EFFICIENT AND HEALTHY SCHOOLS

2022/23 Efficient and Healthy Schools Webinars

Retrofit Packages for Schools: Performance Requirements, Energy Savings and Costs

U.S. Department of Energy and Lawrence Berkeley National Laboratory

Oct 12, 2022

EFFICIENT AND HEALTHY SCHOOLS

Efficient and Healthy Schools Campaign Webinar

Welcome!

- Agenda is in the chat
- Webinar is being recorded
- All attendees are muted during this webinar
- Please enter questions into the chat or Q&A at any time
- We will send out the slides and presentation recording shortly after the webinar

Today's Agenda

- Efficient and Healthy Schools Campaign – Alexandra (Allie) Johnson, Berkeley Lab
- Retrofit packages for schools: performance requirements, energy savings and costs
  - Paul Mathew, Ph.D., Staff Scientist, Berkeley Lab
    - Brief Q&A
  - Duane Kubischta, P.E., Project Manager, kW Engineering
- Q&A. You can also send questions to EHSC@lbl.gov
- Closing and helpful links - Allie Johnson

Efficient and Healthy Schools Campaign

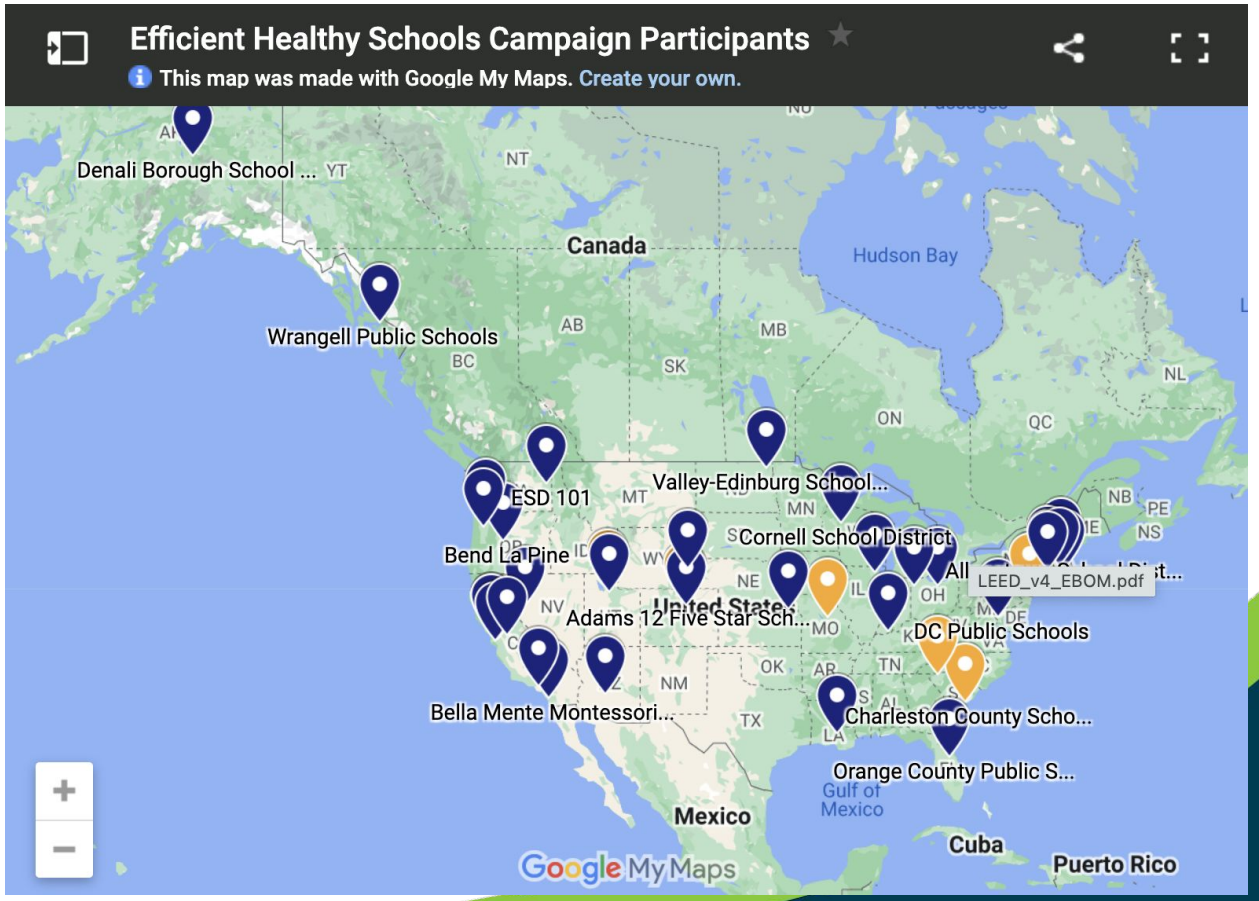
- The campaign aims to:
  Improve energy performance, reduce carbon emissions, and promote a healthy learning environment in schools.
- The Campaign engages K-12 schools especially those serving low-income student populations and in rural areas.
- This campaign is led by the U.S. Department of Energy with technical support from Lawrence Berkeley National Laboratory.

Organizing partners:

Become a Participant or Supporter

- Campaign participants can:
  - Access technical assistance and resources on best practices, guidance, case studies, and webinars
  - Receive recognition for their efforts to improve energy performance, health, and resilience

- Campaign supporters are encouraged to share and promote goals and benefits of efficient and healthy schools



Previous Recognition

- Schools and school districts that use technical specifications for HVAC retrofits, upgrades, and replacement, resulting in reduction in energy costs and improvements in energy efficiency and indoor environmental quality (IEQ). Categories:
  - HVAC Inspection and Maintenance for IAQ
  - Efficient HVAC for Indoor Environmental Quality
  - Ongoing Monitoring and Analytics for HVAC Performance
  - Team Approach to Support Strategic Investments in Efficient and Healthy Schools

Recognition Program: 2022/23 Second Round!

The campaign will recognize exemplary solutions and efforts by K-12 schools and districts in the following categories:

Energy Efficiency Plus Health - To recognize schools and districts for improving energy efficiency and indoor environmental quality (IEQ: indoor air quality, lighting, thermal comfort, acoustics)

Emissions Reduction and Resilience - To recognize schools and districts for reducing carbon emissions and improving resilience

Title I schools, rural schools, and schools in disadvantaged communities are especially encouraged to apply.

Energy Efficiency Plus Health

As an example, HVAC retrofits can improve one or more aspects of indoor environmental quality by

- Improving occupant thermal comfort
- Ensuring quieter HVAC equipment to reduce background noise in classrooms
- Providing adequate outdoor air ventilation to improve indoor air quality
- Enhancing air filtration to remove particulate matter (e.g., from traffic, wildfires) and respiratory aerosols for infection control

EFFICIENT AND HEALTHY SCHOOLS

https://betterbuildingssolutioncenter.energy.gov/toolkits/low-carbon-technology-strategies-toolkit

Emissions Reduction and Resilience

Better Buildings® U.S. DEPARTMENT OF ENERGY

Low Carbon Technology Strategies

PRIMARY SCHOOL

Driving our nation's buildings to low and zero carbon saves money, creates jobs, and leads to a healthier environment and more resilient economy. The table below includes steps that building owners and operators can implement to achieve smart, healthy, and low-carbon primary schools within their existing building portfolios. Primary schools often use packaged rooftop units for heating, cooling, and ventilation. Assess current conditions in your building against the simple, intermediate, and advanced options to begin planning your next steps to reduce carbon emissions. If you have a commercial kitchen, include low carbon strategies for kitchens (equipment, ventilation, refrigeration, and water heating).

Technology		Simple	Intermediate	Advanced
Lighting	Interior Lighting	• Install Type B tubular TLEDs that meet DesignLights Consortium (DLC) technical requirements • Reduce overlit spaces • Install occupancy sensors or vacancy sensors	• Install dimmable LED retrofit kit or replace with LED fixture that meets DLC technical requirements • Install daylighting controls and occupancy / vacancy sensors • Integrate with building automation system (BAS) if possible	• Install retrofit kit or new luminaire with luminaire level lighting controls • Include integrated daylight and occupancy sensor networked lighting controls that meet DLC requirements, load shed via Auto-DR interface, and integrate with BAS
	Exterior and Parking Lot Lighting	• Install LED screw base replacement for HID lamps that meets DLC requirements • Install photocell to control lighting	• Replace with area luminaires that meet DLC requirements • Install time clock and reduce lighting at night	• Redesign using the Better Buildings Parking Lot specification and include video-based occupancy sensors
Space Conditioning and Water Heating	HVAC	• Verify and repair dampers • Test and seal ducts • Install advanced RTU controls retrofit (variable speed supply fan, integrated air-side economizer, and RTU-level demand-controlled ventilation (DCV))	• Replace equipment with right-sized, high-efficiency equipment (CEE Advanced Tier) • Install air source heat pump RTUs, dual fuel RTUs, or variable refrigerant flow (VRF) systems • Add energy recovery ventilators • Implement air cleaning technology to reduce ventilation • Install active thermal energy storage for load shifting and system optimization • Add evaporative cooling in dry climate zones	• Install water source or ground source heat pumps • Switch to radiant or chilled beam systems with a dedicated outdoor air system (DOAS) for ventilation • Implement natural ventilation, controlled in coordination with mechanical ventilation
	Water Heating	• Reduce water heating demand through various technologies like low-flow faucets and showerheads	• Install point-of-use electric water heaters for small, distributed loads • Install high-efficiency, connected heat pump water heaters	• Install CO_2 air-to-water heat pumps
Controls and Analytics	Install or Upgrade Controls	• Widen zone temperature dead band on existing thermostats • Install wireless networked thermostats to centrally manage heating/cooling set points, setbacks, and schedules • Implement building Re-tuning™ process • Automatically shut off equipment (exhaust fans, room air cleaners, other loads) during unoccupied times	• Add controls to support holiday scheduling, optimal start, and additional monitoring points • Reduce airflow to zones during unoccupied times with zone-level DCV • Implement demand limiting RTU controls and continuous demand management	• Reduce airflow to zones during unoccupied times by integrating occupancy sensors from the lighting control system into the HVAC control system • Implement controls that integrate building loads, thermal/battery storage, on-site co-generation plants, PV, and EV charging to provide demand flexibility (Market Brief)

Learn more at betterbuildingssolutioncenter.energy.gov/ U.S. DEPARTMENT OF ENERGY

Better Buildings® U.S. DEPARTMENT OF ENERGY

Low Carbon Technology Strategies

SECONDARY SCHOOL

Driving our nation's buildings to low and zero carbon saves money, creates jobs, and leads to a healthier environment and more resilient economy. The table below includes steps that building owners and operators can implement to achieve smart, healthy, and low-carbon secondary schools within their existing building portfolios. Secondary schools often include complex heating and cooling systems or packaged rooftop units and can include specialty equipment for gymnasiums, pools, and buses. Assess current conditions in your building against the simple, intermediate, and advanced options to begin planning your next steps to reduce carbon emissions. If you have a commercial kitchen, include low carbon strategies for kitchens (equipment, ventilation, refrigeration, and water heating).

Technology		Simple	Intermediate	Advanced
Lighting	Interior Lighting	• Install Type B tubular LEDs that meet DesignLights Consortium (DLC) technical requirements • Reduce overlit spaces • Install occupancy sensors or vacancy sensors	• Install dimmable LED retrofit kit or replace with LED fixture that meets DLC technical requirements • Install daylighting controls and occupancy / vacancy sensors • Integrate with building automation system (BAS) if possible	• Install retrofit kit or new luminaire with luminaire level lighting controls • Include integrated daylight and occupancy sensor networked lighting controls that meet DLC requirements, load shed via Auto-DR interface, and integrate with BAS
	Exterior and Parking Lot Lighting	• Install LED screw base replacement for HID lamps that meets DLC requirements • Install photocell to control lighting	• Replace with area luminaires that meet DLC requirements • Install time clock and reduce lighting at night	• Redesign using the Better Buildings Parking Lot specification and include video-based occupancy sensors
Space Conditioning and Water Heating	HVAC Cooling and Heating Equipment	• Clean condenser and evaporator coils • Add a heat exchanger and water side economizer controls • Optimize boiler combustion efficiency • Install boiler energy recovery • Implement alternative water treatment system and optimize cooling tower performance • Install advanced RTU controls retrofit (variable speed supply fan, integrated air-side economizer, and RTU-level demand-controlled ventilation (DCV))	• Replace chillers with high-efficiency, low-GWP systems and consider heat recovery chillers • Utilize a small or modular, high-efficiency chillers for highly variable loads • Upgrade to high-efficiency condensing boilers • Utilize a modular boiler configuration to avoid low part load operations • Use dual fuel heat pump RTUs to target 90% of heating with heat pumps and 10% with gas heating • Add evaporative cooling to air cooled condensers on chillers and RTUs • Install active thermal energy storage systems for load shifting and system optimization	• Replace chiller and gas/oil boiler systems with air source, water source, or ground source heat pumps or variable refrigerant flow (VRF) systems • Install a small high-efficiency gas boiler in combination with heat pumps if difficult to meet 100% load with heat pumps • Implement a building or district water loop heat exchange and heat pump system
	HVAC Air and Hydronic Systems	• Rebalance air systems and set static pressure resets • Verify and repair dampers • Test and seal ducts • Install synchronous-drive fan belts • Verify hydronic system operation and repair valves and controls	• Install VFDs on fan and pump motors >5 hp • Replace fan and pump motors with variable speed premium efficiency motors • Install high-efficiency, intelligent distribution pumps • Add energy recovery ventilators	• Switch to radiant or chilled beam systems with a dedicated outdoor air system (DOAS) for ventilation • Implement natural ventilation, controlled in coordination with mechanical ventilation

Learn more at betterbuildingssolutioncenter.energy.gov/ U.S. DEPARTMENT OF ENERGY

← Resources on low carbon technologies for primary and secondary schools

BERKELEY LAB
LAWRENCE BERKELEY NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

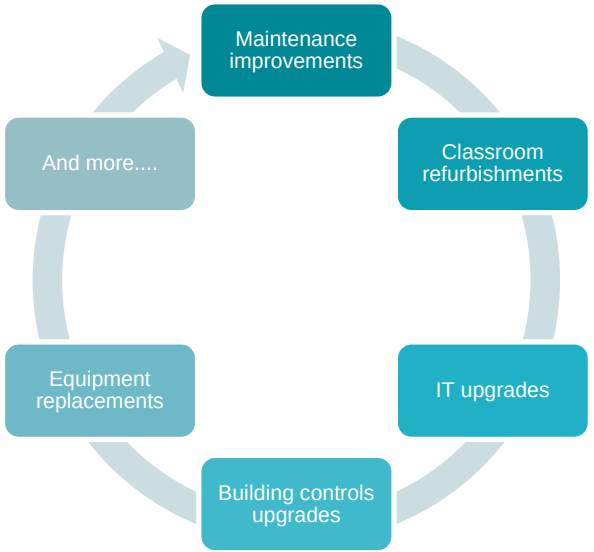
Energy Efficiency Packages for Schools

Paul Mathew, Ph.D. Lawrence Berkeley National Laboratory
Duane Kubischta, P.E. kW Engineering

Premise: Decarbonization urgency requires that we seize every opportunity for energy efficiency – even if modest

- Schools undergo many upgrades over their lifetime – small and large. These are key opportunities to incorporate EE.
  Don't miss them!
- The scope of each upgrade may limit the level of EE, but even incremental EE adds up over the building lifecycle.

Note: These opportunities are in addition to (and not in lieu of) dedicated "deep retrofits" needed for greater levels of energy/GHG savings (but may not always be feasible).



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Common infrastructure projects

Chiller Replacement

RTU Replacement

Boiler Replacement

BMS Replacement

How can these projects be leverage to increase energy efficiency?

Chiller Replacement EE package

- High efficiency chiller
  - Air and water cooled unit EERs based on ASHRAE 90.1
- Chilled water supply temperature resets
  - 45 - 55 °F trim and respond reset based on valve position
- Chilled water pump VFDs
  - Pump speed controled to maintain remote coil DPs
- Super premium efficiency motors
  - International Efficiency standard 4
- BMS replacement or upgrade
  - Could be a trigger event for outdated BMS

These complementary EE measures are proven, widely available, and relatively modest additions to project scope

Boiler Replacement EE package

- High efficiency boiler
  - Minimum efficiency based on ASHRAE 90.1
- Hot water supply temperature resets
  - Reset from 150 – 180 °F based on wide open valves
- Hot water pump VFDs
  - Pump speed controlled to maintain remote coil DPs
- Boiler lock-outs
  - Disable heating system with warm outdoor air temperatures.
- Condensing boilers
  - If return water can be 120 °F or lower, typically requires new coils.
- Networked thermostats
  - Good upgrade if only stand-alone thermostats
- Super premium efficiency motors
  - If motors are at end of life

These complementary EE measures are proven, widely available, and relatively modest additions to project scope

RTU Replacement EE package

- High efficiency RTU
  - Consortium for Energy Efficiency tier 2 EERs; heavier units
- Networked thermostats
  - Great upgrade if only stand-alone thermostats
- Networked thermostats w/ CO2 sensors and econ. control
  - Schools are great spaces for CO2; pair w economizer controller
- Low pressure drop filters
  - More surface area if they fit
- VFDs on fans
  - More common for high efficiency RTUs
- Economizer commissioning
  - Testing and calibration
- Supply air temperature reset
  - More common to be built in

These complementary EE measures are proven, widely available, and relatively modest additions to project scope

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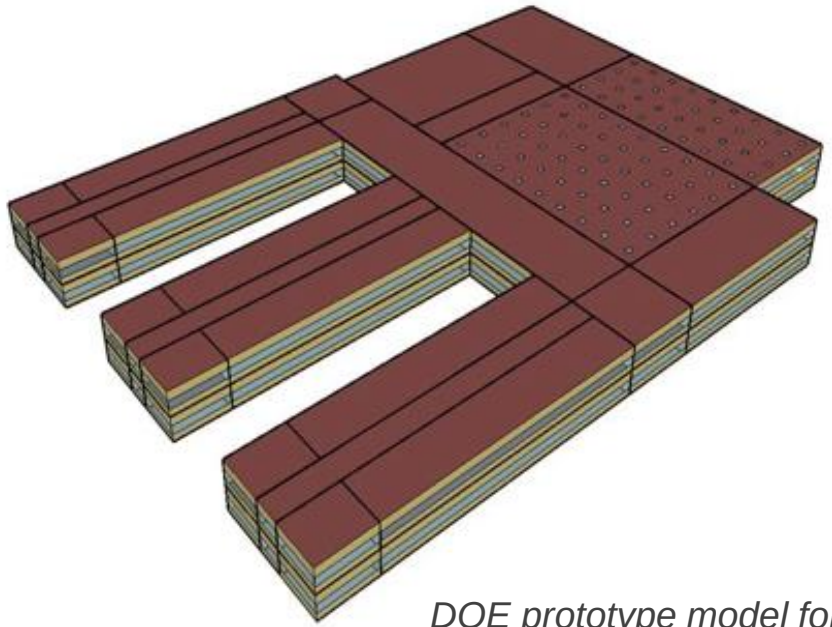
BMS Replacement EE package

- Supply air temperature reset
  - Reset from 57 – 65 °F based on zone temperature cooling loops
- Duct static pressure reset
  - Reset based on max VAV damper position
- Supply fan VFD
- Chilled water pump VFD
- Chilled water temperature reset
- Heating hot water pump VFD
- Heating hot water temperature reset
- Optimum start – adaptive scheduling
- Comprehensive retro-commissioning – make sure it works

These complementary EE measures are proven, widely available, and relatively modest additions to project scope

Cost benefit analysis of EE packages

- Simulation-based analysis using DOE prototype models for primary and secondary schools
- Cost data from RS Means and other industry sources
- Calculated energy, GHG and cost savings, simple-payback.
- Savings calculated relative to a) existing building; b) business-as-usual (BAU) replacement
- *Caveat: "Your mileage may vary!"*



DOE prototype model for a secondary school

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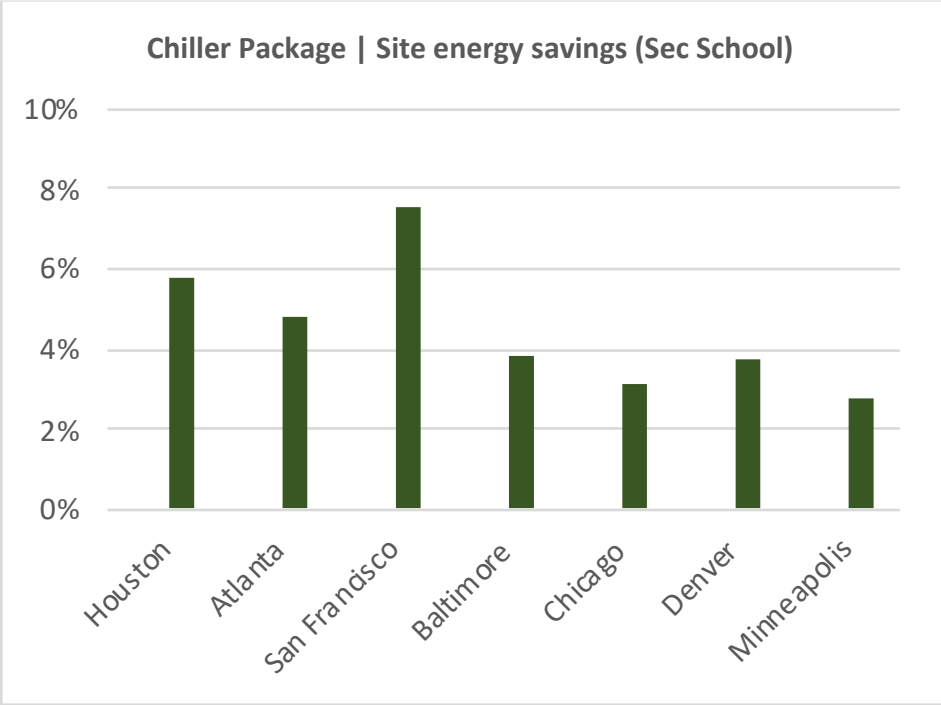
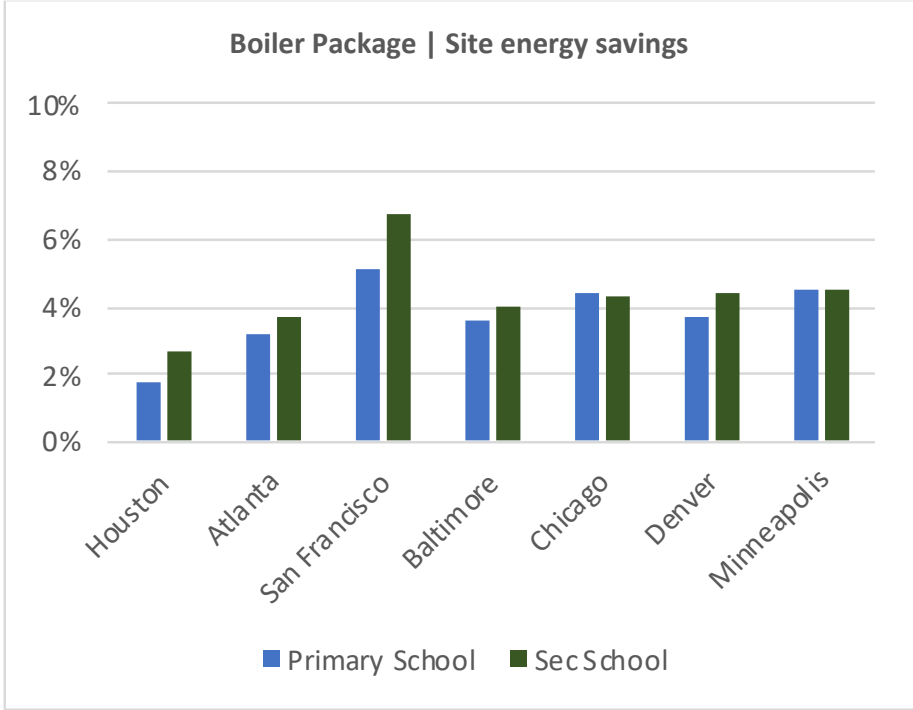
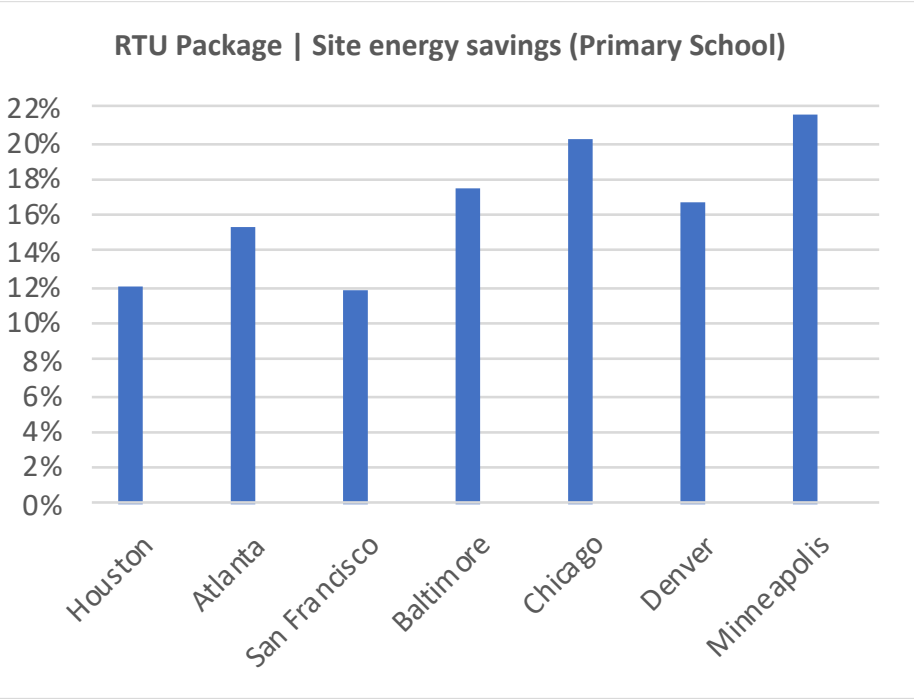
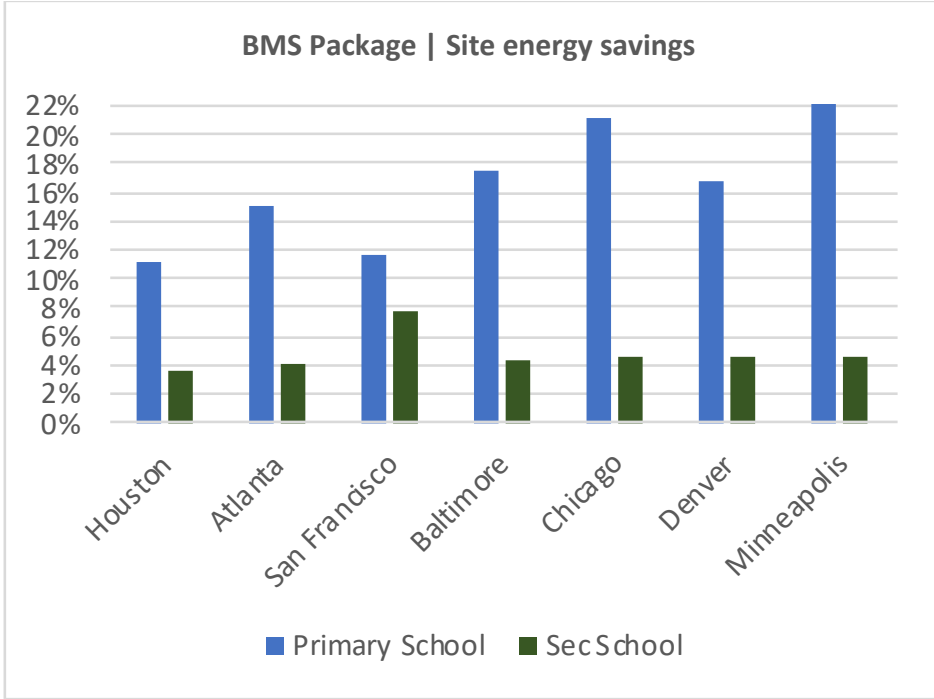
Site energy savings



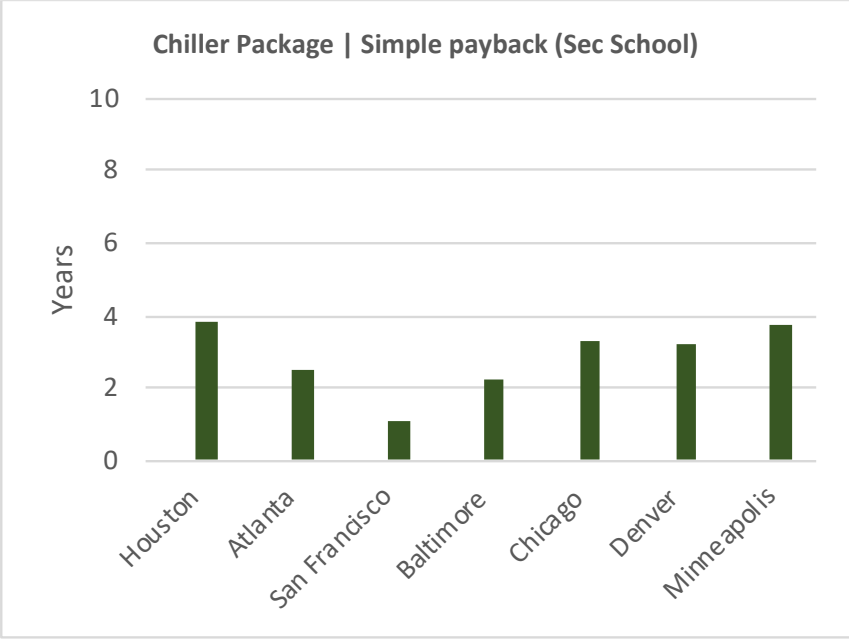


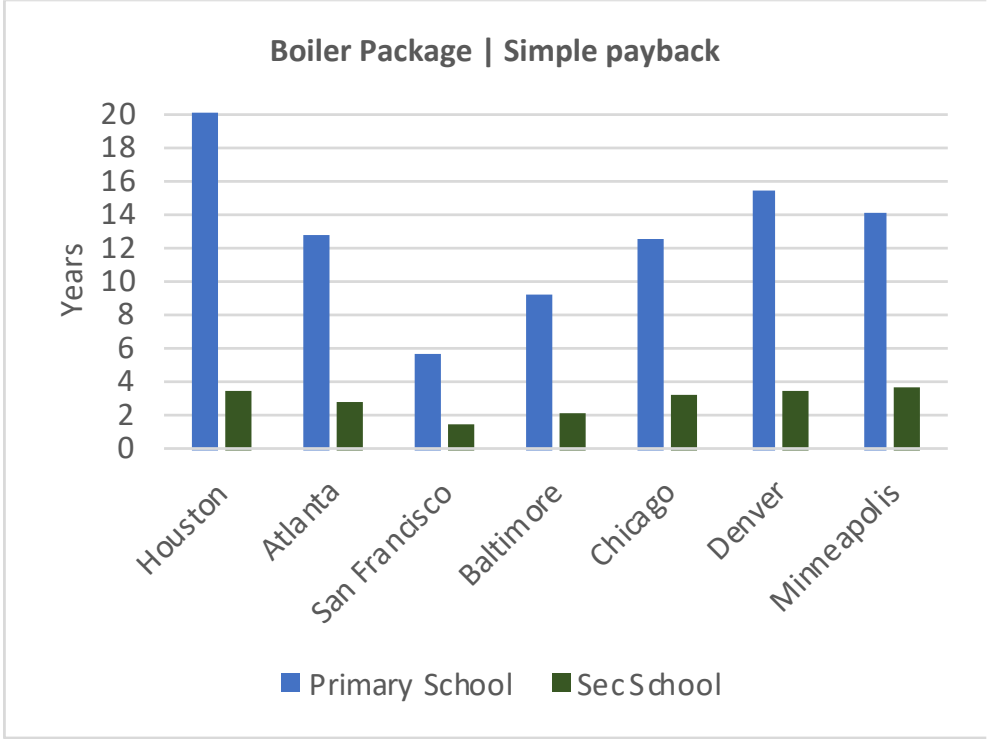
Site energy savings





Simple payback (relative to BAU replacement)





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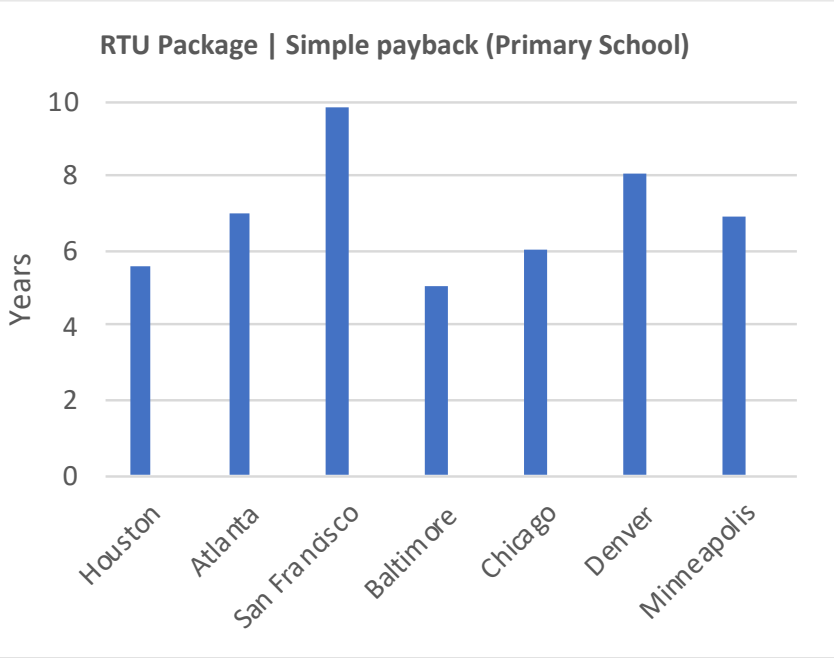
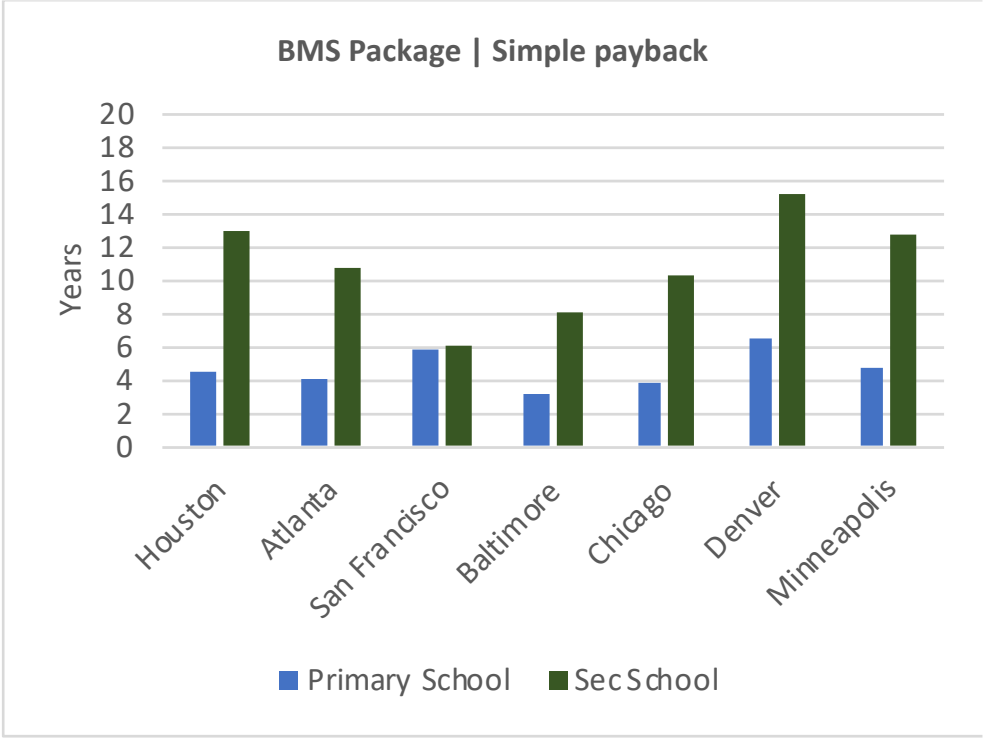


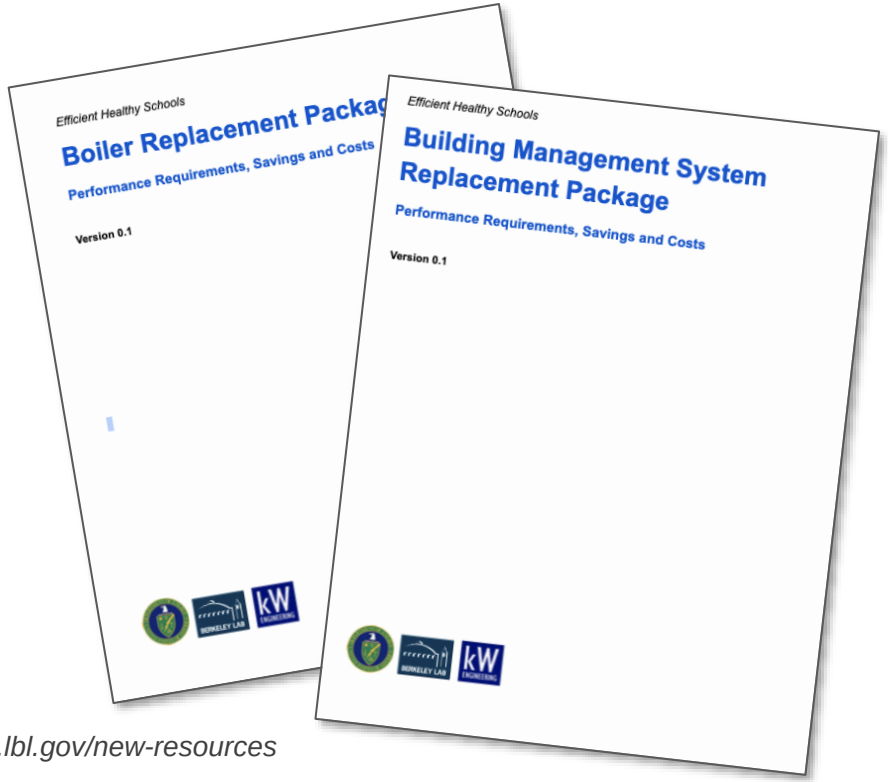


Key takeaways

- Even modest EE measures added to routine upgrades can provide meaningful energy savings with reasonable cost effectiveness.
- Don’t miss these opportunities to incrementally reduce energy and GHG over time and ease the path to deep savings. Build them into every upgrade!

EE package Guidelines

Includes: Performance requirements, Energy and GHG savings, Cost estimation data



https://efficienthealthyschools.lbl.gov/new-resources

Contact

Paul Mathew
pamathew@lbl.gov

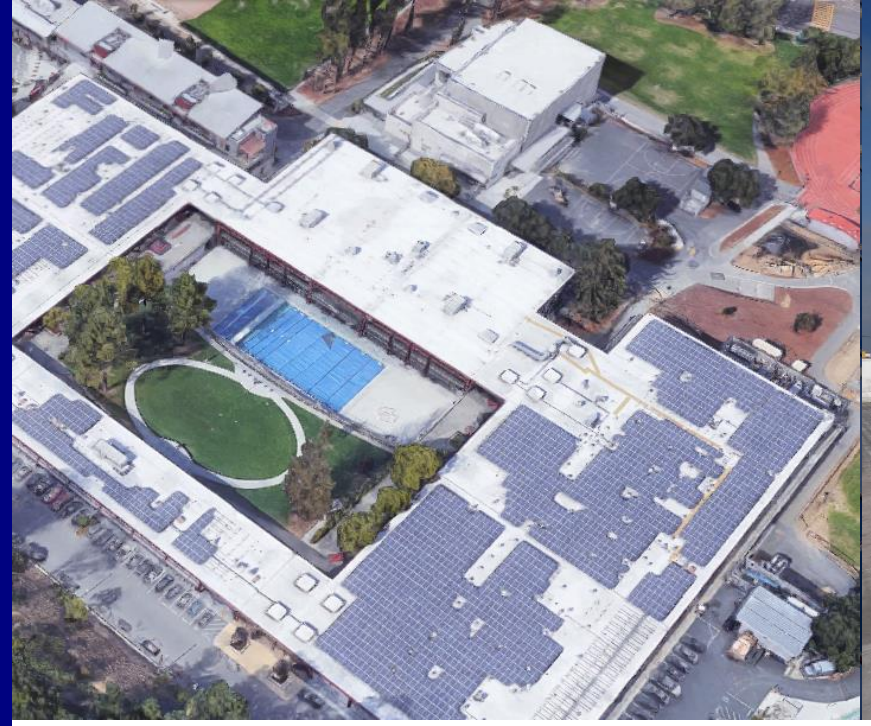
Duane Kubischta
dkubischta@kw-engineering.com

Schools Implementation Lessons

Duane Kubischta P.E.
10/12/2022

kW ENGINEERING

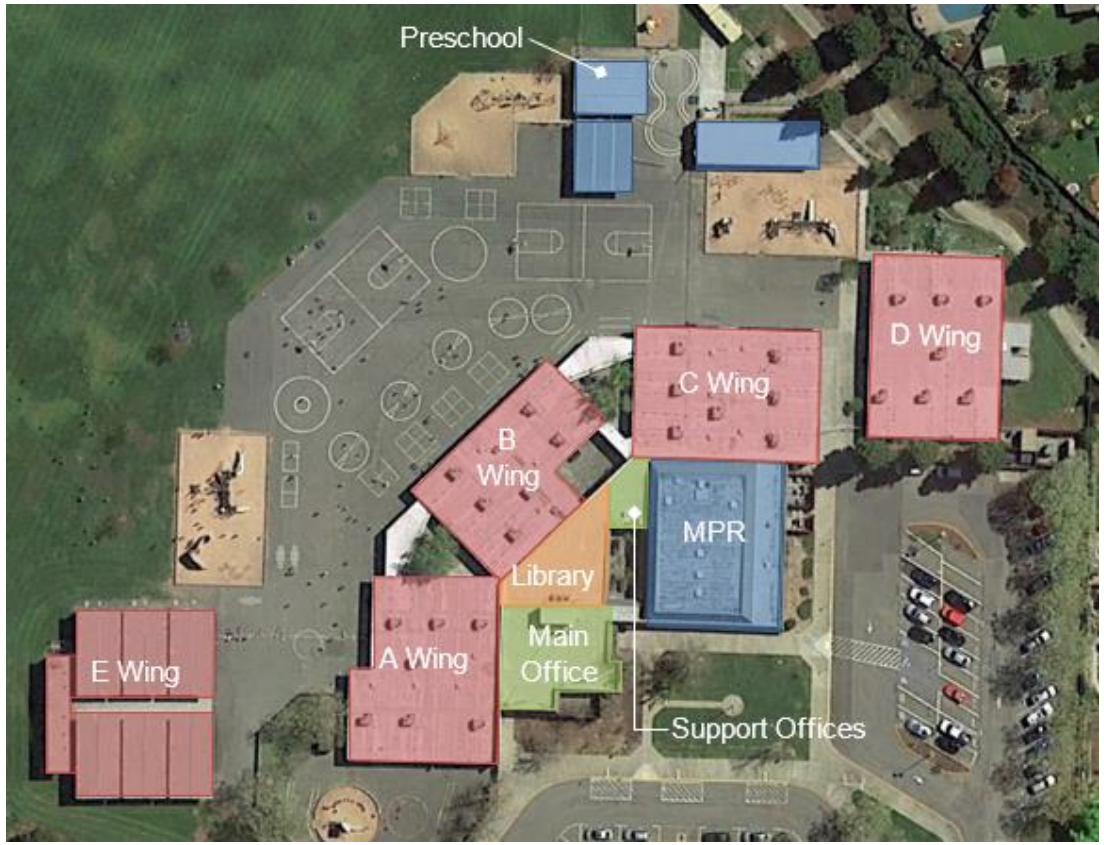
Agenda



- Dive right into a few Districts examples and lessons learned.

District 1 – Bay Area Outskirts

- Suburban in Bay Area
- Prop 39 funding, and bond money



District 1 – Remote Tstats & RTUs

- Smart thermostats everywhere
- Some RTUs, based on age
  - Made a comprehensive spreadsheet, ordered by age
- Economizer controls
  - Did skip these on older RTUs remaining (5-7 yr)
- CO2 sensors for most spaces
  - Not offices
- Optimum start was tricky to get going correctly
- Some iterations on wireless network
  - Repeaters checked and moved before mounting permanently
  - T&M w electricians

District 1 – Remote Tstats Benefits

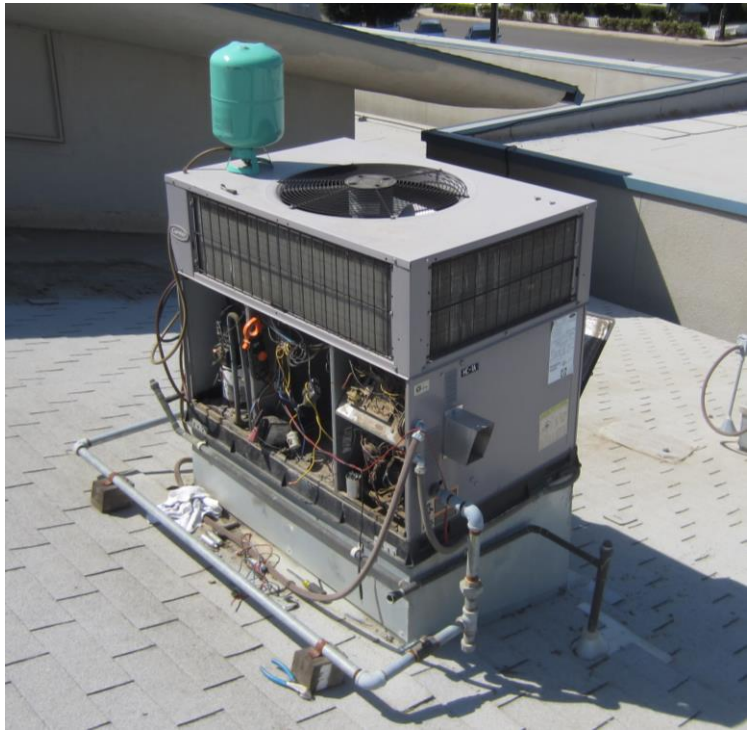
- Energy project, but also comfort and control
- Centralized economizer disable during wildfires
  - Created a shelter in place mode
- Hot and cold calls
  - Remote diagnosis
  - HVAC techs came around e.g. belt and compressor issues
    - Used web interface on smart phones
  - Have data to compare against complaints

District 1 – Lessons

- Coordination with Trades
- Don’t forget cage protectors for thermostats and repeaters in gyms and hallways
- BMS upgrade is huge cost so look for broken things to save energy
  - Huge cycling on dual duct, needed to be tuned

District 2 – Misc in Bay Area

- Urban and suburban in Bay Area
- Prop 39 funding, as well as bond funding
- Energy Managers and Bond Fund Managers
  - Internal versus outside labor

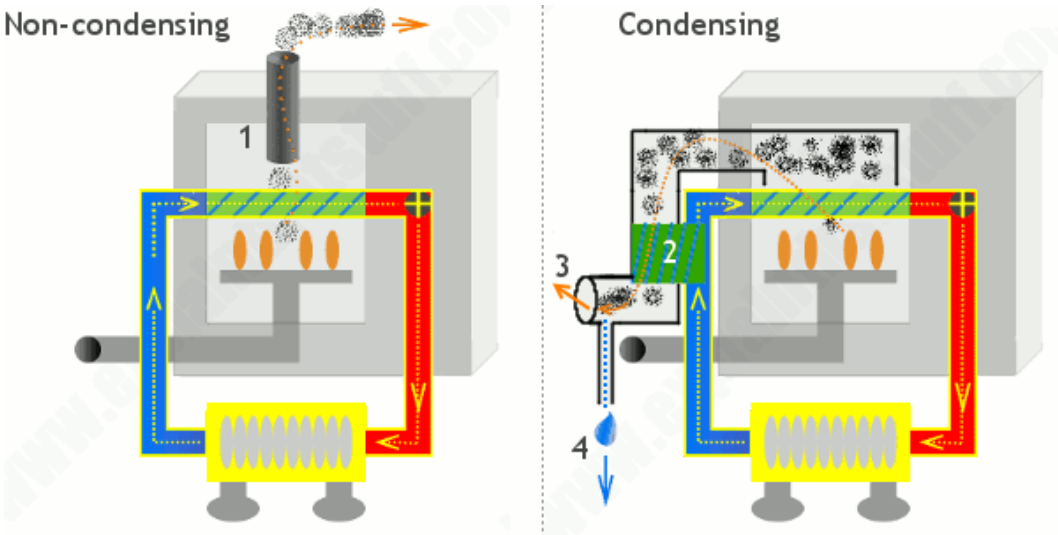


District 2 – RTU Replacements

- Long lifetime so high efficiency will pay over time
- Networks thermostats is a slam dunk add on
  - Missed by one district and had to go back
- Increased weights may require structural review
  - Long and slow, so work with DSA or other agency early
- Consider starting small, Bard units
  - Dial in the integration with a smaller project before expanding
- Keep everyone talking
  - Talk to the contractors, and purchasing

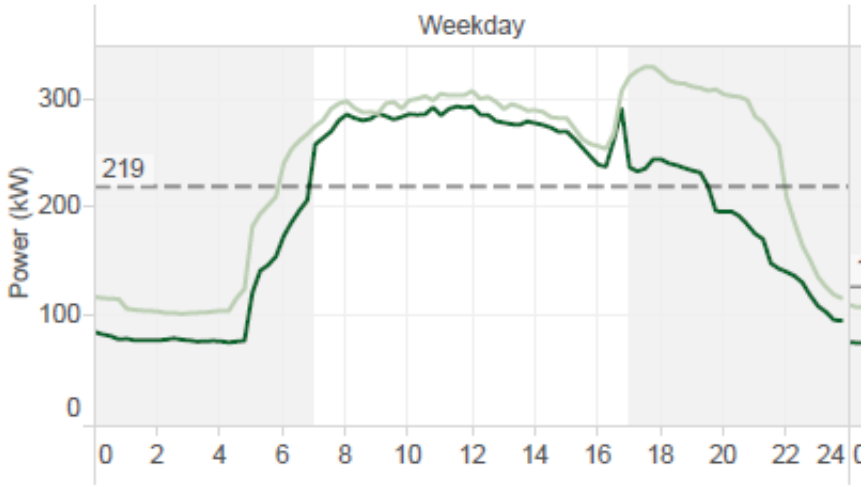
District 2 – Condensing Boilers

- Condensing boiler need a lower return temp to operate efficiently
  - Conduct system analysis to ensure lower EWT into the boilers.
    - Boilers are most efficient when the EWT is in the range of 90 °F
    - Existing heating hot water coils capable of handling that delta T ? If not, look for high-efficiency non-condensing boiler as an alternative.
- Staff on board with new approach
  - Appetite, capacity, blessing, training
- One district decided against
- Package addresses condensing boilers



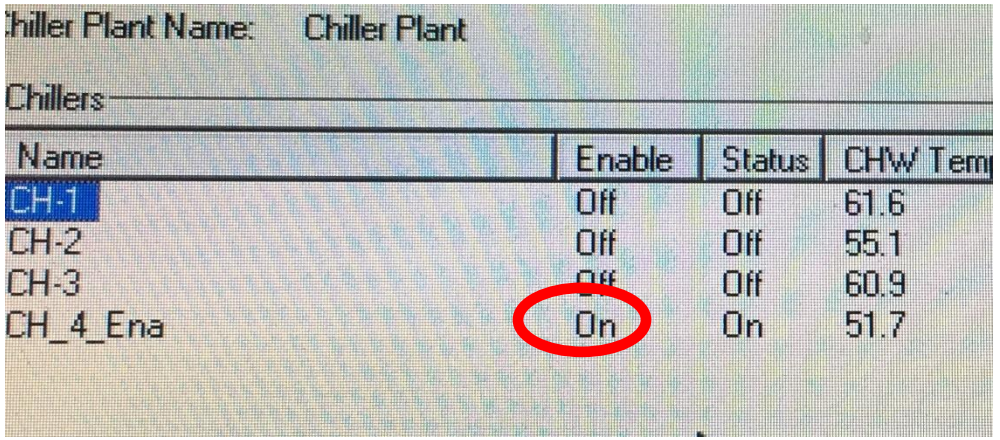
District 3 – UHSD in Bay Area

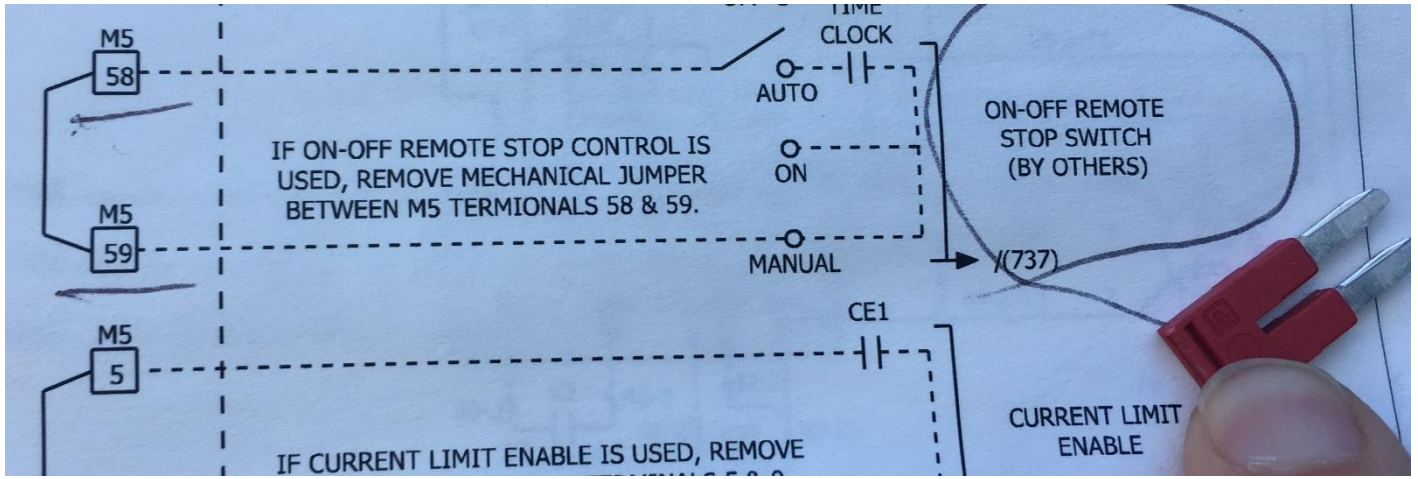
- Six high schools
- Solar at all sites
- Prop 39 Funding
- Waves of bond funded projects
- Proposed an RCx effort (agile)



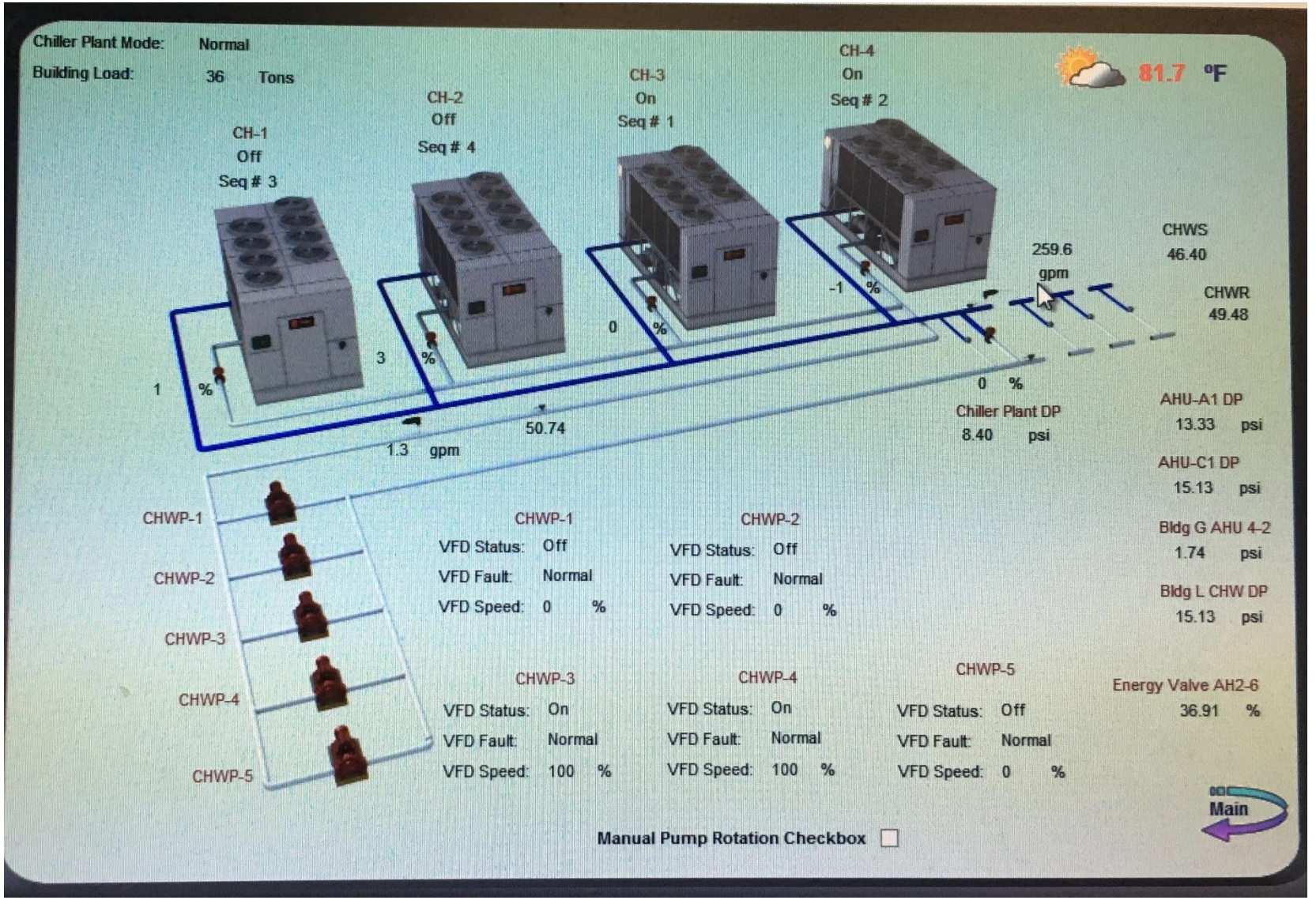
District 3 – Example Finds

- Scheduling!
  - Chillers operating continuously
- Graphics improvements for visibility
- Simple OAT-based resets

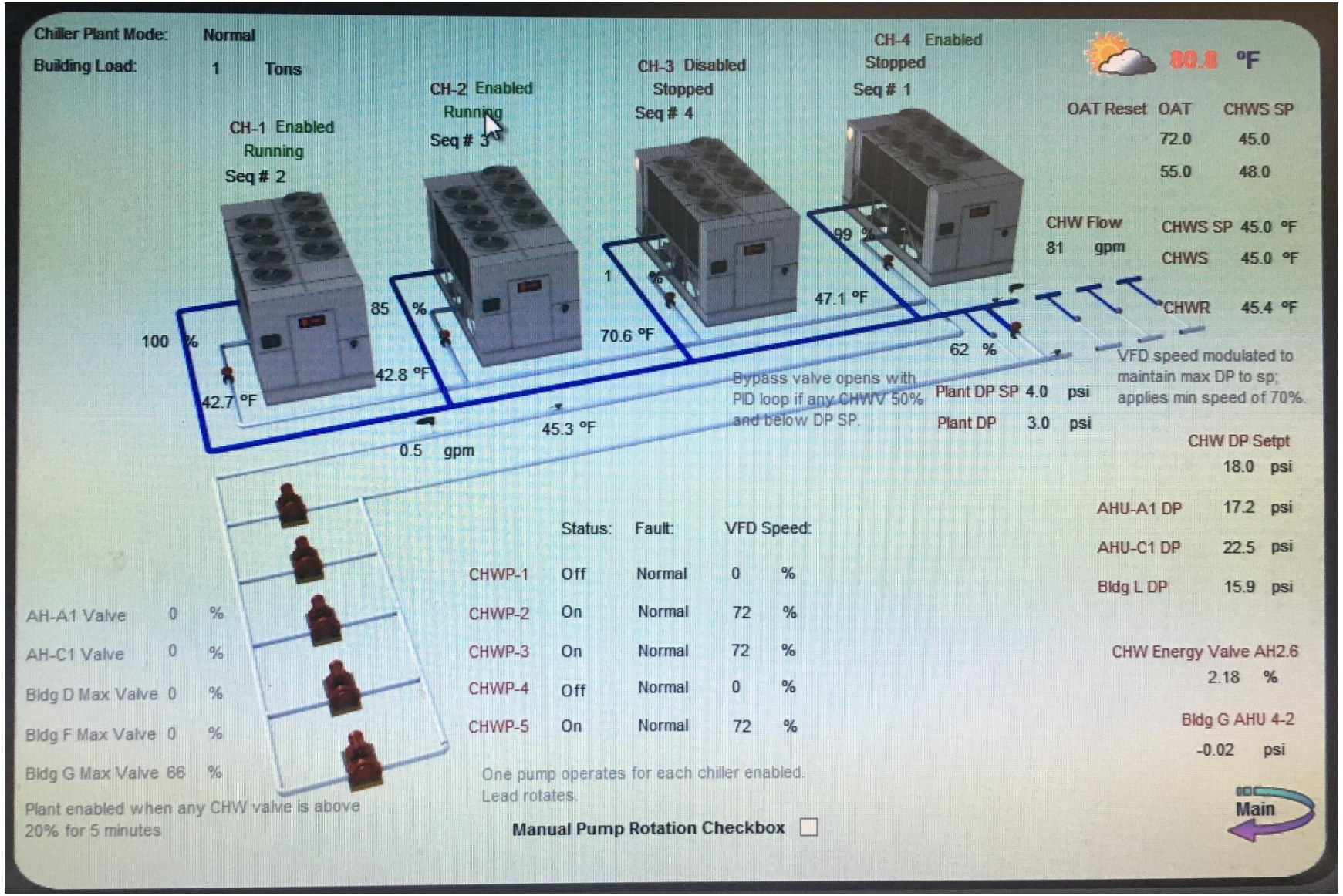




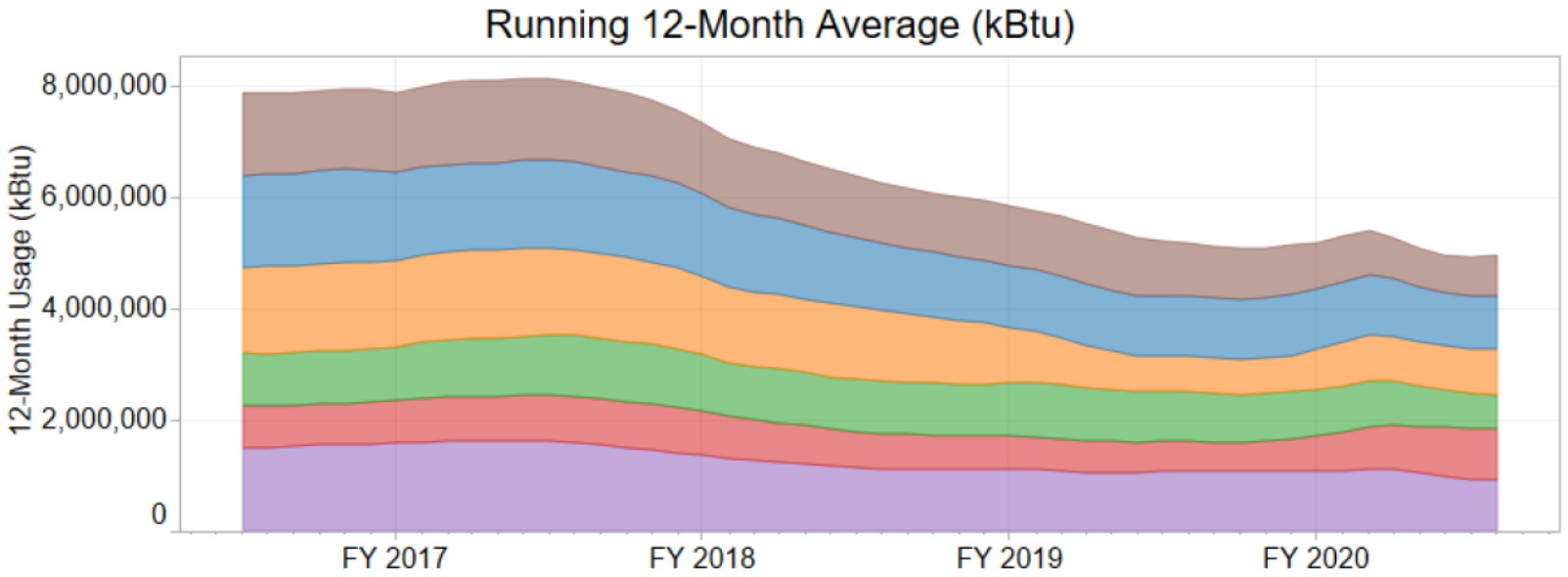
District 3 – Graphics Before



District 3 – Graphics After



District 3 – Results

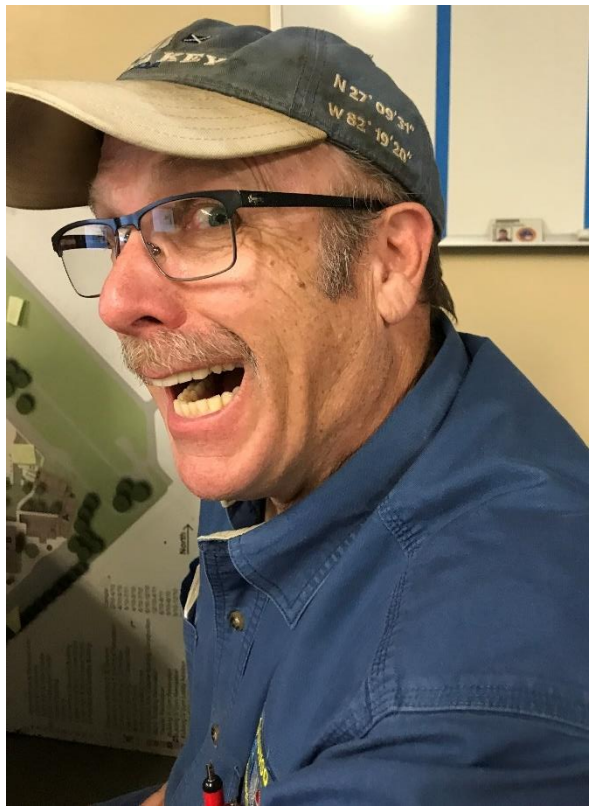


Results – Cumulative Cost savings

- FY 2016-2017 Base Year
- FY 2017-2018 1st year results $517,000 savings over base year
- FY 2018-2019 2nd year results $880,000 savings over base year
- FY 2019-2020 3rd year results $1,160,000 savings over base year
- **Total Savings** **$2,500,000 over last three years**

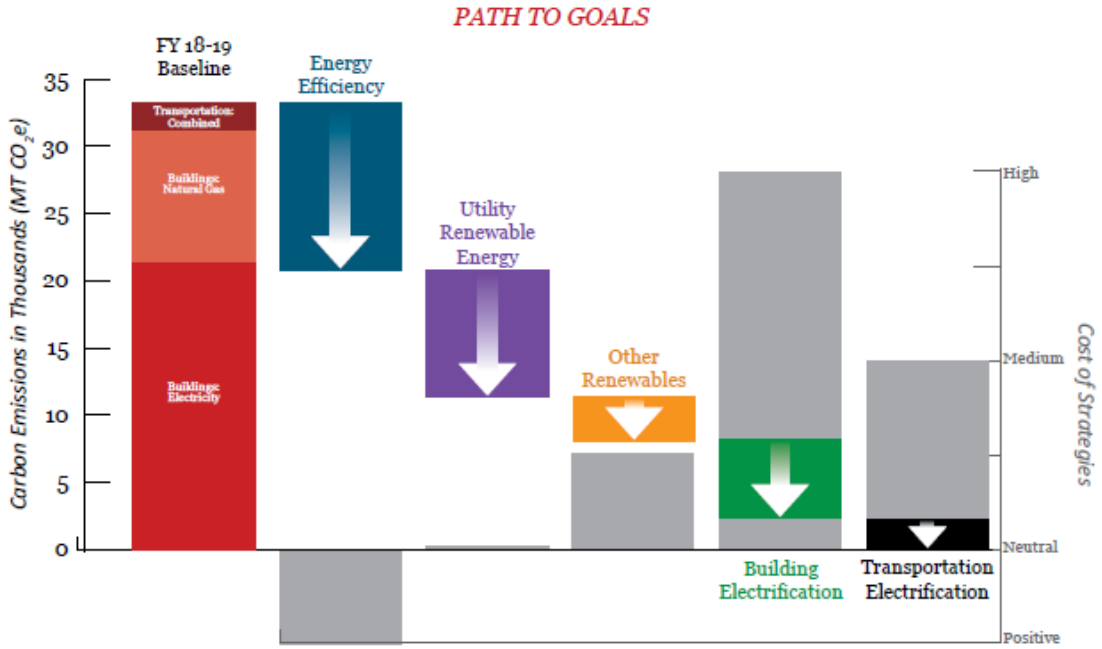
District 3 –Lessons

- Even if you have all the measures, they need to operate correctly
- People Matter



District 4 – Urban SD in Utah

- Diverse and large SD for entire city
- Extreme climate with prolonged hot and cold
- Pushing further with electrification at 2 pilot sites



District 4 – Example Finds

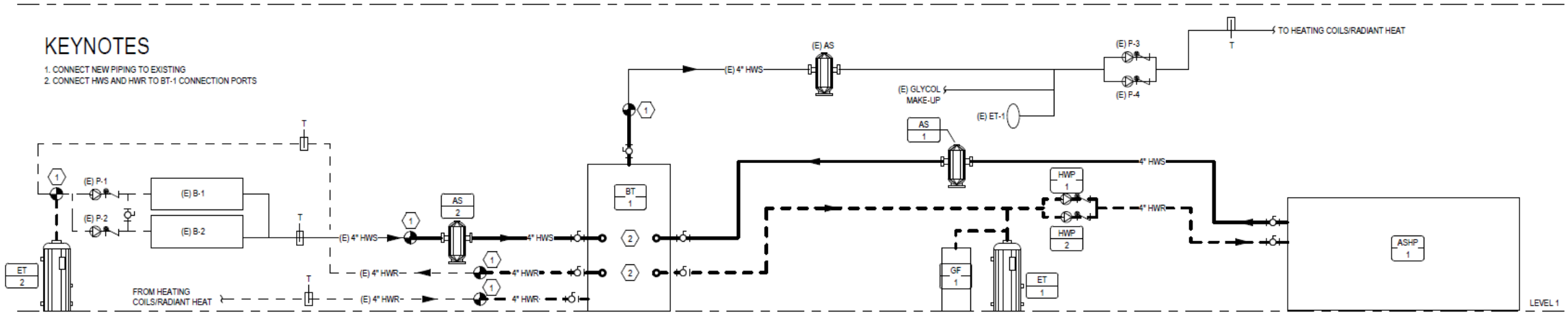
- Right sizing
  - TAB needs to be conducted as part of any BAS or controls upgrade
  - 1,500 cfm needing heating is much different than 1,000 cfm
  - This can lead to saving energy, but also reduced costs for upgrades/right-sizing
    - Any comfort savings too!
- Electrification is hard and expensive
  - Good controls and staff who understand them

District 4 – Cold Weather Warnings

- Hybrid electrified approach is getting more common for electrification
  - Peak natural gas boiler instead of more heat-recovery units
  - Even electric boiler if its too cold for heat pumps
- Recovery sequences should be well tested
  - Do not want to lose the building when near equipment limits.
  - Higher resets on SAT than typical. Minimum of 65 in winter.
- If VFR, then plan on extensive commissioning
  - Don’t want to see 50% compressor failures
  - LEED and Compliance Cx are not enough.

District 4 – Lessons

- Staff Training: EUI of 20-60 kBtu/s.f. range for exact same school
- How will you buy your 3rd schools BMS?
  - Standardization and consistency are not aligned with low bid



Final Points

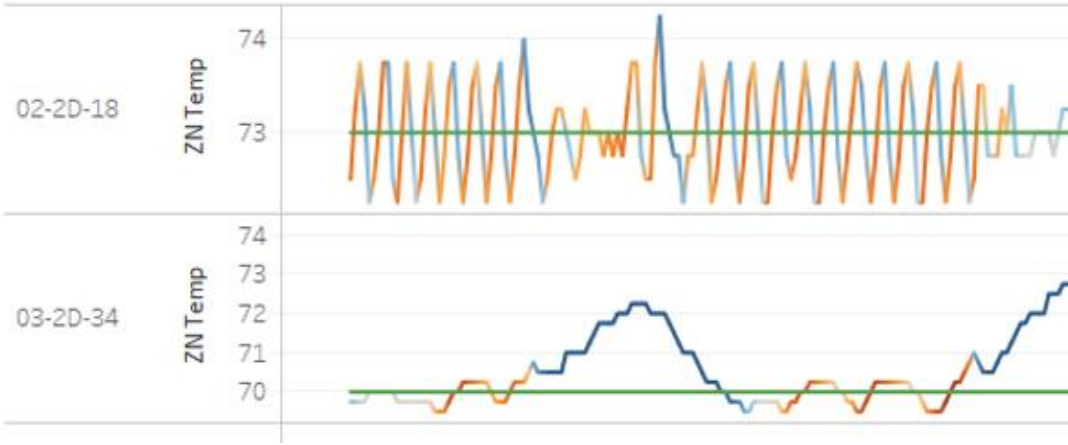
- Engaged staff, energy champions
- Emergency planning

Duane Kubischta P.E.
DKubischta@kw-engineering.com

kw-engineering.com

Thank you

kW



Q&A

Contact us at EHSC@lbl.gov

Resources

- Check out previous webinars. Topics include:
  - Ongoing Monitoring and Analytics for HVAC Performance,
  - Efficient HVAC for indoor environmental quality,
  - HVAC Inspection and Maintenance for Indoor Air Quality, and
  - A Team Approach to Support Strategic Investments in Efficient and Healthy Schools
- Check out our campaign site's resource pages, these include tools and guides relevant to the categories above.

Join us for our next webinar!

Oct 27th, 10-11am PT, 1-2pm ET. Registration Link.

- **Jordan Shackelford from LBNL will discuss:**
  - Recognition projects relevant to lighting
  - Useful lighting standards, tools, and guides for schools
  - Measurement and verification, along with research that highlights the health and safety benefits of lighting retrofits in schools.
- **Axel Pearson from PNNL will discuss:**
  - DOE's Integrated Lighting Campaign and how schools can be a part of this campaign
  - An in-depth example of an innovative lighting project at Holt Public Schools