



Helping Schools be BETR with the Building Electrification Technology Roadmap

November 30, 2023

RESOURCE
REFOCUS

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New Buildings Institute (NBI)

Mission: We push for **better buildings** that achieve **zero energy, zero carbon, and beyond**—through research, policy, guidance, and market transformation—to protect people and the planet.



St James Intermediate School | Myrtle Beach, SC
Credit: sfL+a Architects

Today's Presenters



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Resource Refocus (RR)

Resource Refocus provides innovative, technical consulting on **energy use in buildings** to help building industry stakeholders design and deliver **zero net energy**, **zero carbon**, and **energy efficiency** research, projects, and initiatives.

RESOURCE REFOCUS



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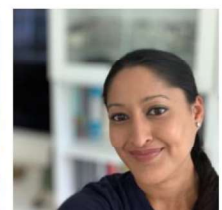
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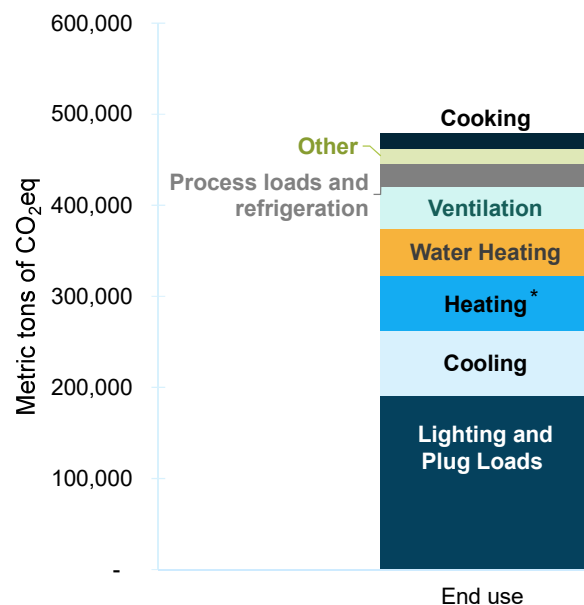
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Introduction

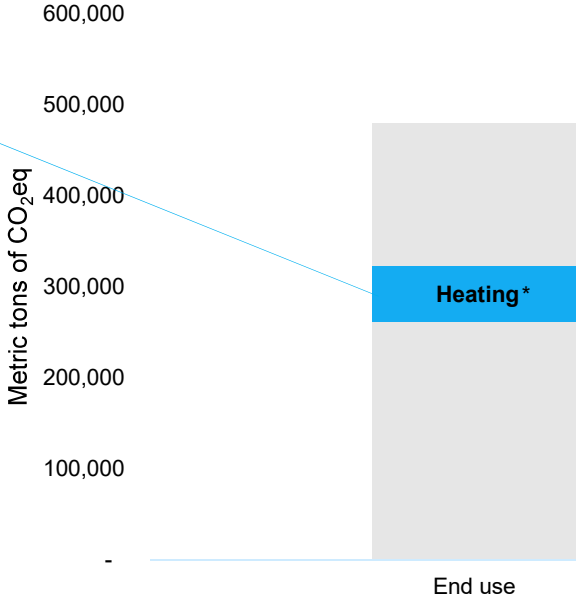
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California's K-12 schools emit an estimated **1.6 million metric tons** of emissions annually

Estimated metric tons of CO₂eq by end use, schools in SCE territory



Estimated metric tons of CO₂eq by end use, schools in SCE territory



*94% of heating emissions are from onsite gas

Fuel choice greatly impacts carbon emissions

Burning gas-powered equipment is common for space heating, water heating and kitchen equipment.



Credit: Nik Kaestner, San Francisco USD

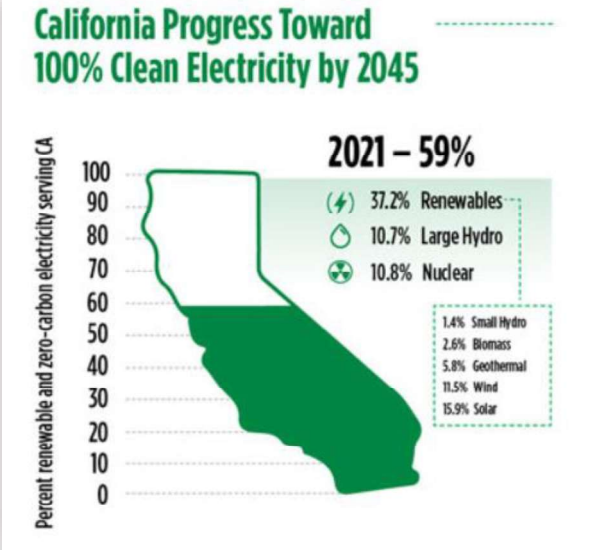


Credit: CT Brayton and Sons Incorporated

California electricity supply is moving toward 100% renewables

“Cleaner” electric grids = lower emissions

 Peak percentage of renewables compared to demand
103.5%
May 8, 2022 at 3:39 p.m.

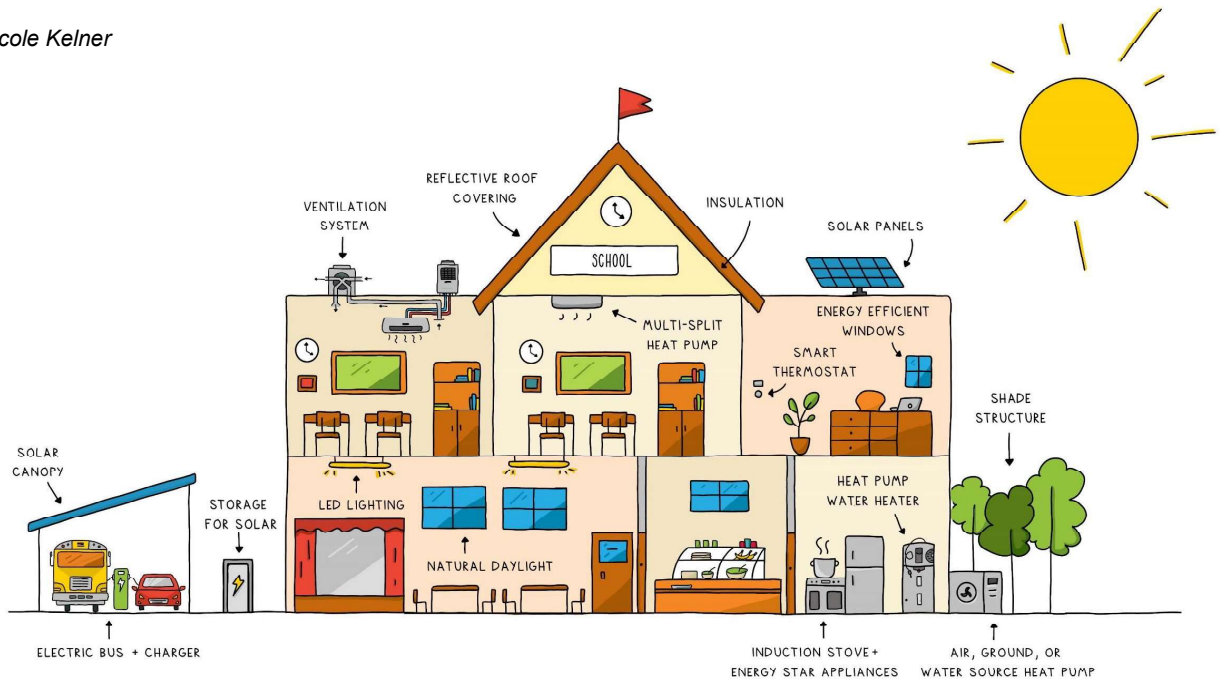


Source: CAISO

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All-electric schools have no onsite combustion

Artwork by Nicole Kelner



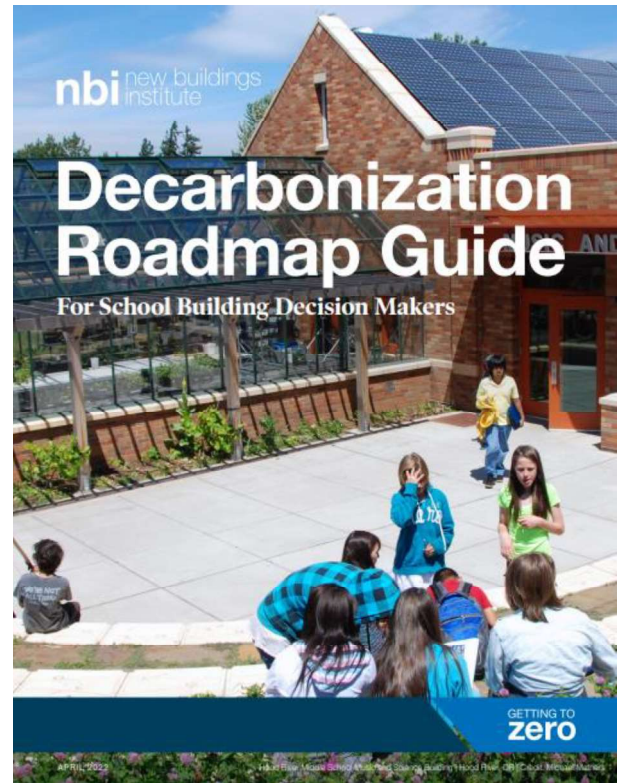
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Overall approach

Getting to zero over time is a concept that ensures the correct tools are in place to address a building lifecycle event in a way that aligns with the school district's long-term energy and carbon reduction goals.

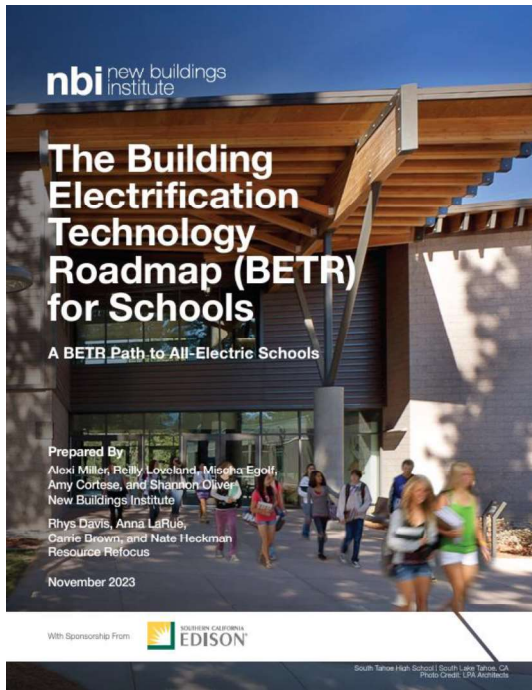


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BETR Report and Interactive Tool



Intro | Cost Estimator | Overall Summary | Upfront Costs per ft² | Upfront Total Costs

Upfront Cost Estimation Tool

Input your school building size and select the prompts from the dropdown menus below to calculate upfront cost estimates by equipment type and end use. See intro tab for more details on the inputs.

Input Your Building Size in ft²
 Note: For most equipment, this tool uses average \$/sq ft values to estimate upfront project costs. If your square footage is greater than 25,000 square feet, select "Large" as your building type.

Select your project type

What type of equipment are you planning to upgrade?

Range of Total Upfront Electrified Equipment Investment Costs

End Use	Electric Equipment	Total Cost Estimate Low	Total Cost Estimate High
Cooking	Countertop Kitchen Equipment	\$500	\$5,800
Domestic Hot Water	120 Volt HPWH	\$2,100	\$3,400
	Tankless Water Heater	\$4,100	\$26,900
Laundry	Heat Pump Dryer	\$400	\$2,200
Space Conditioning	Multi-Zone Rooftop Heat Pump	\$121,500	\$272,200
	Single-Zone Rooftop Heat Pump	\$148,500	\$515,700
Grand Total		\$277,200	\$826,200

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Electrification scenarios

Event in Building Lifecycle

Goals

Emergency Replacement

Minimal upfront costs, non-invasive installation, readily available equipment

Planned/Routine Capital Improvement & Deferred Maintenance

Minimal upfront costs, non-invasive installation, some lead time and planning for improved air quality

Efficiency & Cost Savings Project (Deep Efficiency Retrofit)

Lifecycle cost savings on utility bills and maintenance

Addition to Existing Building

Minimal upfront cost, lifecycle cost savings, improved air quality, fitting in with existing systems

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Electrification scenarios

Event in Building Lifecycle

Goals

Be proactive to avoid this one!

Emergency Replacement

Minimal upfront costs, non-invasive installation, readily available equipment

Planned/Routine Capital Improvement & Deferred Maintenance

Minimal upfront costs, non-invasive installation, some lead time and planning for improved air quality

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Addition to Existing Building

Minimal upfront cost, lifecycle cost savings, improved air quality, fitting in with existing systems

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Building size categories

- Most applicable equipment will depend on building size:
 - **Large** school buildings: $\geq 25,000$ sf
 - **Small** school buildings: $< 25,000$ sf
 - **Relocatable** classroom buildings: 1,000 - 10,000 sf

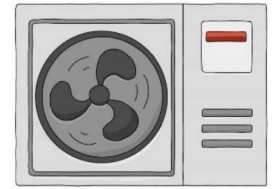
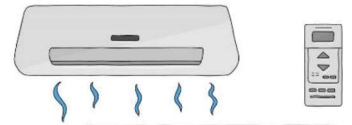
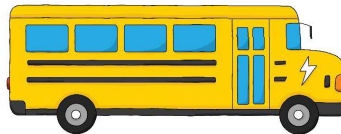


Hood River Middle School | Hood River, OR
Credit: Opsis Architecture

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Electric technologies for schools

- Space conditioning and ventilation (HVAC)
- Water heating
- Kitchens and cooking
- Laundry
- Transportation



Artwork by Nicole Kelner

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Electric technologies for schools – HVAC example

Baseline equipment

Electric options

Ducted heating

- 240V Air Source Heat Pump (ASHP) – split system or packaged rooftop unit (RTU)

Ductless heating

- Packaged Terminal Heat Pump
- Ductless ASHP split system (“mini-split”)

Central boiler heating

- Variable Refrigerant Flow (VRF)
- Water Source/Ground Source heat pump
- Air to water heat pump

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Study Methodology and Cost Results

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What do we need to know about electrification options?

- In what **scenarios** are they feasible?
- In what **building types** are they appropriate?
- Upfront **cost** and **installation** challenges
- **Energy** and **GHG** impacts
- **Air quality** impacts

Costs

- **Gathered** from RS Means, state and utility reports, and retailers
- **Adjusted** to include SoCal union labor rates & cost multipliers
- **Normalized** by building area and/or capacity
 - Multiple sources used to determine **cost ranges**

New York State Climate Action Council Scoping Plan
Integration Analysis Technical Supplement, Section I, Annex 1: Inputs and Assumptions

Prepared by:
 Energy+Environmental Economics

Credit: New York State, E3

Economic Analysis of Heat Recovery Equipment in Commercial Dedicated Outside Air Systems

For: Northwest Energy Efficiency Alliance (NEEA)

Final Report

Credit: Red Car Analytics

RSMeans data
from 

Credit: Gordian



Search Data Manage Estimates Square Foot Estimator Life Cycle Cost ☆ My Favorites

Cost Data Commercial New Construction Type Assembly Labor Type Standard Union Location RIVERSIDE (925) Release Year 2023 Quarter 3

Installation Considerations

- Do panels need to be upsized?
- Can existing infrastructure be used?
 - Wiring
 - Piping
 - VAV boxes
 - Ducts
- Are there many components?
- Is a DSA review required?

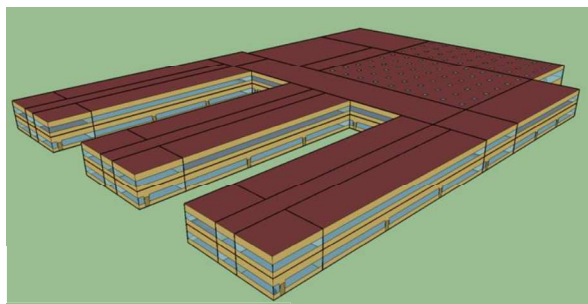




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Operation Considerations

- Each project will require **custom hourly energy modeling** to determine **specific** energy cost and GHG impacts
- However, based on system efficiencies and typical designs, we can **estimate impacts** of technologies **relative to the existing system**



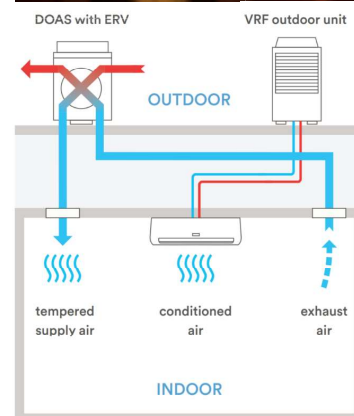
Credit: Department of Energy

Air Quality Considerations

- **Existing** school building systems often do not provide **sufficient air quality needs**
- Electrification retrofits can address air quality issues
 - **Indoor** gas combustion **replaced** by electric
 - **Retrofitted ventilation systems** combined with electric space conditioning



Credit: Billy Spatz, SBG



Credit: Building Energy Exchange


Space Heating Electrification Matrix



TECHNOLOGY	UPFRONT COST RANGE (\$/SF)		SCENARIO				BUILDING TYPES			UTILITY COST IMPACT		BENEFITS				
	Low	High	Emergency Replacement	Planned Capital Improvement	Deep Efficiency Retrofit	Addition to Existing Building	Small	Large	Relocatable	Lower or similar utility costs	Likely to increase utility costs	Ease of Maintenance	Ease of Install	IAQ improvement potential	GHG emission reduction	Low GWP Refrigerant Option
Packaged Terminal Heat Pump	\$1.03	\$1.48	✓						✓	✓		●	●	-	○	✓
Single-Zone Ducted Package ASHP + MERV 13	\$9.90	\$34.38	✓	✓		✓	✓	✓	✓			○	●	○	◐	
Single-Zone Non-Ducted Minisplit ASHP w/ DOAS	\$11.90	\$17.47		✓	✓	✓	✓	✓	✓			◐	◐	●	●	✓
Multi-Zone Ducted ASHP + MERV 13	\$8.10	\$18.15	✓	✓		✓	✓		✓			○	●	○	◐	
Multi-Zone Multi-split ASHP w/ DOAS	\$10.82	\$25.27			✓		✓	✓	✓			◐	◐	●	●	✓
Air-to-Water Hydronic Heat Pump	\$4.09	\$8.40		✓	✓	✓	✓			✓		○	○	-	◐	

○ Low ◐ Medium ● High
Full circles are most desirable.

Water Heating Electrification Matrix



TECHNOLOGY	UPFRONT COST RANGE (\$/SF)		SCENARIO				BUILDING TYPES			UTILITY COST IMPACT		BENEFITS				
	Low	High	Emergency Replacement	Planned Capital Improvement	Deep Efficiency Retrofit	Addition to Existing Building	Small	Large	Relocatable	Lower or similar utility costs	Likely to increase utility costs	Ease of Maintenance	Ease of Install	IAQ improvement potential	GHG emission reduction	Low GWP Refrigerant Option
Electric resistance tankless WH	\$0.28	\$1.80	✓				✓		✓		✓	●	●		○	
120 Volt HPWH (<80 gallons)	\$1.23	\$2.04	✓	✓			✓		✓	✓		●	●		●	
240 Volt HPWH (<80 gallons)	\$1.27	\$2.54		✓	✓	✓	✓		✓	✓		●	◐		◐	✓
Central HPWH (>80 gallons)	\$0.36	\$1.43		✓	✓	✓	✓	✓		✓		◐	○		◐	✓

○ Low ◐ Medium ● High
Full circles are most desirable.

Cooking Electrification Matrix



TECHNOLOGY

○ Low ◐ Medium ● High
Full circles are most desirable.

TECHNOLOGY	UPFRONT COST RANGE		SCENARIO				BUILDING TYPES			UTILITY COST IMPACT		BENEFITS			
	Low	High	Emergency Replacement	Planned Capital Improvement	Deep Efficiency Retrofit	Addition to Existing Building	Small	Large	Relocatable	Lower or similar utility costs	Likely to increase utility costs	Ease of Maintenance	Ease of Install	IAQ improvement potential	GHG emission reduction
Full Electric Commercial Kitchen Equipment (total kitchen cost)	\$14,265	\$63,873		✓	✓	✓	✓	✓		✓		◐	◐	●	○
Electric Small Countertop Kitchen Equipment (total kitchen cost)	\$489	\$5,787	✓	✓	✓	✓	✓		✓	✓		●	●	○	○

Laundry Electrification Matrix



○ Low ◐ Medium ● High
Full circles are most desirable.

TECHNOLOGY

TECHNOLOGY	UPFRONT COST RANGE		SCENARIO				BUILDING TYPES			UTILITY COST IMPACT		BENEFITS			
	Low	High	Emergency Replacement	Planned Capital Improvement	Deep Efficiency Retrofit	Addition to Existing Building	Small	Large	Relocatable	Lower or similar utility costs	Likely to increase utility costs	Ease of Maintenance	Ease of Install	IAQ improvement potential	GHG emission reduction
Heat Pump Dryer (residential)	\$435	\$2,174	✓	✓	✓	✓	✓	✓	✓	✓		●	●	○	○

Electric Vehicle Charging & Service Matrix



TECHNOLOGY	UPFRONT COST RANGE		SCENARIO				BUILDING TYPES			UTILITY COST IMPACT		BENEFITS			
	Low	High	Emergency Replacement	Planned Capital Improvement	Deep Efficiency Retrofit	Addition to Existing Building	Small	Large	Relocatable	Lower or similar utility costs	Likely to increase utility costs	Ease of Maintenance	Ease of Install	IAQ improvement potential	GHG emission reduction
EV Chargers for Passenger Vehicles	\$3,335	\$15,000		✓	✓	✓				✓		●	◐	◐	●
Level 2 EV Charger for School Buses	\$3,335	\$15,000		✓	✓	✓	✓	✓	✓	✓		●	◐	●	●
Level 3 EV Charger for School Buses	\$60,000	\$100,000		✓	✓	✓	✓	✓	✓		✓	●	◐	●	●
Electrical Service Panel	\$0.14/ft ²	\$1.18/ft ²	✓	✓	✓	✓	✓	✓				●	○		
Distribution Transformer	\$0.17/ft ²	\$1.27/ft ²	✓	✓	✓	✓	✓	✓				●	○		

○ Low ◐ Medium ● High
Full circles are most desirable.

Electric technologies for schools: key takeaways

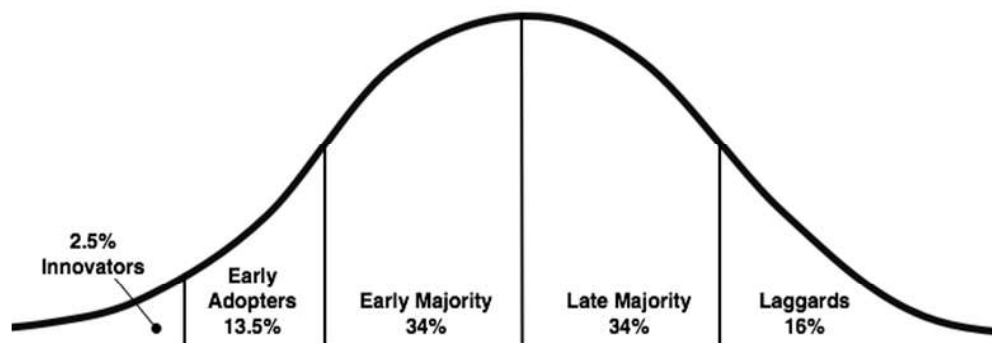
- **Make a plan!**
- **HVAC** replacements will have the **biggest impact**
- Always choose **heat pumps!**
 - Look for **low-GWP** refrigerant
- Select **ENERGY STAR** certified equipment
- Consider how retrofits can support **air quality improvements**
- Consider electrical panel and transformer upgrades

Helping schools with BETR decision making

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Decisions Are Made by People

- Consider where your district is on the curve.
- Consider where your district *leaders* are on the curve.
- What motivates district *leaders*: head, heart, or wallet?



Source: Everett Rogers, *Diffusion of Innovations* manual

Behaviors – Benefits or Barriers

- Risk perception drives behaviors
- Individual vs Organizational
- Internal vs External



Why are we talking about behavior change??

Be Prepared, do Your Homework

Be Clear and Concise

Be Consistent and Persistent



Offsetting costs with IRA: Large School HVAC

Existing

Boiler
Chiller
AHU/VAV



Proposed

Multi-zone ASHP
VRF
DOAS/ERV

- **Existing system** replacement cost: **\$0.8-1.5 million**
- Proposed electrification cost: \$3.3-5.4 million
- Incremental cost: \$2.5-3.9 million
- Potential 179D deduction: \$0.6-1.1 million
- **Adjusted incremental cost: \$1.9-2.8 million**

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Offsetting costs with IRA: Small School Hot Water

Existing

50-gal Gas
Water heater



Proposed

120v OR 240v
65-80 gal HWHP

- **Existing system** replacement cost: **\$1,350-3,925**
- 240v option electrification cost: \$2,325-5,025
- 120v option electrification cost: \$2,550-4,450
- **Incremental 240v option cost: \$975-1,100***

**may be further offset through 179D deductions*

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Thank you to Southern California Edison for their support of our school decarbonization efforts!



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Upcoming Efficient Healthy Schools Webinar!

- **December 14, 2023**
11-12 PT / 2-3pm ET
- Learn about Program benefits
- Hear from previous Program honorees
- Register here:
https://lbnl.zoom.us/webinar/register/WN_8vpE3j8yR-SiFb8xeX5Bdg#/registration



We believe every school and district can achieve efficient and healthy school spaces through facility improvements. We especially encourage schools in rural areas and schools serving students in disadvantaged communities* to join the Program.

* Disadvantaged communities are defined by the Justice40 Initiative according to this methodology.

Our team will provide one-on-one onboarding to find the right resources and support for your schools, along with the following offerings:

- **Recognition** for your school's efforts to create efficient and healthy learning environments in order to build trust and awareness in your community.
- **FREE technical assistance** on practical solutions such as benchmarking, retrofit plan development and review, and indoor air quality (IAQ) monitoring guidance.
- **A nationwide support network** of schools and districts sharing best practices and lessons learned in peer-to-peer discussions and working groups.
- **Talored resources** to assist your school in all phases of energy efficiency or IAQ projects, including templates, case studies, and webinars.

Still have questions?
Check out our FAQs, or contact us at schools@lbl.gov.
To learn more...
Please visit efficienthealthyschools.lbl.gov.



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South Tahoe High School
Credit: LPA Architects

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Thank you!

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Questions?

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