing out existing interior light bulbs for LED bulbs can avoid the costly Title 24 requirement to install dimming controls when a set of entire light fixtures is replaced. While replacing the fixtures would be a better solution, the cost savings achieved by just switching out bulbs may free up funds for other EEMs and provide a better overall package.

APPENDIX C: MODELING ASSUMPTIONS

The modeling software used for this analysis was Energy Pro. The following chart describes the assumptions used for the existing conditions and equipment entered into the baseline energy model.

HVAC			
Item Description	Location	Properties	Source
Carrier 48TJD - Packaged DX	- Classroom 203 - Classroom 212 - Classroom 209 - Classroom 300 - Classroom 301 - Kitchen (E.) - Lobby and Entry	- Heat Capacity (btu/hr.): 72,000 - 80% AFUE - Cool Capacity (btu/hr.): 76,500 - 9.5 EER	Site visit, Manufacturer cut sheets, Historic codes
Carrier 48TJD - Packaged DX	- Classroom 302 - Classroom 303 - Classroom 304 - Computer Classroom - Office B31 (E.) - Counsel B30 (E.) - Staff B35 (E.) - Office B36 (E.) - Nurse B33 (E.) - Psych B28 (E.) - Office B29 (E.) - Office B32 & Entry B34 (E.)	- Heat Capacity (btu/hr.): 72,000 - 80% AFUE - Cool Capacity (btu/hr.): 49,100 - 10.5 SEER / 9.5 EER	Site visit, Manufacturer cut sheets, Historic codes
Carrier 48TJD - Packaged DX	- Kindergarten Classroom - Art & Craft Room - Library - Classroom 202 - Classroom 204 - Classroom 208 - Classroom 210 - First Grade Classroom	- Heat Capacity (btu/hr.): 72,000 - 80% AFUE - Cool Capacity (btu/hr.): 60,600 - 10.5 SEER / 9.5 EER	Site visit, Manufacturer cut sheets, Historic codes
Carrier 48TJD - Packaged DX	- Staff Lounge	- Heat Capacity (btu/hr.): 72,000 - 80% AFUE - Cool Capacity (btu/hr.): 35,400 - 10.5 SEER / 9.5 EER	Site visit, Manufacturer cut sheets, Historic codes
BARD Unit (Portable) -	- Portables 1 & 2 (next	- Heat Capacity	Site visit, Manufacturer

Packaged DX	to 300s) - Portable 3 (next to 300s) - Kindergarten CCSMU (next to parking lot) - TK 501 (next to parking lot) - 502, 503, and Staff Rm 504 (near parking)	(btu/hr.): 24,000 - 7.70 HSPF - Cool Capacity (btu/hr.): 23,600 - 10.5 SEER / 9.5 EER	cut sheets, Historic codes
Gym Unit - Packaged DX	Gym	- Heat Capacity (btu/hr.): 240,000 - 80% TE - Cool Capacity (btu/hr.): 240,000 - 9.5 EER	Site visit, Manufacturer cut sheets, Historic codes
	Walls		
Item Description	Location	Properties	
6" Concrete Wall	- Gym - Kitchen	- R Value: 1.2 - U Factor: 0.82 - Solid Unit Masonry	Site visit, Modernization Plans, Historic codes
R-11 Wall	- All other walls	- R Value: 9.1 - U Factor: 0.11 - Wood Framed	Site visit, Modernization Plans, Historic codes
	Windows		
Item Description	Location	Properties	Source
Clerestory Single Pane Painted Metal Frame Windows	Classrooms (above shade structure)	- U factor: 1.04 - SHGC: 0	Site visit, Modernization Plans, Historic codes
Single Pane Typical Metal Frame Window	All Other Openings	- U factor: 1.04 - SHGC: 0.76	Site visit, Modernization Plans, Historic codes
	Roof		
Item Description	Location	Properties	Source
R-11 Roof Cathedral	- Portables	- R Value: 11.9 - U Factor: 0.084 - Wood Framed Rafter	Site visit, Modernization Plans, Historic codes
R-19 Roof Cathedral	- All Other Locations	- R Value: 19.6 - U Factor: 0.051 - Wood Framed Rafter	Site visit, Modernization Plans, Historic codes

The following load profile schedules were used in the EnergyPro model

Classroom/Portables Load Profile Schedules						
	Lighting	Infiltration	Occupants	Receptacle	Process	DHW
Operating Time	M-F - 8AM to 5PM		M-F - 7AM - 5PM	M-F - 8AM to 5PM	M-F - 8AM to 6PM	na
Office Load Profile Schedules						
	Lighting	Infiltration	Occupants	Receptacle	Process	DHW
Operating Time	M-F - 7AM to 11PM		M-F - 7AM - 11PM	M-F - 7AM to 12AM	M-F - 7AM to 12AM	M-F - 10AM to 3AM
Gym Load Profile Schedules						
	Lighting	Infiltration	Occupants	Receptacle	Process	DHW
Operating Time	M-F - 6AM to 9PM		M-F - 7AM - 4PM	na	na	na

The following are the operation schedules that were used in the EnergyPro model

Classroom/Portables HVAC Operation Schedules			
	Fan	Heating	Cooling
Operating Time	M-F - 6AM to 6PM	M-F - 7AM-8AM @ 63 - 8AM-3PM @ 65 - 3PM-4PM @ 63 - 4PM-7AM @ 55 Sat, Sun, Holiday - All @ 55	M-F - 7AM-8AM @ 87 - 8AM-4PM @ 75 - 4PM-5PM @ 87 - 5PM-7AM @ 95 Sat, Sun, Holiday - All @ 95
Office HVAC Operation Schedules			
	Fan	Heating	Cooling
Operating Time	M-F - 8AM to 3PM	M-F - 7AM-8AM @ 63 - 8AM-3PM @ 70 - 3PM-4PM @ 63 - 4PM-7AM @ 55 Sat, Sun, Holiday - All @ 55	M-F - 7AM-8AM @ 87 - 8AM-4PM @ 75 - 4PM-5PM @ 87 - 5PM-7AM @ 99 Sat, Sun, Holiday - All @ 99

Classroom HVAC Operation Schedules			
	Fan	Heating	Cooling
Operating Time	M-F - 8AM to 3PM	M-F - 7AM-8AM @ 63 - 8AM-3PM @ 65 - 3PM-4PM @ 63 - 4PM-7AM @ 55 Sat, Sun, Holiday - All @ 55	M-F - 7AM-8AM @ 87 - 8AM-4PM @ 78 - 4PM-5PM @ 87 - 5PM-7AM @ 95 Sat, Sun, Holiday - All @ 95

The following are the Life Cycle Cost Assessment Assumptions that were used.

Financial Inputs	
Timeframe (yrs)	20
Discount Rate	5%
Inflation Rate	2%
Reinvestment Rate	5%
Finance Rate	4%
Finance Terms (yrs)	15
LTV	100%
- Inputs were set to align to Prop 39 guidelines - Finance Term and Rate provided by team. All measures assumed to financed except PV (as this was funded by Prop 39)	

Utility Inputs	
Electricty Cost per kWh	$0.23
Electricity Escalation Rate	4%
Gas Cost per Therm	$0.65
Gas Escalation Rate	4%

Notable EEM Assumptions	
PV	Annual efficiency degradation of 0.5% applied to energy savings.
PV	Annual Maintenance cost of $20 per kW system size assumed
Gym RTU	Like for like replacement after 5 years and accounted for in the cash flow
BARD	Like for like replacement after 5 years and accounted for in the cash flow
LEDs	Annualized labor savings of $18 per lamp going from T8's to LEDs