# Zero Net Energy Schools

Presented by Alexis Karolides
May 25, 2017

POINTENERGY
INNOVATIONS

# Part 1: ZNE Retrofit Process

# How ***ZNE*** affects project process

- Site evaluation
- Performance targets
- Retrofit process
- Delivery

# *ZNE* adds another layer of planning

- Optimize ZNE retrofits *across the whole district*
  - Need (comfort, learning)
  - Savings potential
  - Scheduled replacements & renovations (equipment, roofs)
- *Coordinate* ZNE retrofit with non-energy retrofits at the school, too!
- Meet additional performance and cost requirements
  - ZNE requires ability to site enough renewable power (roof? parking? playground canopy?)
  - SIR requirements may conflict with other school district goals, such as prevailing wage

# Site Evaluation Parameters

- Where to put solar?
  - When are roofs *not* the cheapest location?
- Plan for DSA requirements
- Determine unique conditions (ask the staff!)
  - Planned retrofits
  - Behavior & preferences
  - Maintenance team needs
  - Peculiar local requirements or inspectors
  - Prevailing wages may hamper SIRs

# The **30%** conundrum

- Resistance to upgrading?
- Need for IEQ improvements?
- Energy implications?

# Site Evaluation

- Unique design features
- Daylighting opportunities, shading
- Air sealing & heat recovery ventilation?
- Lighting, unique conditions
- HVAC condition & replacement schedule
- Portables - condition of lighting & Bard units
- BMS / occ sensors - are lights/HVAC left on?
- Opportunities in the kitchen (energy & water)

Painted clerestories

Excess lighting

Dark film

# Performance Targets

California Energy Commission Prop 39 Requirement: SIR ≥ 1.01

**SIR = NPV/(Project Installation Cost – Rebates – Other Grants – Non-energy Benefits)**

**Non Energy Benefits** (Improved lighting quality,acoustics, IAQ, comfort, health & safety, accessibility) Considered by CEC to be 5% x project installation cost)

**NPV = Energy Cost Savings + Maintenance Savings**

- Energy Cost Savings = Total energy cost savings over equipment's life: kWh energy, kW demand, natural gas & other liquid fuel savings)
- Maintenance Savings = Annual maintenance cost/savings (≤ 2% of project cost)
- Assume: Energy cost escalation rate = 4 percent, Discount rate = 5 percent, Inflation = 2 percent

***Your* performance targets?**

# Process of the Retrofit Project

- Plan: optimize scarce funds (juiciest retrofit first, best solar PV locations)
- Identify school's goals, funding & implementation strategy
- Evaluate site
  - Identify possible energy efficiency measures (EEMs)
  - Identify red flags or challenges
- Model & calibrate with utility bills
- Analyze packages of measures for SIR *and other goals*
- Select the package and coordinate implementation
- Deliver & monitor

# Ensuring Delivery on Time, on Budget, and to ZNE

- Align ZNE project with other retrofits
- Plan adequate funding upfront - timeframe may be critical
- Backup plans for bumps along the way
  - Unexpected DSA ruling
  - Timeframes extended by other factors
  - Contractor issues
  - Conflicts with other retrofits
  - Unforscene aesthetic concerns, operational concerns . . .
  - Unforscene asbestos, lead . . .

# Lessons Learned

- Plan across the whole district
- Ensure *practicality* of onsite solar array (or, why not offsite . . . ?)
- Troubleshoot ahead (school staff interview checklist; backup plans)
- Use imagery, site visits & conference calls with other schools (for Solatube installations, etc.)
- It's not the standard audit, ZNE pushes the envelope!

# Part 2: ZNE Retrofit Technologies

# Technologies: Opportunities in ZNE School Retrofits

- Design approaches & construction considerations
- Technologies in PG&E ZNE retrofits
- Plans for operation & ongoing evaluation
- Occupant engagement
- Lessons learned

# Approaching the Retrofit in the Right Order

- Consider comfort and health first (thermal, acoustic comfort, daylight, views)
- Align with other retrofits (new roof? gut renovation? plans for portables?)
- Start with load reduction
  - Envelope first (sealing/caulking, insulating, shading, windows)
  - Shed unnecessary lighting & plug loads
- Then optimize mechanical *design*
- Then optimize mechanical equipment
- *Then* consider PV &/or other renewables

# People First

- Glare-free natural light
- Views
- Clean fresh air
- Quiet
- Thermally comfortable

# Daylighting (2002, Heshong Mahone, PG&E)

**Students in daylit schools progress 20-26% faster on test scores**

--Heshong Mahone Group, Pacific Gas & Electric Daylighting Study 2002

## Air quality (2015, Harvard)

# Elevated CO2 Levels Directly Affect Human Cognition

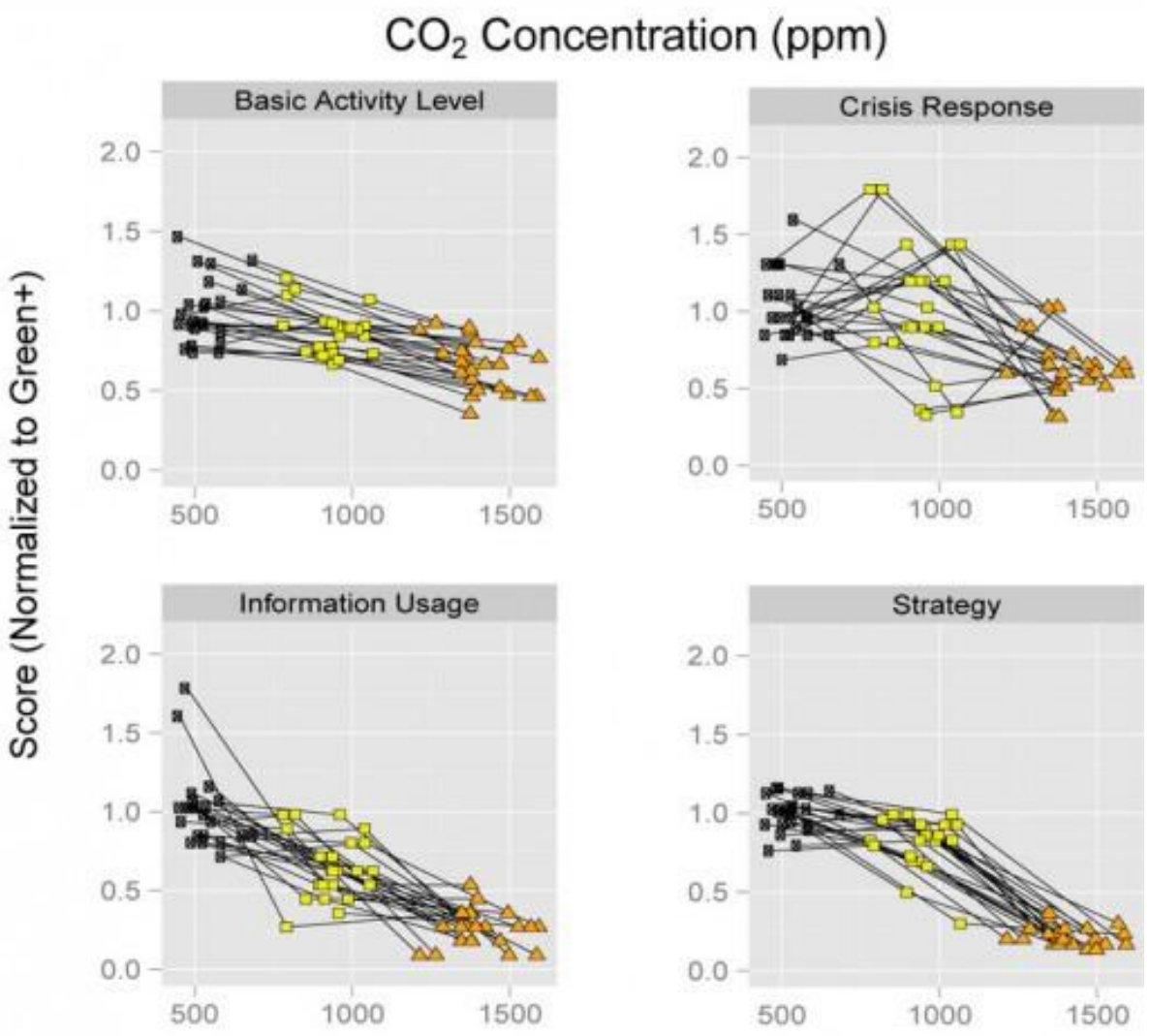
LEED ventilation (low CO2, low VOCs) improved scores for:

Crisis Response 97-131%
Information Usage 172-299%
Strategy 183-288%

--Joseph G. Allen, et al, Harvard, 2015; https://ehp.niehs.nih.gov/15-10037/

# How CO2 Levels Affect Human Cognition -

Allen et al (2015), Harvard Study




Normalized cognitive function scores by participant and corresponding CO2 levels in their cubicle. The Green+ case had CO2 in the 500 ppm range due to high levels of outside air. It was compared to office settings in the 930 ppm range (yellow squares) and in the 1400 ppm range (orange triangles).

Green+ Medium $CO_2$ High $CO_2$

# Implications of not running ventilation system

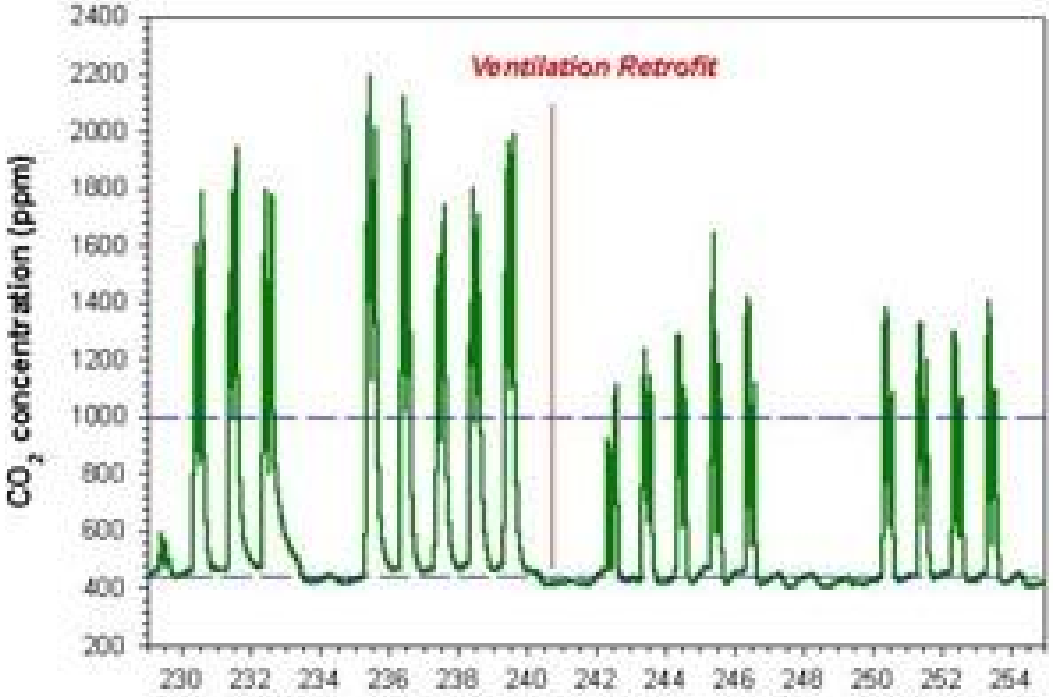
"The HVAC [standard Bard unit] is so loud, I heat the classroom before school starts, but then I just leave it off when I'm teaching"

--OUSD teacher, 2016

HVAC provides 15 cfm/person required by law, only when the unit is either heating or cooling, or fans are turned on manually.Teachers struggling to teach over noisy HVAC sometimes preferred to suffer in  a hot, cold, or stuffy room

--LBNL Study, 2002

CO2 Level in Portables, before & after new HVAC w/ERV



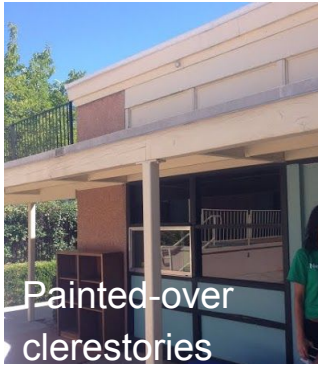

--Florida Portable Classroom Study (1999)

# Technologies in PG&E ZNE Retrofits

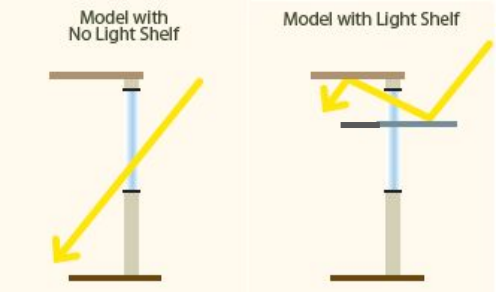

# Addressing “temporary” classrooms

Inefficient, noisy units have quiet efficient versions

# Deep and glare-free daylight

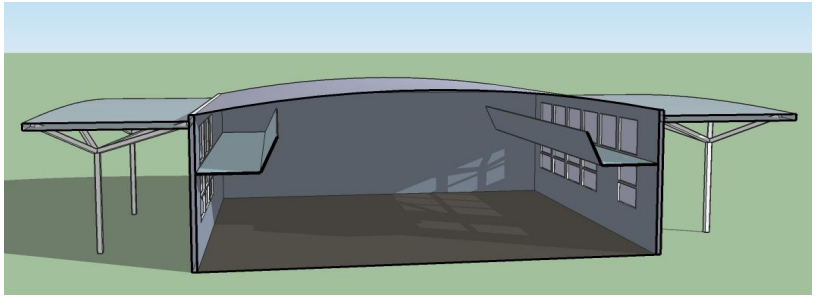



Goal: restore daylight




Original daylight design was optimal


Avoid this



Design modification mid-retrofit, 2017

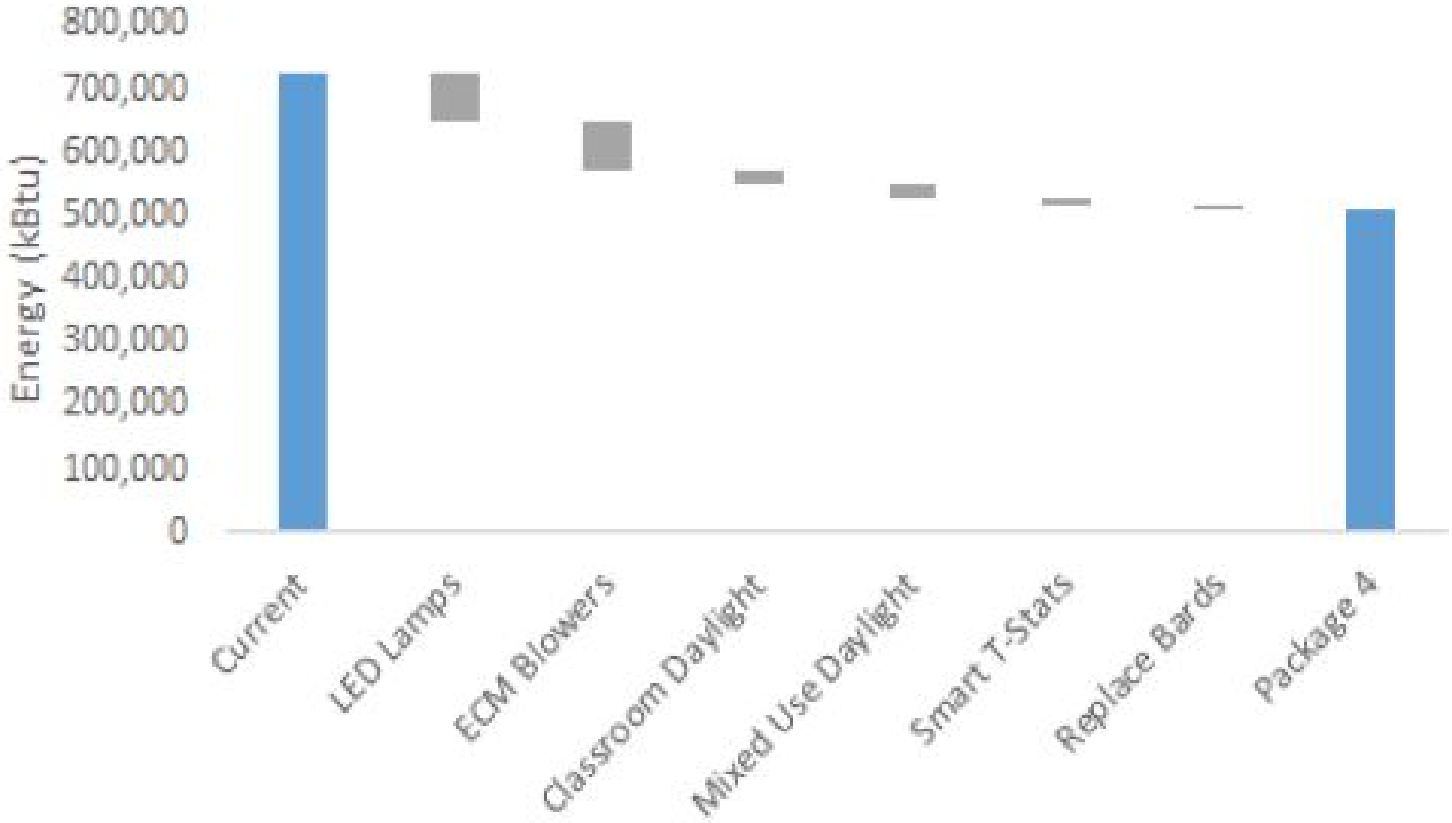
# Solatube skylighting

# Replacing interior lamps & exterior fixtures with LEDs

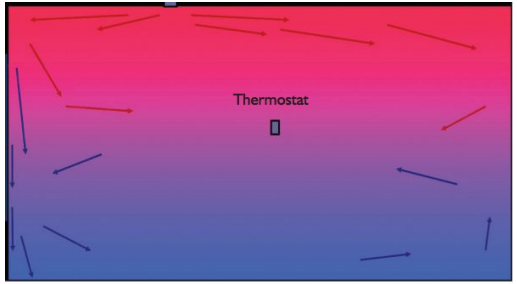
Replacing interior fixtures is more costly than replacing bulbs, and triggers T24 controls upgrades

# EEMs in an elementary school reduce EUI 32%

# EEMs in another elementary school reduce EUI 30%



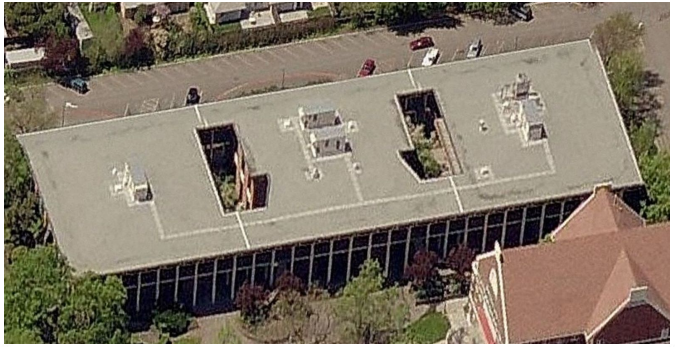
# Community College Example

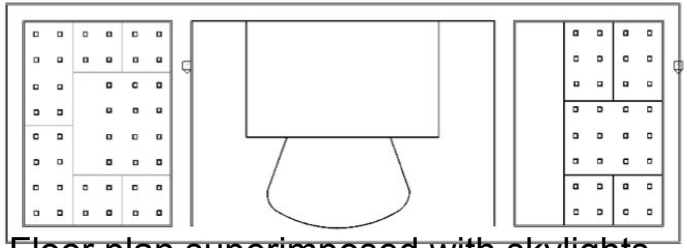




*e 1: Typical overhead heating scenario.*

# Community College EEMs

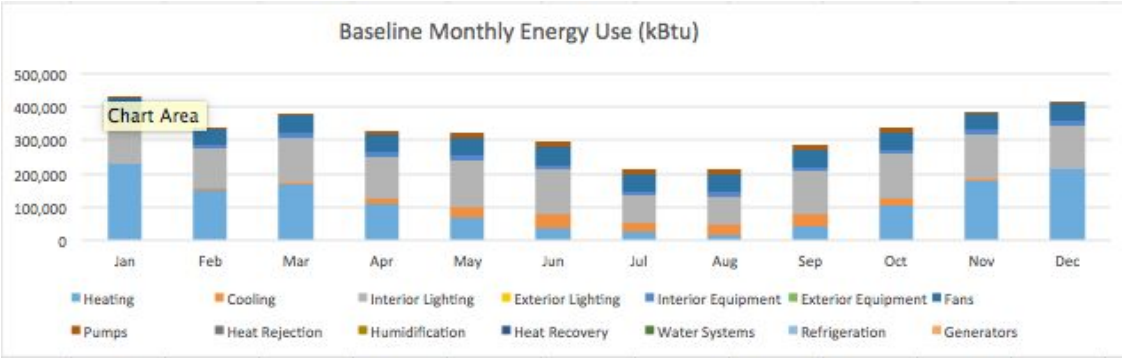
| Measure | Est. Max Savings |
|---|---|
| **Building insulation (roof, walls) & reflective roof coating** | 4% |
| **Sealing and Caulking** | TBD |
| **Classroom Daylighting** (Solatubes) | 5% |
| **Lighting:** Int & ext ILED fixtures, auto dimming & occ sensors | 27% |
| **HVAC air-based package** | 15% |
| Efficient Roof AC unit (custom tall AI same-weight unit) | |
| Modern VAV reheat boxes with lower temp reheat coils | |
| Demand ($CO_2$) controlled ventilation (classrooms & auditorium) | |
| **HVAC 4-pipe fan-coil based package** | 12% |
| Chiller replacement | |
| Boiler replacement | |
| New DHW heater (electric heat pump, or point-of-use) | |
| New variable frequency drive pumps | |
| Baseboard convector replacement (high heat transfer radiators) | |
| Modern VAV reheat boxes with lower temp reheat coils | |
| **Transformer replacement** | 1% |
| **Mini-split for computer room** | TBD |
| **Install PV panels to offset remaining energy use** | |

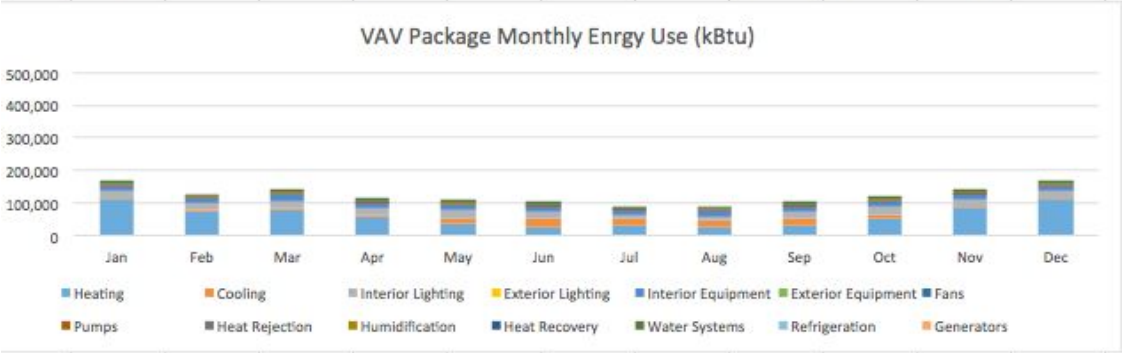


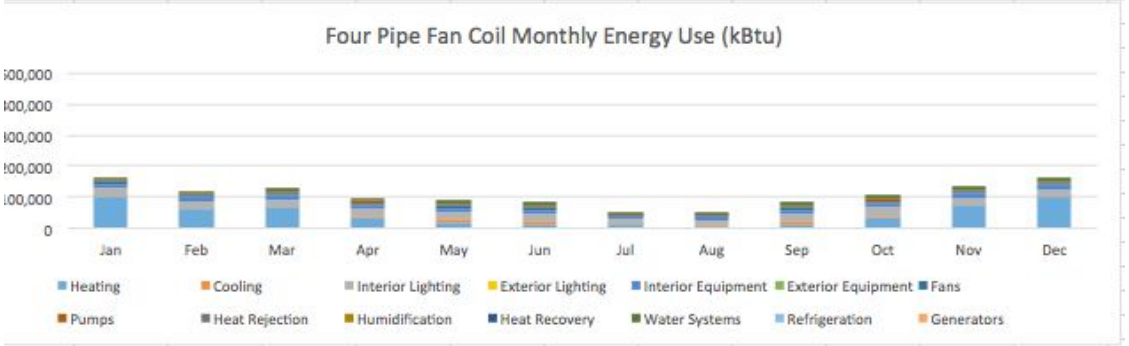


Floor plan superimposed with skylights

# Taking a 94 kBtu/sf/yr EUI down to ~35?



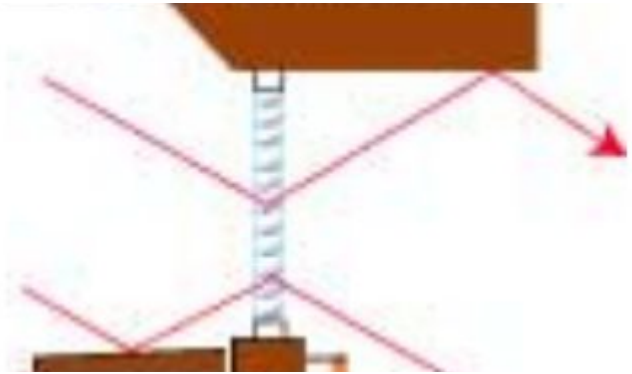
# Plans for Operation & Ongoing Evaluation

- Metering is key
- Consider monitoring CO2
- Visual display and feedback mechanism for users?
- Operational training for facilities managers
- Education program (user's manual) for teachers & other staff


Ecobee Smart Thermostat has logging capability for temperature and setpoint settings

# Occupant Engagement

- Manual control of lights vs occupancy sensors
- Running the Bards for adequate ventilation in the modular classrooms
- Optimal use of blinds (eliminate glare but avoid blocking all daylight!)
- Solatubes without dimming - user feedback
- Teaching opportunities for students



Properly used, blinds redirect rather than block all daylight

# Lessons Learned

- ZNE retrofits can uncover dramatic unmetered inefficiency
- CA needs a comprehensive plan to address its 30% “portable” classroom stock
  - Major retrofits have DSA & cost issues
  - At minimum: fix the IEQ problems and save energy
  - Philosophical question: equality of daylighting and air quality
- SIR of replacing light fixtures (and triggering T24) can’t compete with relamping
- Many IEQ retrofits (quieter Bards, daylight) may not compete on SIR alone
- High effic HVAC may not meet SIR unless due for replacement anyway
- Heavier (more efficient) HVAC units trigger DSA (try customizing)
- Overworked maintenance staff favor time- and energy saving of BMS
- User training is essential to reap the *energy* benefit of daylighting

# Thank You

**San Francisco**
220 Montgomery St. Suite 321
San Francisco, CA 94104

**Oakland**
5201 Harbord Dr.
Oakland, CA 94618

Phone: (415) 663-6340

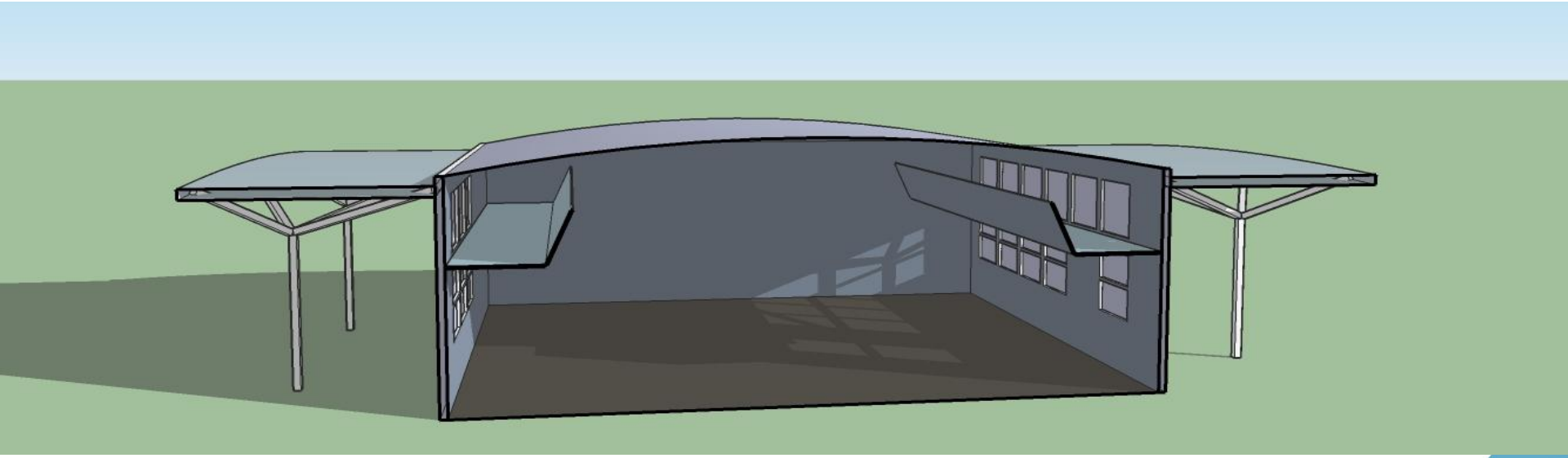
POINTENERGY INNOVATIONS

**Energy 2.0:**
Reimagining all things Energy

# Appendix

# Modeling of new outdoor canopy design

- Existing design with clear clerestories
- New proposed design with and without Kalwall, internal light shelves, shelf wings, 2-foot and 4-foot extensions on the outdoor overhangs.



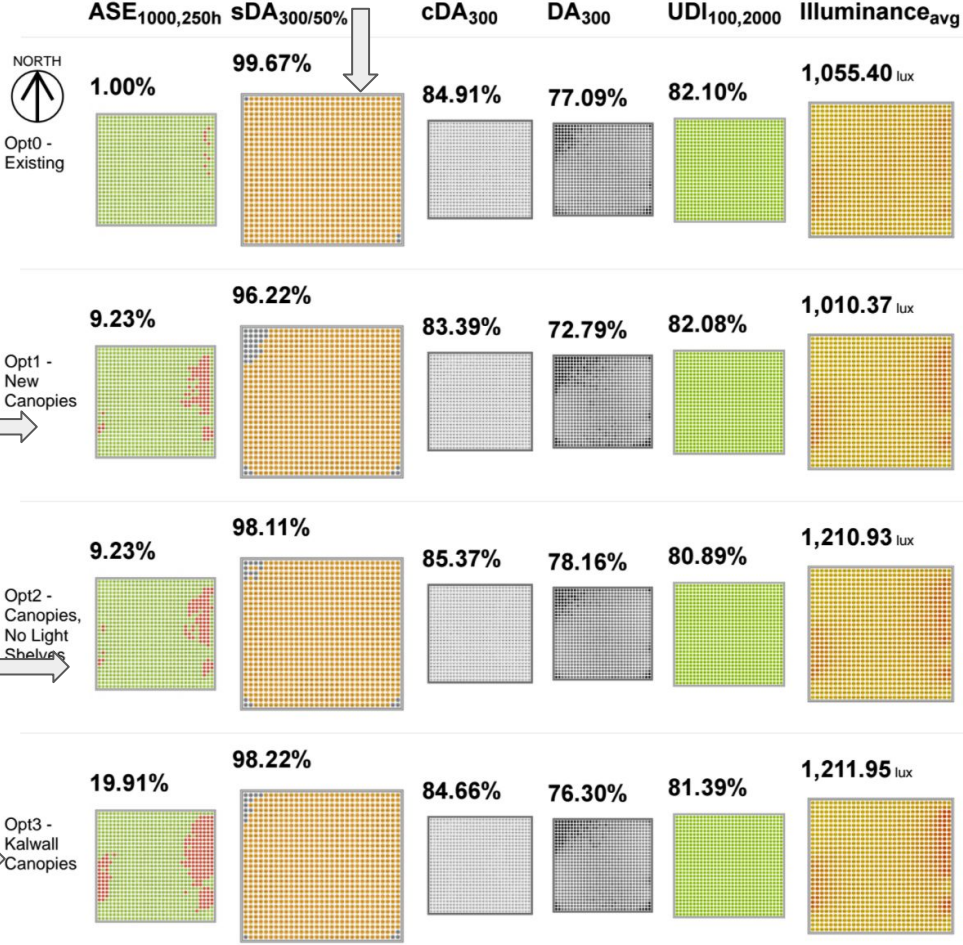
# Results

Good spatial daylight autonomy

Classroom 203 (East and West facades)
Annual Daylight Metrics --no wings

Point Energy Innovations
4/12/17

| | LEED V4 Metrics | | Other Metrics | | | |
|---|---|---|---|---|---|---|
| | $ASE_{1000,250h}$ | $sDA_{300/50\%}$ | $cDA_{300}$ | $DA_{300}$ | $UDI_{100,2000}$ | $Illuminance_{avg}$ |
| Opt0 - Existing | 1.00% | 99.67% | 84.91% | 77.09% | 82.10% | 1,055.40 lux |
| Opt1 - New Canopies | 9.23% | 96.22% | 83.39% | 72.79% | 82.08% | 1,010.37 lux |
| Opt2 - Canopies, No Light Shelves | 9.23% | 98.11% | 85.37% | 78.16% | 80.89% | 1,210.93 lux |
| Opt3 - Kalwall Canopies | 19.91% | 98.22% | 84.66% | 76.30% | 81.39% | 1,211.95 lux |




Moderate glare

Moderate glare

Significant glare

# Results

Good spatial daylight autonomy

Classroom 203 (East & West facades) Annual daylight metrics--no wings

LightStanza

| | LEED V4 Metrics | | Other Metrics | | | |
|---|---|---|---|---|---|---|
| | $ASE_{1000,250h}$ | $sDA_{300/50\%}$ | $cDA_{300}$ | $DA_{300}$ | $UDI_{100,2000}$ | $Illuminance_{avg}$ |
| Opt4 - Canopies +2ft (Minimal glare) | 6.01% | 95.22% | 82.74% | 71.24% | 82.40% | 920.14 lux |
| Opt5 - Canopy +4ft (Almost no glare) | 4.12% | 94.66% | 82.15% | 69.75% | 82.81% | 853.53 lux |