AMERICAN MADE
U.S. DEPARTMENT OF ENERGY

Understanding Your Buildings and Identifying Opportunities for Efficiency

SCEP
STATE & COMMUNITY ENERGY PROGRAMS

Welcome

Let's get to know each other!	10 mins
Lesson Plan • Recap of Fundamentals • Climate-specific Approaches • Sustainable Practices Deep-Dive	1 hour 20 mins
Discussion	30 mins

Today's Presenters

Dimitri Contoyannis

President

Model Efficiency

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Technical Associate

New Buildings Institute

Icebreaker

The Mentimeter Marmot returns!

Instructions:

- Scan the mentimeter code on your phone or enter on your computer browser.
- Respond to the prompts and answers will populate real time.

Introduction

Recap of Fundamentals

Course Objective

Understand what building science is and how can it be used to optimize building performance, decrease energy use/cost, and alleviate dependency on fossil fuels.

1. Participants will be able to identify major energy using systems common in K-12 school buildings.

2. Participants will understand the impacts of building upgrades, maintenance, and operation on efficiency and occupant health.

3. Participants will understand how to begin the process of project planning and preparation to achieve efficient and healthy school buildings.

Why building science matters to schools

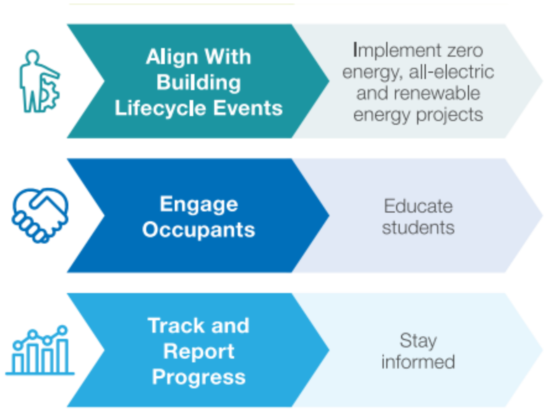
- Upgrades to school facilities can:
  - ✓Improve air quality
  - ✓Improve comfort and health conditions
  - ✓Support better student learning
  - ✓Provide significant reductions in school energy bills
  - ✓Help to stabilize utility costs for annual budgeting
  - ✓Opportunities for safety and security

Student Performing Energy Audit, Los Angeles USD, CA
Credit: Los Angeles USD

Source: https://www.energy.gov/eere/buildings/efficient-and-healthy-schools

Covered in Module 1

- ✓ Foundational energy and carbon concepts in buildings
- ✓ Health, safety, and comfort issues
- ✓ Introduction to the building as a system
- ✓ Project planning

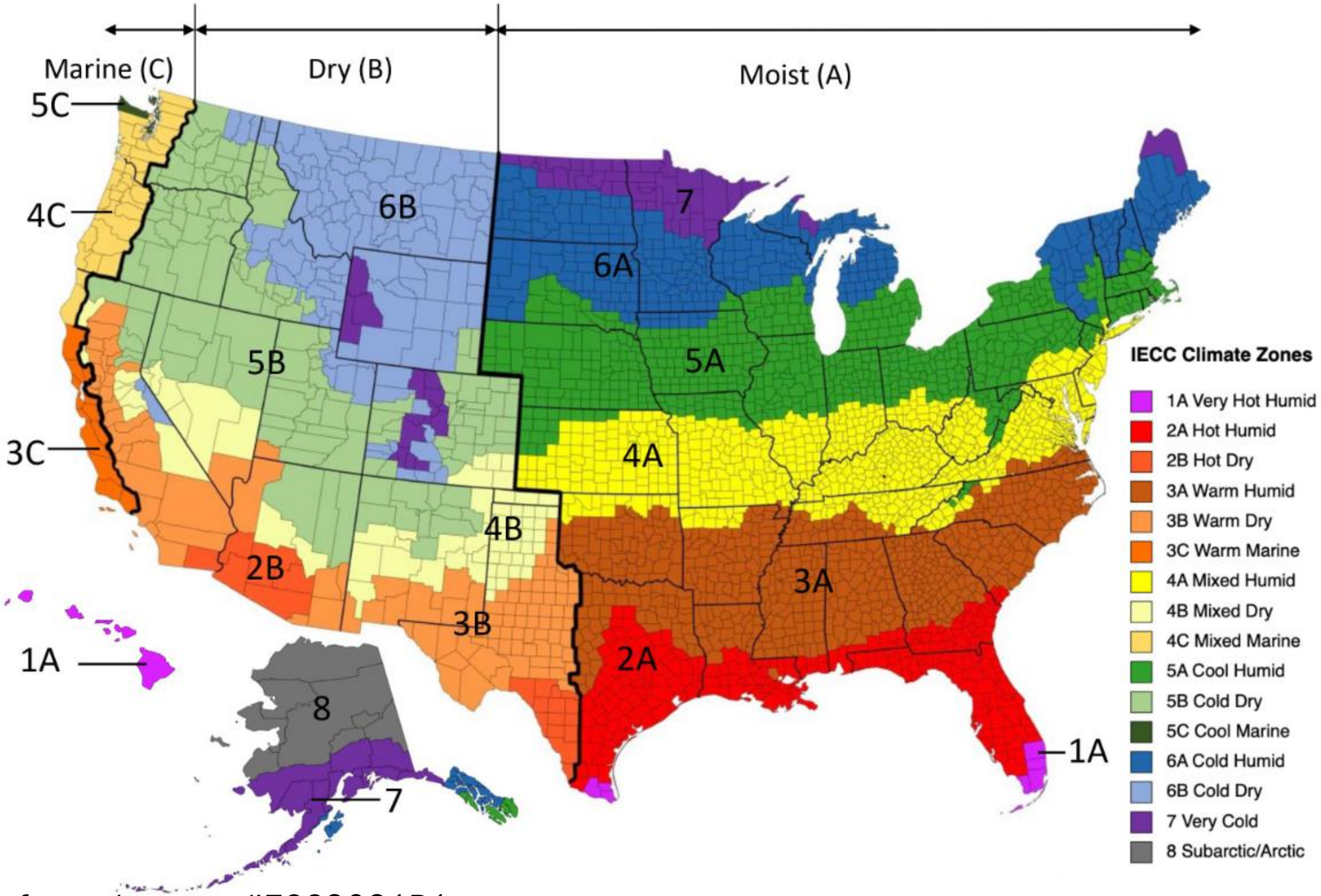


Today's goals

- Build on the themes and concepts of Module 1
- Get into the weeds on:
  - Climate-specific project considerations
  - Specific building systems

Climate-specific Approaches

Which Climate Zone Are You?

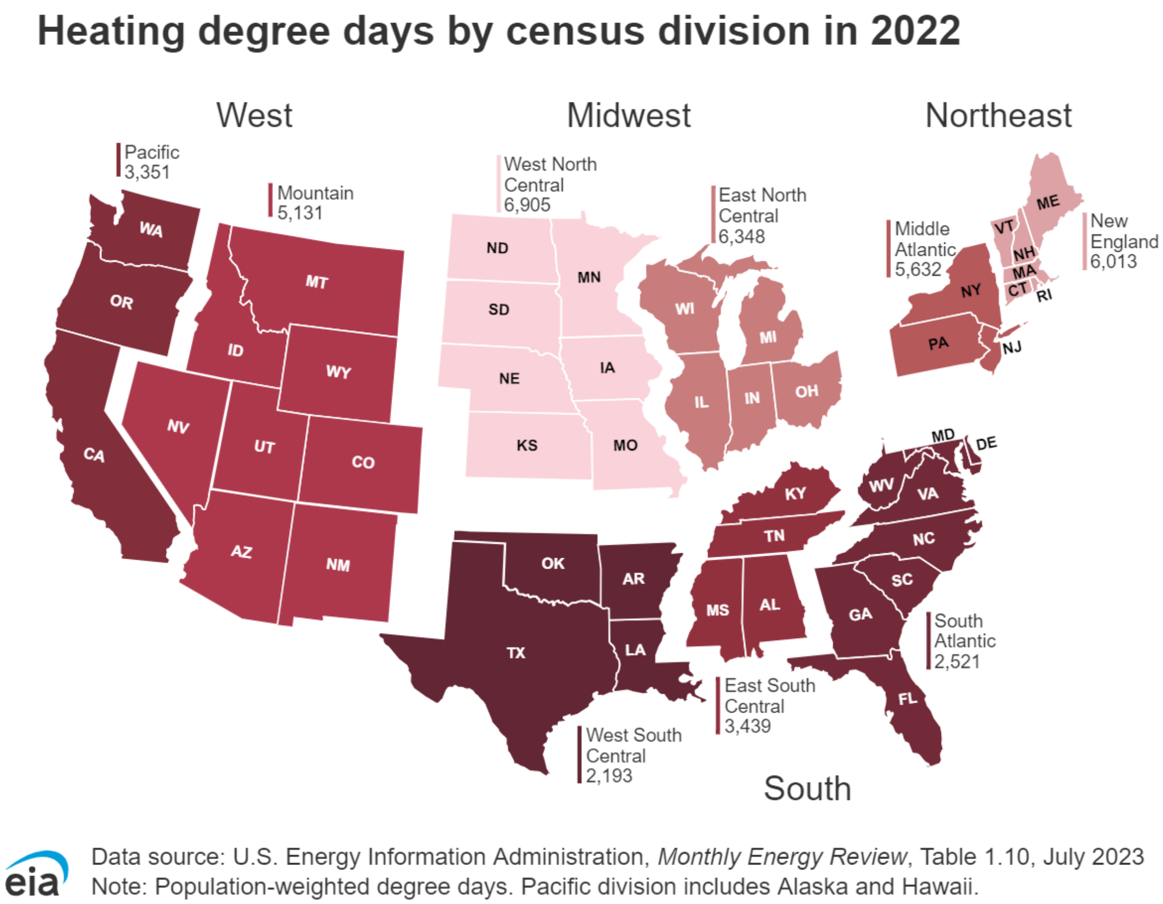


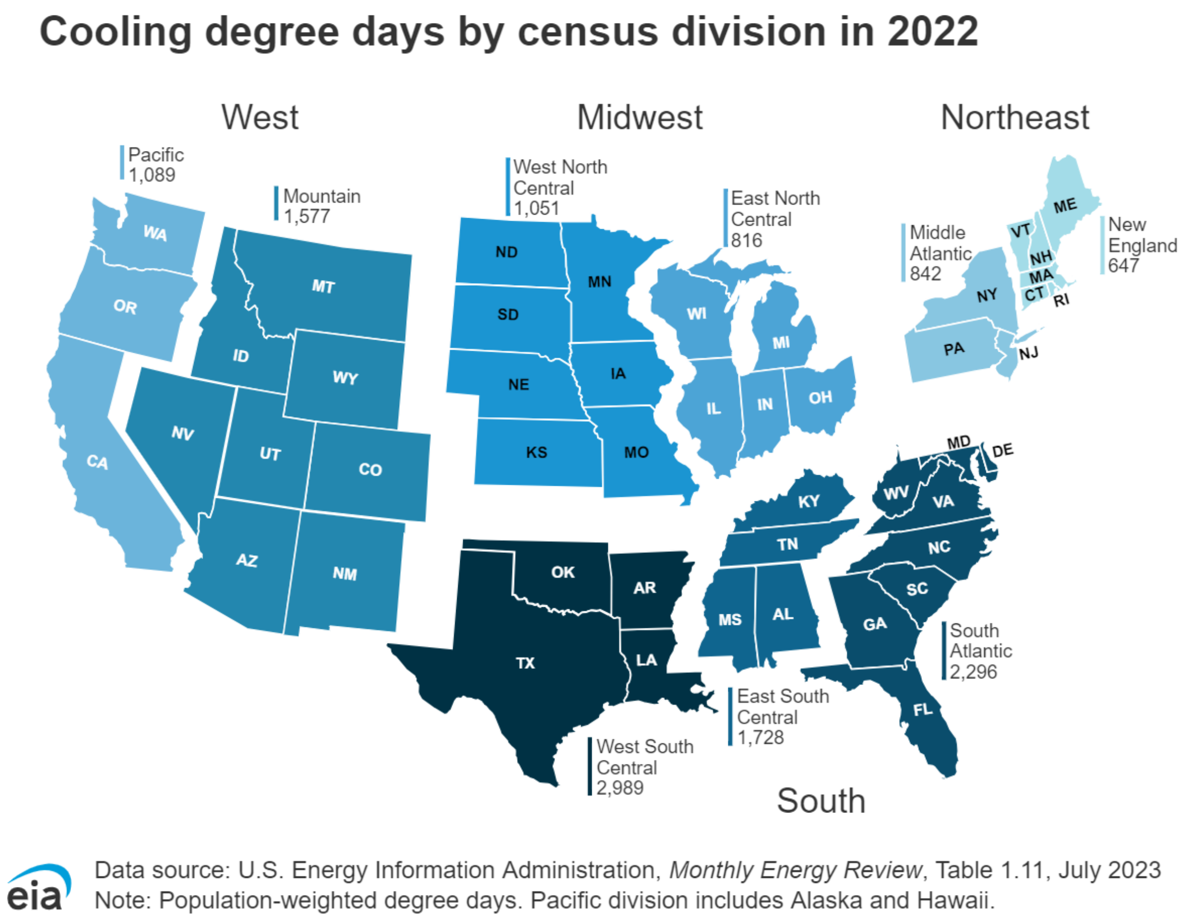
Source: https://codes.iccsafe.org/content/IECC2021P1

Climate specific design

HDD = How often the temperature is below 65F

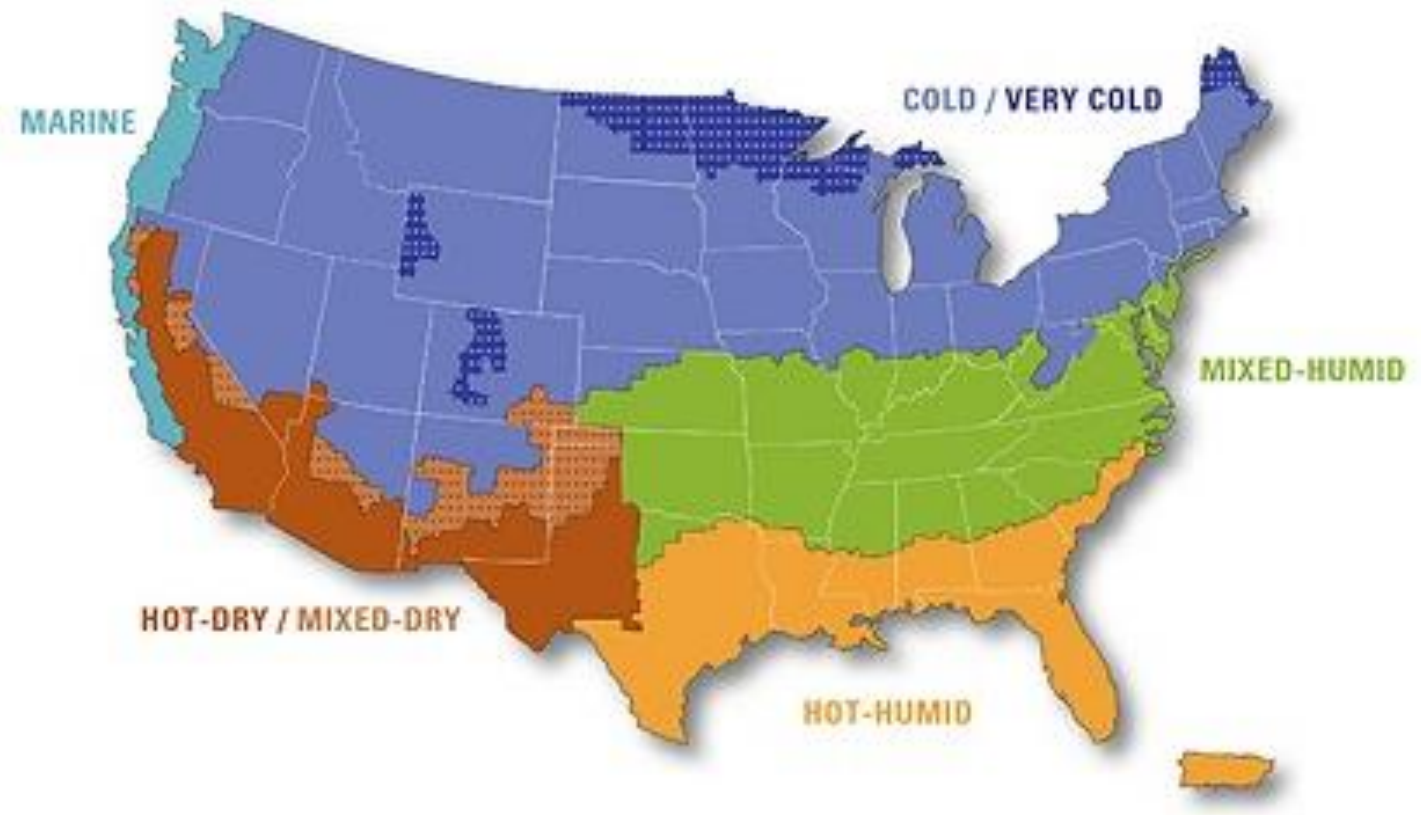
CDD = How often the temperature is above 65F





Climate specific design

- Climate zone determines:
  - Energy code requirements
  - Heating and cooling demand
  - Where buildings use more energy
- Other regional factors:
  - Precipitation
  - Flooding and stormwater management
  - Tornadoes and high winds
  - Seismic events
  - Forest fires
  - Solar availability
  - Outdoor air pollution levels



Source: https://www.energy.gov/eere/buildings/building-america-climate-specific-guidance

Sample School Considerations

School	Location	Climate Zone	Setting	Condition
A	Pacific Northwest	4C (Marine)	Coastal rural	1960s build, 20,000 ft^2 with baseboard heating and no air conditioning

Retrofit case:

Rising temperatures and frequent wildfire smoke prompt the need for air conditioning and high-quality ventilation

Options:

- Heat pump for high-efficiency heating *and* cooling
- Dedicated outdoor air system with MERV13 filters for ventilation
- Blower door test and air sealing to limit air infiltration

Sample School Considerations

School	Location	Climate Zone	Setting	Condition
A	Pacific Northwest	4C (Marine)	Coastal rural	1960s build, 20,000 ft^2 with baseboard heating and no air conditioning

Operation:

- Temperate climate allows for natural ventilation via operable windows and economizer control for much of the year
- Night flush control to cool the building overnight in the summer
- Air quality monitoring educates building operator on when to avoid natural ventilation
- Lighting systems respond to available daylighting (or lack thereof in the winter)

Sample School Considerations

School	Location	Climate Zone	Setting	Condition
A	Pacific Northwest	4C (Marine)	Coastal rural	1960s build, 20,000 ft^2 with baseboard heating and no air conditioning

Maintenance:

- Coastal climate leads to shorter equipment lifespan and more regular maintenance checks of outdoor equipment exposed to salty conditions
- Frequent filter replacement – particularly during wildfire season
- Additional backup filters and maintenance equipment in stock due to rural setting

Sample School Considerations

School	Location	Climate Zone	Setting	Condition
B	Southeast US	1A (Hot-humid)	Urban city-center	1990s build, 300,000 ft^2 with rooftop units and gas heating

Retrofit case:

Major HVAC equipment is approaching end-of-life, and the school received a grant for an electric school bus

Options:

- Replace rooftop units with efficient heat pump counterparts equipped with energy recovery ventilation
- Add electrical infrastructure for EV chargers while electricians are on site for HVAC work

Sample School Considerations

School	Location	Climate Zone	Setting	Condition
B	Southeast US	1A (Hot-humid)	Urban city-center	1990s build, 300,000 ft^2 with rooftop units and gas heating

Operation:

- Outside conditions are typically too hot, too humid, too polluted, or too noisy for natural ventilation during school hours – opening windows is discouraged
- When night-time conditions allow, flush the school to cool the building overnight
- Lighting systems on the perimeter of the school are dimmed in response to long periods of available daylight

Sample School Considerations

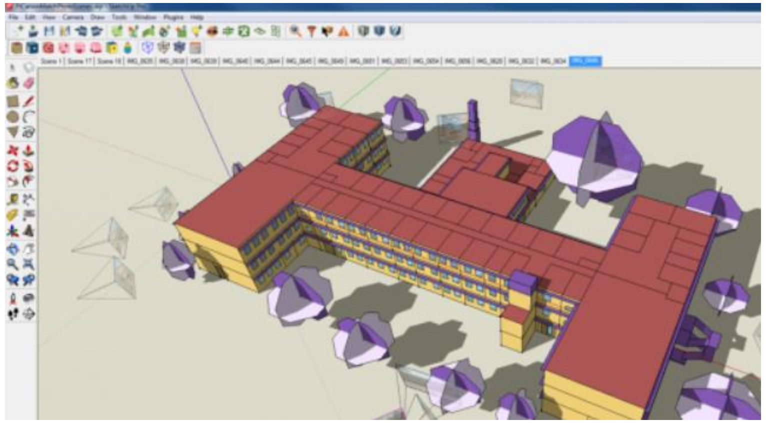
School	Location	Climate Zone	Setting	Condition
B	Southeast US	1A (Hot-humid)	Urban city-center	1990s build, 300,000 ft^2 with rooftop units and gas heating

Maintenance:

- Larger school has many rooftop units – clear documentation and maintenance tracking is key
- Equipment is nearing end-of-life – make a replacement plan to not be caught without cooling during a heat wave
- Regularly check for signs of moisture where it shouldn't be due to high humidity

Importance of an energy model

- Buildings are complex systems
- Energy models help to:
  - Identify the most impactful retrofit measures by comparing a baseline model and a design model
  - Inform the best design for new construction or major renovations
  - Design upgraded building systems (e.g., HVAC)



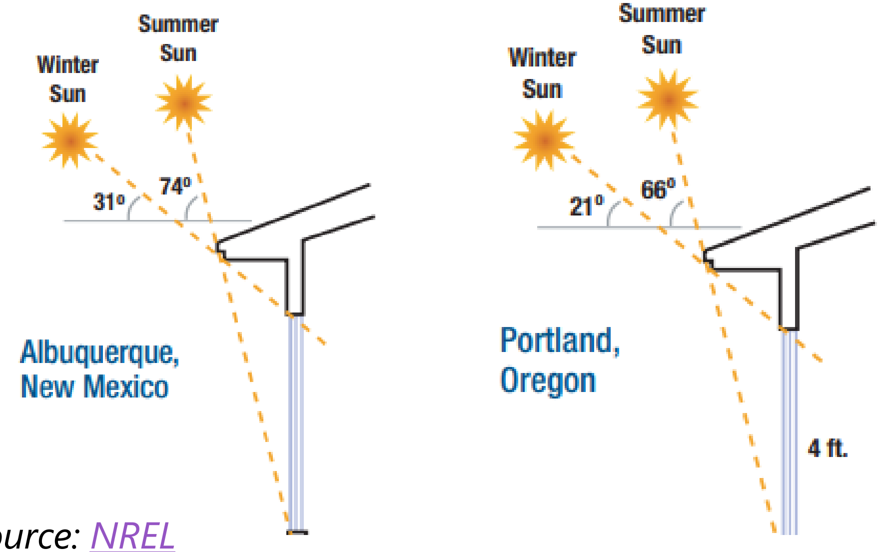
Source: DOE

Example questions a modeler will ask

- When is the weather "comfortable?"
- Do operable windows make sense for this project?
- When will HVAC systems be necessary?
- What is the topography and how does it impact wind conditions?
- How should the building be oriented to take advantage of natural ventilation potential?
- Do we need to control solar gains for thermal or visual comfort?
- What other design strategies are appropriate for this climate?
- Do I need to do anything special to comply with a code or standard?

Key consideration: designing with the sun

- Establish the building on an east-west axis and minimize east- and west-facing glass
- Single-story designs maximize daylighting
- In multiple-story schools, minimize the depth of the rooms to maximize daylighting



Source: NREL

Sustainable Practices Deep-Dive

Recap: Major building elements

Building systems

- HVAC
- Water heating
- Lighting
- Kitchen equipment
- Electrical systems
- Plug and process loads
- Controls

Building Envelope

- Roofs and walls
- Foundation
- Windows and doors

Key resource: K-12 Advanced Energy Design Guide (AEDG)

Strategy Type	Examples
Building and site planning (BP)	Site selection and building orientation
Envelope (EN)	Air leakage control, thermal mass
Daylighting (DL)	Daylighting and view impact on student performance
Electric lighting (EL)	Light-emitting Diode (LED)/Solid-State Lighting (SSL), Control strategies
Plug load management (PL)	Policy, controls, monitor usage
Kitchen equipment (KE)	Menu design, efficiency equipment, controls
Service water heating (WH)	Efficiency, controls, heat recovery
HVAC (HV)	Distributed generation, system selection, DCV
Renewable energy (RE)	Sizing, storage, metering, rates

https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download

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Key Resource: DOE's Better Buildings

Better Buildings®
U.S. DEPARTMENT OF ENERGY

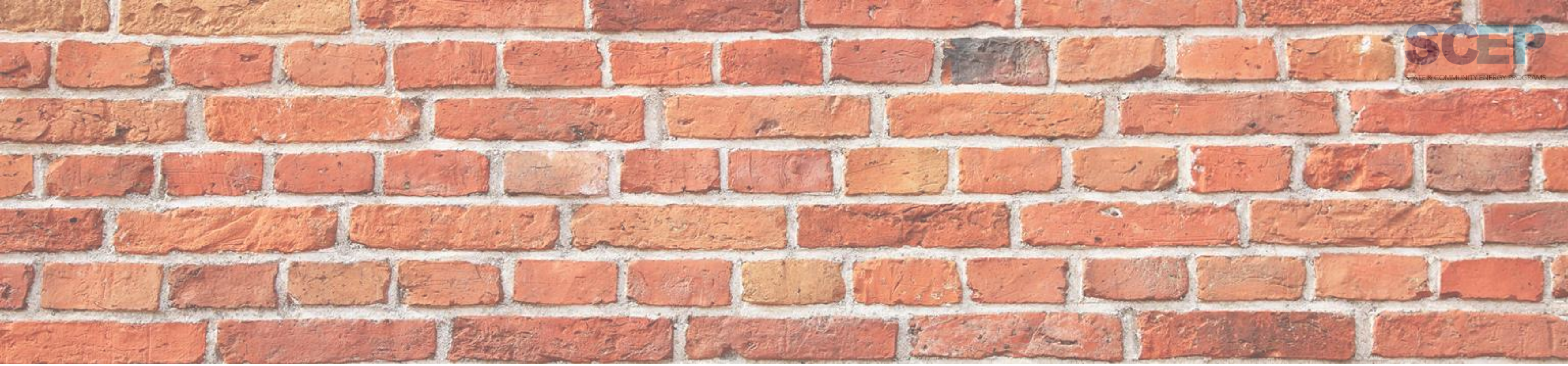
Low Carbon Technology Strategies

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	• 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

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Primary_School_BB_Carbon_Strategies.pdf

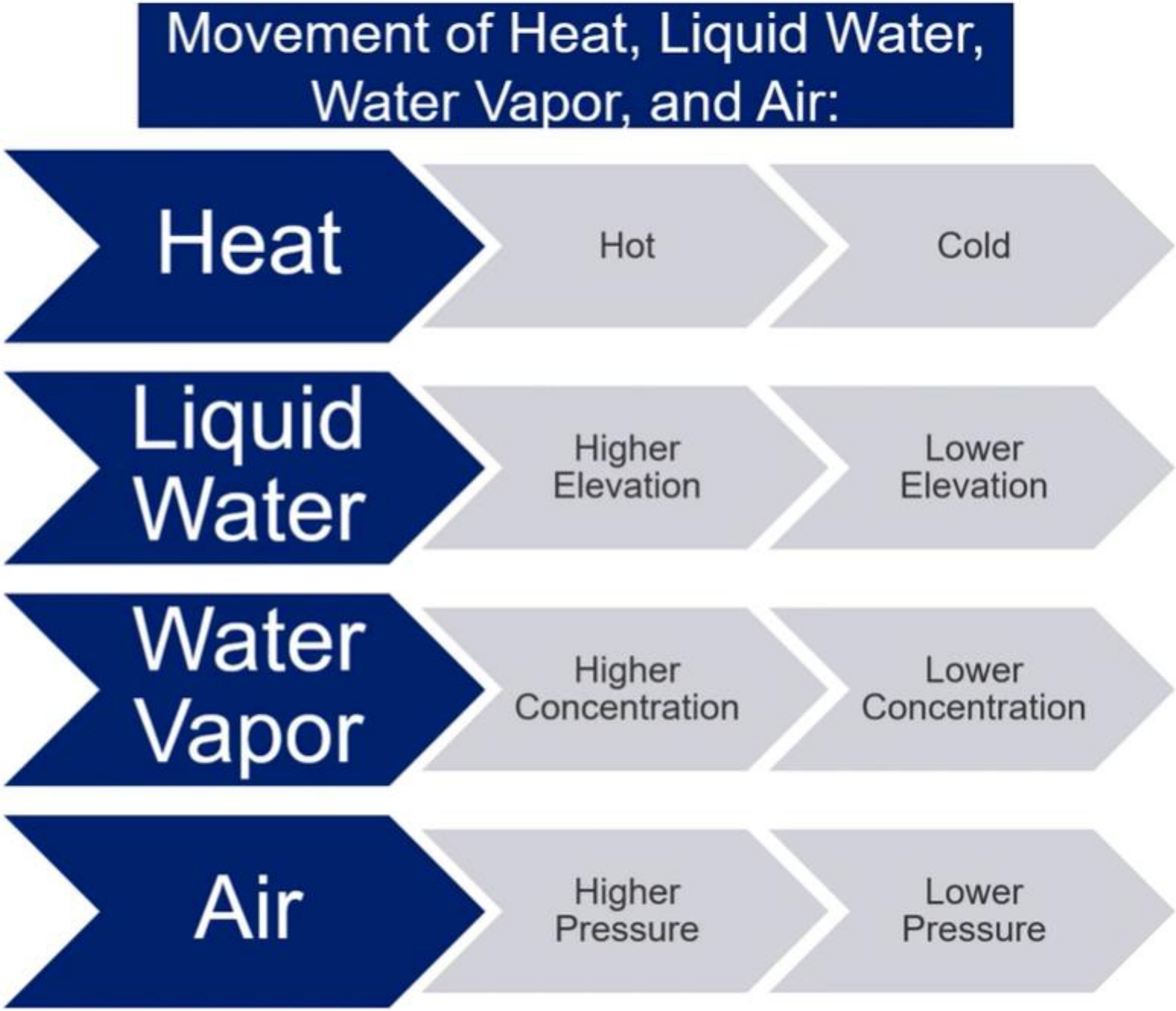


Building Envelope

- A well-designed, airtight envelope keeps occupants comfortable and will reduce the overall energy needs of the building.

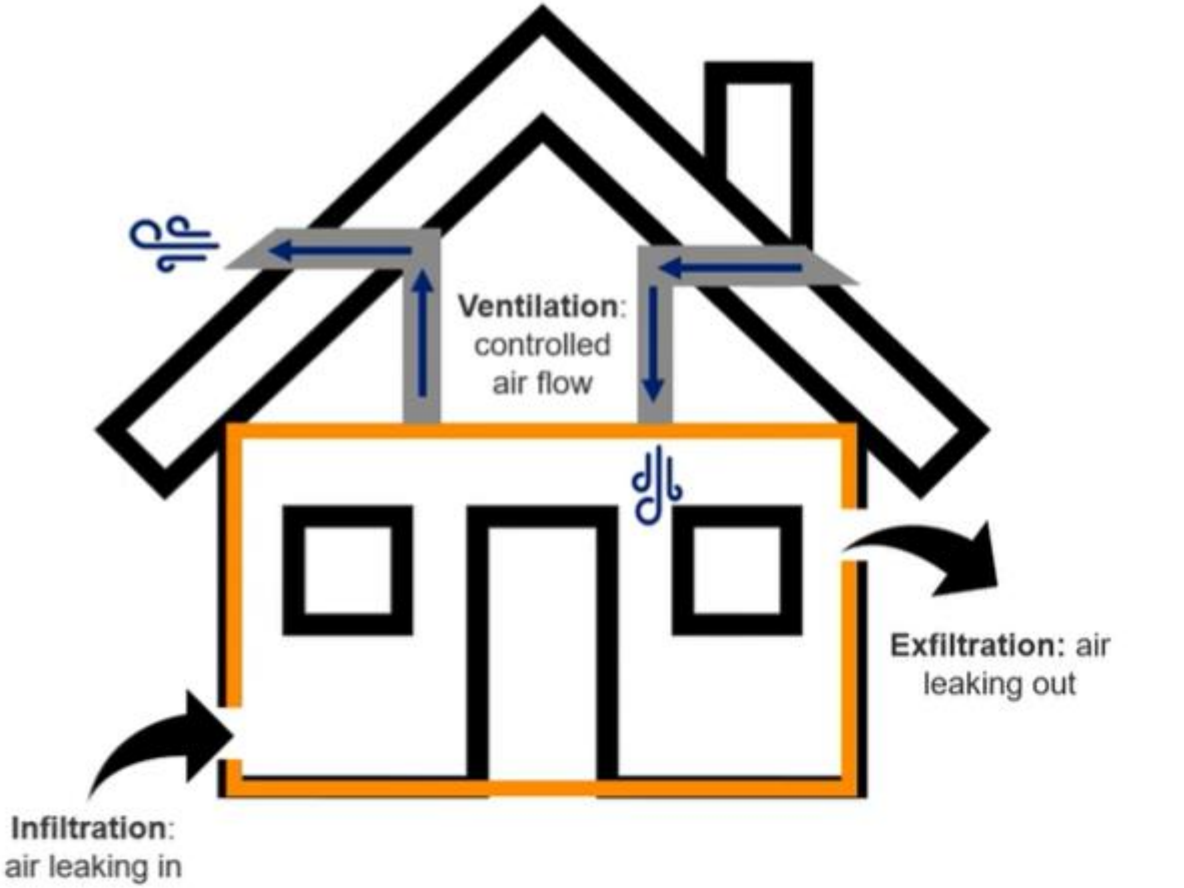
Envelope

- Controls transfer of heat, moisture, and air between the inside and outside of the building
- We will focus on heat and air as the biggest contributors to energy, but don't forget these are connected to moisture!

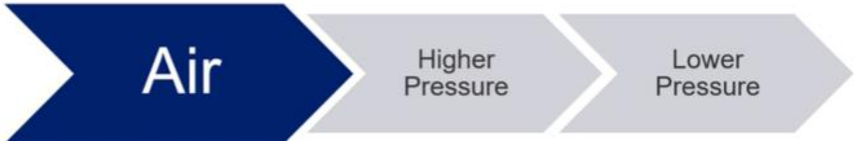


Air leakage

- Major cause of energy loss
- Causes HVAC system to work harder
- Evaluate via blower door testing
- Goal: create a continuous air barrier around roof, walls, and lowest floor
- **Mitigation strategies**:
  - Sealing gaps, seams, and holes (weatherstripping, caulking, spray foam)
  - Continuous insulation

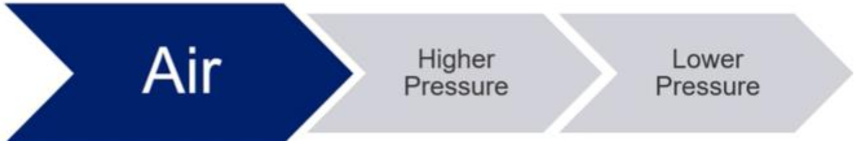


Source: DOE Solar Decathlon



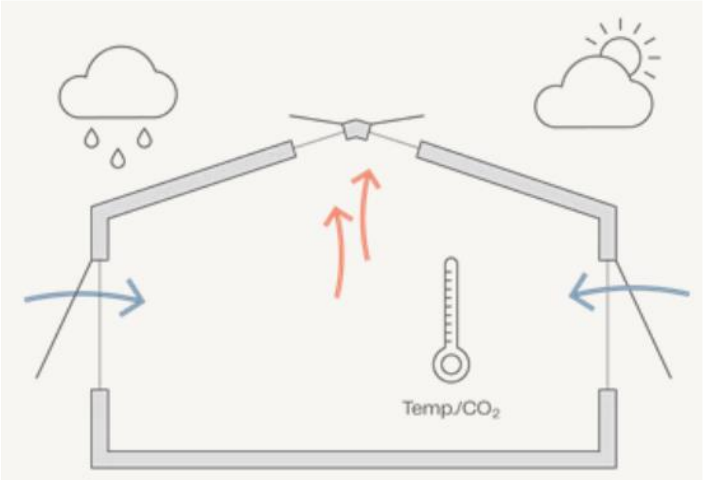
Natural ventilation

- Operable windows provide benefits, if used properly
  - ❑ Open windows when the air outside is cooler and drier than inside in the warm season
  - ❑ Consider safety, noise, pollution, and other factors before opening windows
  - ❑ Ensure that HVAC is not running when windows are open

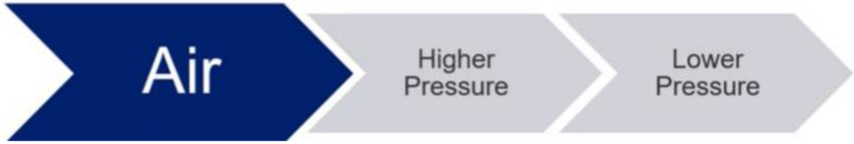


Natural ventilation strategies

- **Cross ventilation:** open windows at opposite ends of a room or building
- **Stack ventilation:** open windows at a high and low point (warm air rises)
- **Night flushing to cool:** open windows at night to cool down the building
- **Combine with active systems:** some control systems can automatically operate windows based on outside air conditions and time of day



Source: WindowMaster

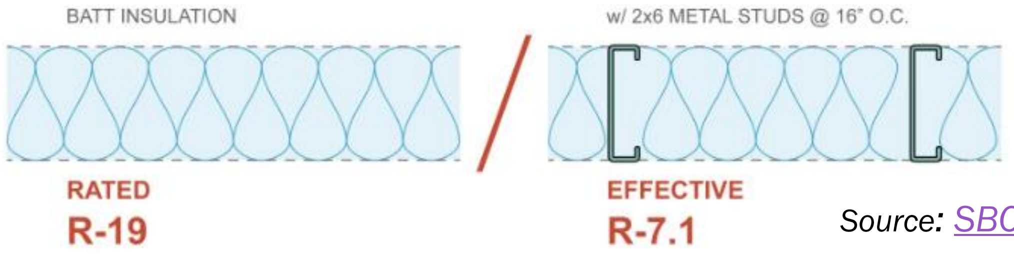


Envelope materials: U and R-values

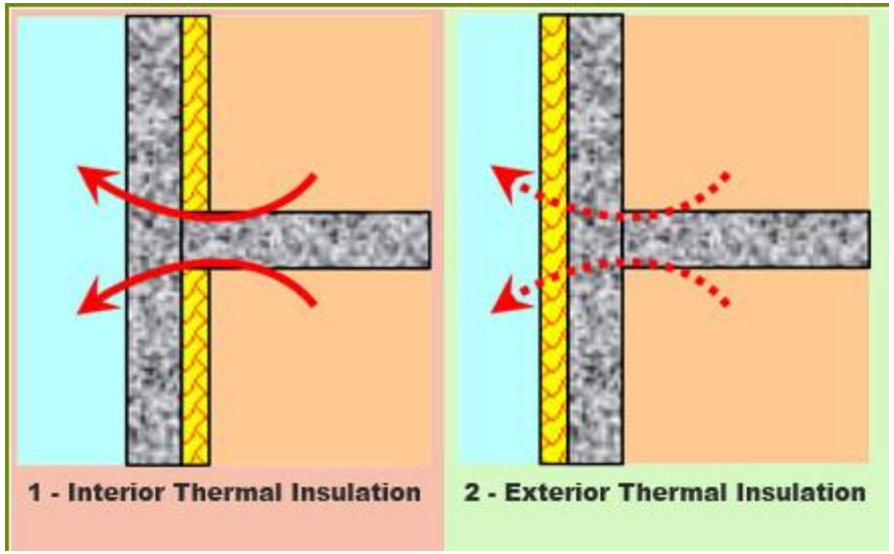
Metric	Used for	Definition	Scale
U-value (or U-factor)	Glass	The magnitude of heat flow or heat loss. Lower = better	0.1 (little loss) to 1.0(high loss)
R-value	Walls, floors, roofs	Resistance to heat flow or heat loss Higher = better	1 (solid board) to ~60

Envelope materials: Effective R-value

- Overall thermal resistance of the *assembly*
- Thermal bridges are localized "heat loss highways"; eliminate as much as possible



Source: [SBC Magazine]

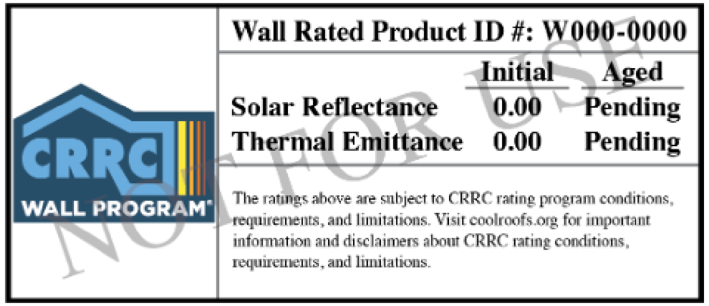


Source: [Beodom]

Source: [Deep Energy Retrofit]

Roof and wall performance

- Roof and wall material can have a significant impact on energy use
- Select “cool roof” and “cool wall” products (not necessarily white!) with higher Solar Reflectance (SR), Thermal Emittance (TE), and Solar Reflectance Index (SRI)
- Consider PV suitability
  - Maintain access to unobstructed sun

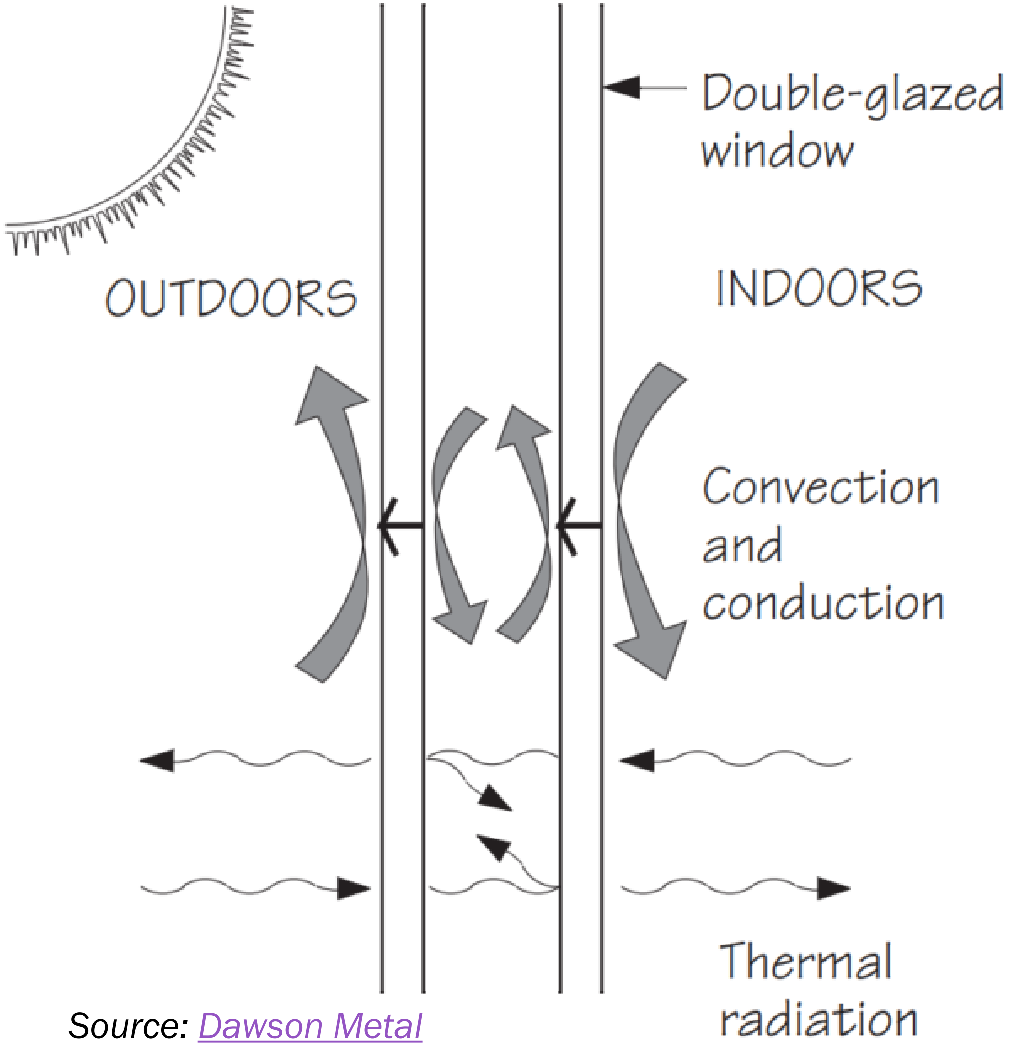


Source: *Cool Roof Rating Council*

Source: *LBNL Heat Island Group*

Windows and doors

- Heat moves from warmer to colder areas
- **Radiation:** heat gain through the glass
  - Mitigated with low-E coatings
- **Convection:** through the edges and frame
- **Conduction:** between the panes
- **Leakage:** between operable sash and frame



Source: Dawson Metal

Window performance

- Single, double, or triple pane
- Solar heat gain coefficient (SHGC)
  - Solar energy allowed through window (0 = none)
- Visible transmittance (VT)
  - Opaque (0) to transparent (1)
- Air leakage
  - 0 = airtight

https://www.nfrc.org/energy-performance-label/

Using windows for daylighting

- Reduces electric lighting needs and minimizes solar heat gain without compromising illumination levels or creating glare
- Provides views to the outside for safety and comfort
- Impacted by space layout, colors and textures
- Controlling for comfort
    - Exterior shading
    - Interior shades

Source: [Lighting Research Center]

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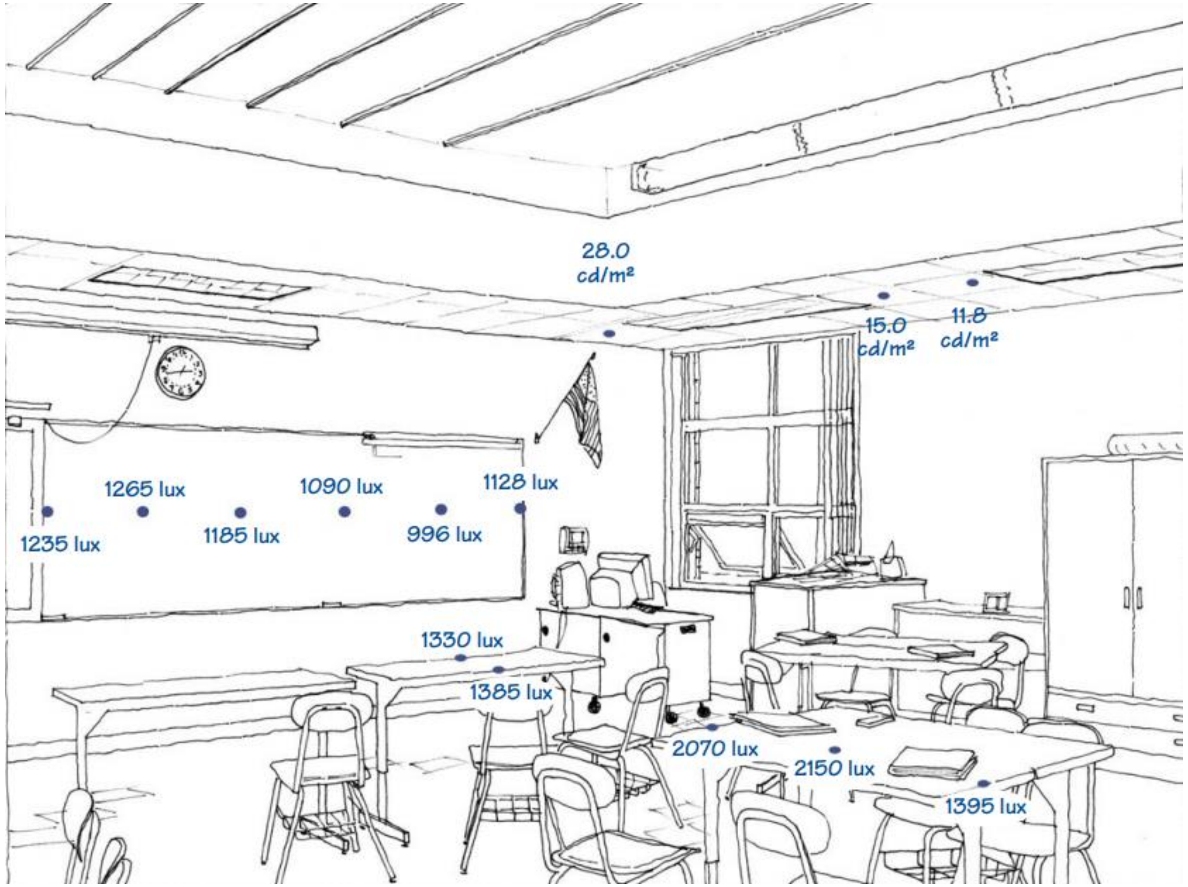
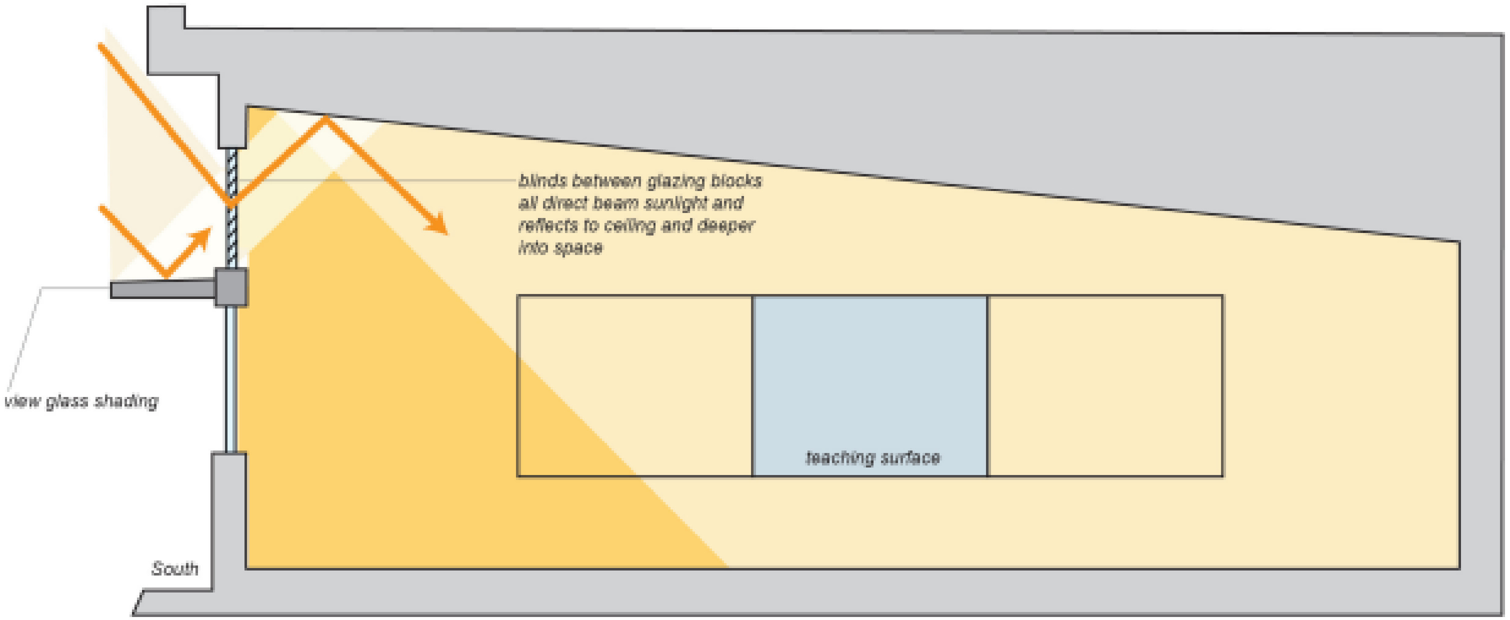
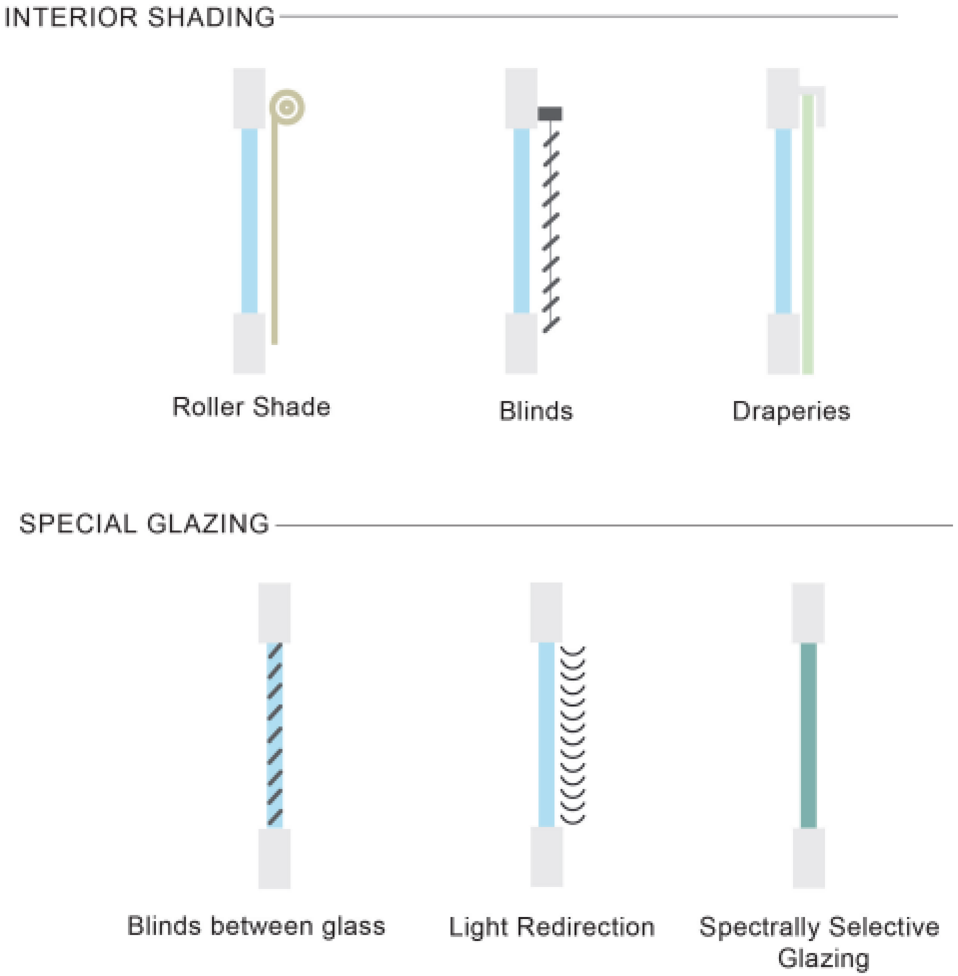


Source: *[Lighting Research Center]*

Daylighting

- AEDG provides multiple examples

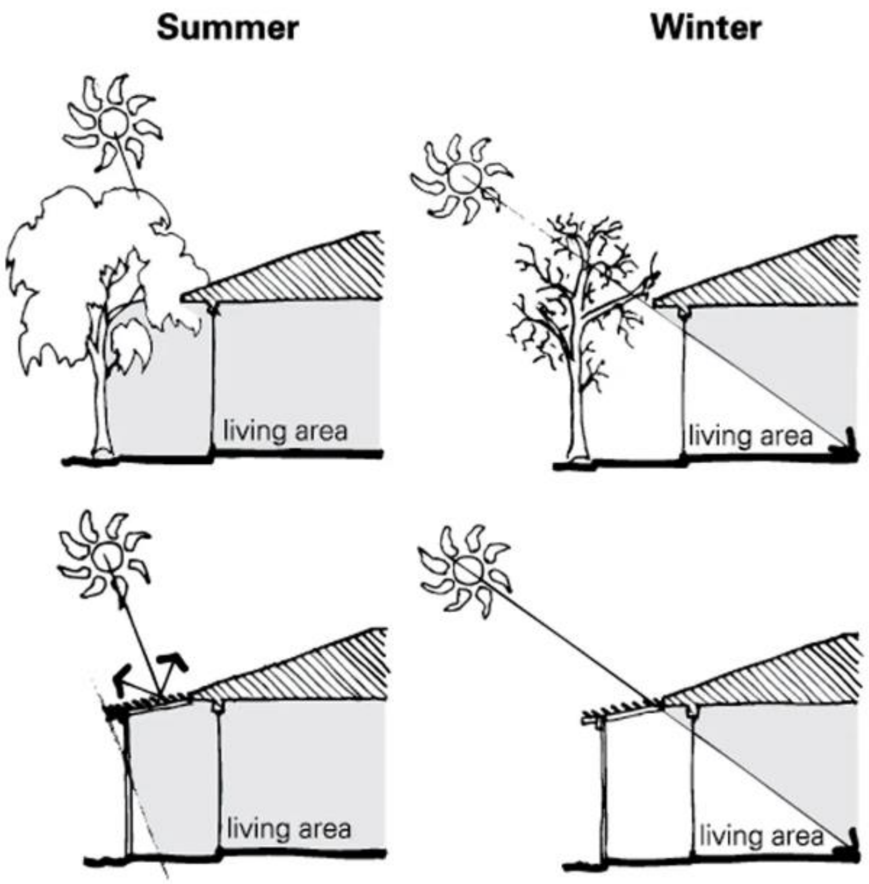




https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download

External shading

- Goal: Maximize occupant comfort to minimize unwanted heat gain and glare
- Important to consider solar angles
- Example strategies:
  - Vegetation/landscaping
  - Overhangs
  - Vertical fins
  - Lightshelves



Source: Archi-Monarch

Heating, Ventilation, and Air Conditioning (HVAC)

- Space heating is the largest energy user in schools. Combined with cooling and ventilation, it accounts for 64% of annual energy use.

HVAC Systems

- HVAC system provide warm and cool air to the building and control humidity to ensure occupants are comfortable
- In non-residential buildings, HVAC systems are responsible for bringing fresh, filtered air to the building
- HVAC is often the number one energy consumer in a building
- High-efficiency heat pumps and energy recovery systems can significantly reduce energy consumption

Common HVAC Systems

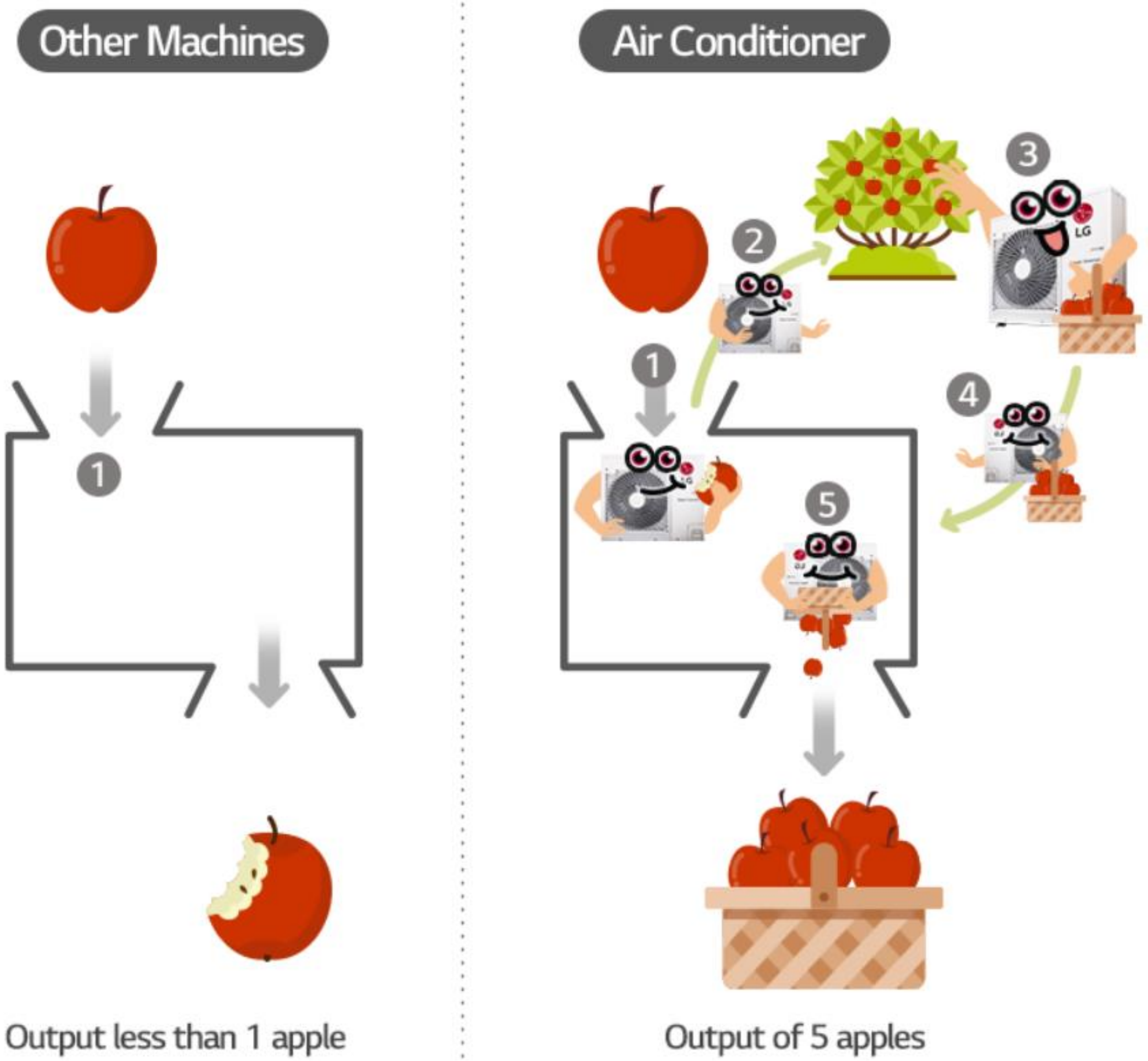
Rooftop Units (RTUs)

Air Handling Units (AHUs)

Chillers and boilers

HVAC efficiency metrics

- **Coefficient of Performance (COP)**
  - Energy generated vs. energy required (input)
- **Energy Efficiency Ratio (EER)**
  - Cooling output / energy input
- ***Seasonal* Energy Efficiency Ratio (SEER)**
  - Cooling output / energy input, for a specified season
- In all cases, higher = better



https://www.lghvacstory.com/hvacefficiency/

Efficient HVAC system options

- Other options:
  - Air to water heat pump
    - Replacing hydronic gas boilers
  - Geothermal heat pumps

VRF

Air source heat pumps

https://methodeg.com/blog/vrf-for-k12

https://www.wmhendersoninc.com/heating/ductless-split-systems/

Key considerations

- Selecting a system
  - ❑ Proper sizing
  - ❑ Location (weight, ambient conditions for heat pumps)
  - ❑ Efficiency
  - ❑ Upfront and operational cost (ROI)
  - ❑ Noise
  - ❑ Low GWP refrigerant
  - ❑ Retrofit options (economizer, variable speed fan, DCV)

Source: Pioneer mini-split

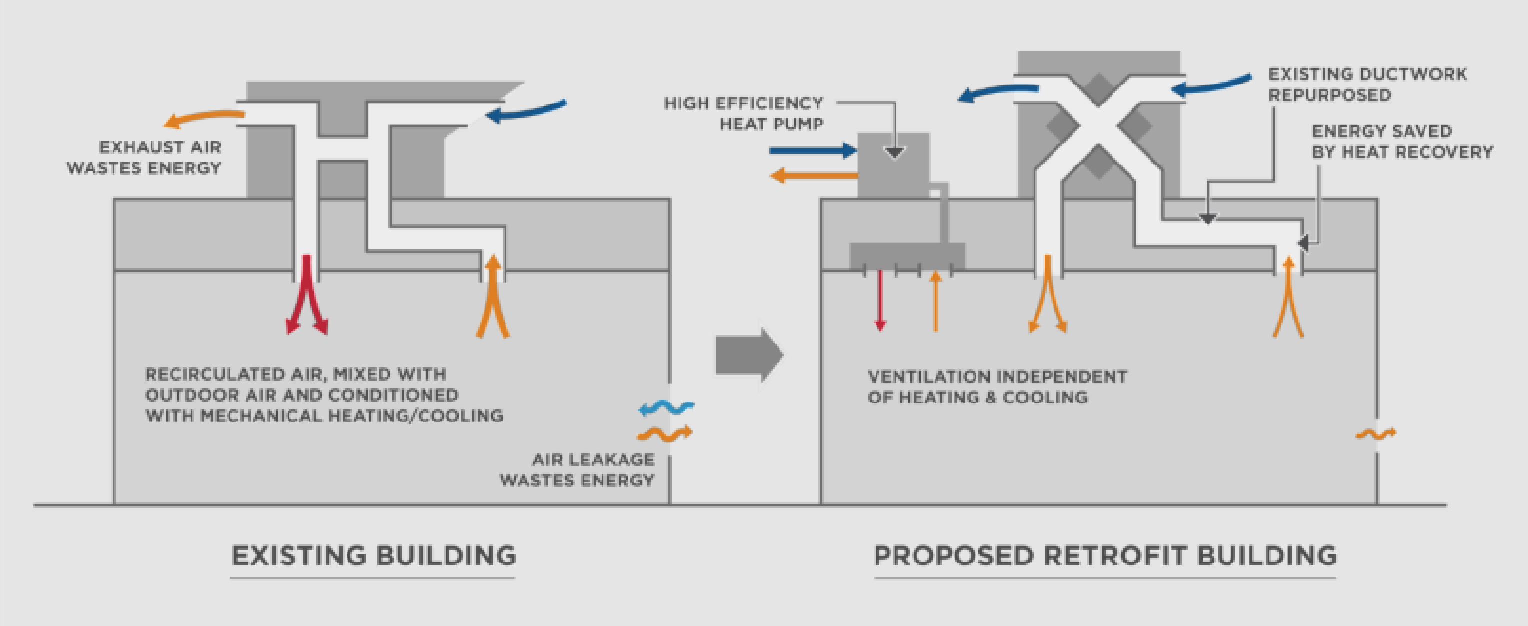
Key considerations

- Installation
  - ❑ Commissioning
  - ❑ Controls
- Maintenance
  - ❑ Filters
  - ❑ Test and seal ducts
  - ❑ Test and repair dampers

https://www.achrnews.com/articles/124595-doe-leaky-ducts-are-top-energy-waster

Mechanical ventilation

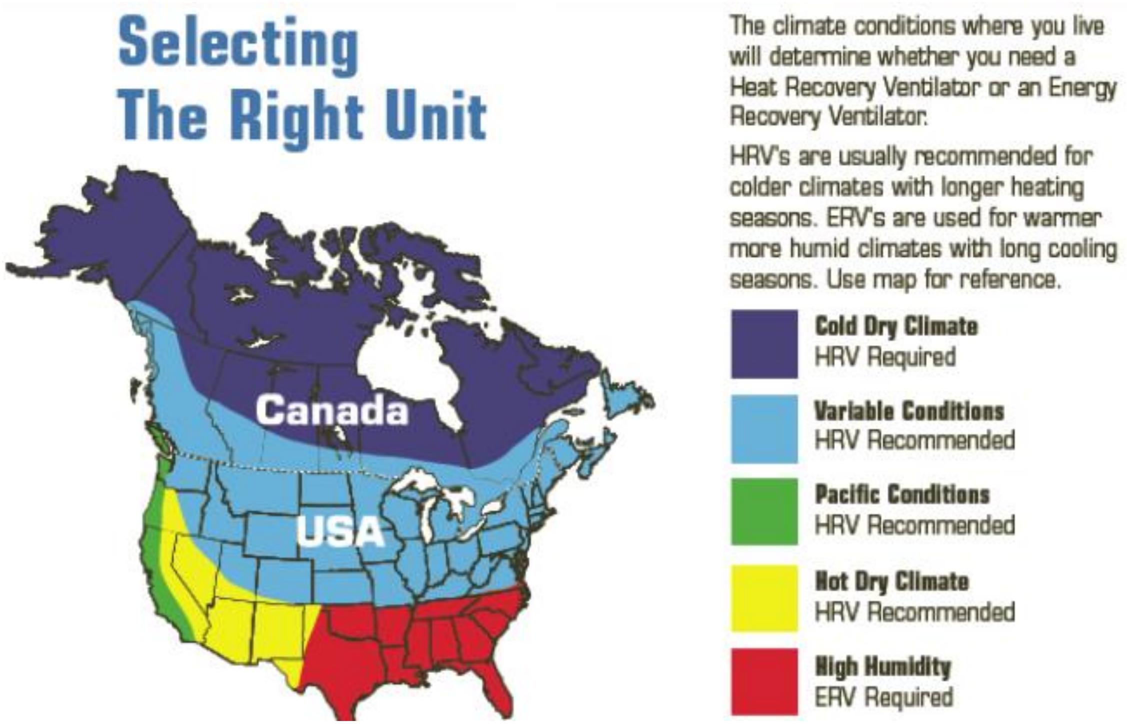
- Mechanical ventilation requirements are dictated by code and vary by location
- Prioritize separation of ventilation from conditioning
- Utilize dedicated outside air systems (DOAS)



Source: BetterBricks

Mechanical ventilation

- Heat Recovery Ventilation (HRV):
  - Transfers heat energy between the supply and exhaust airstreams
- Energy Recovery Ventilation (ERV):
  - Transfers both moisture and heat
  - Can significantly reduce RTU compressor and/or furnace run time
  - Balances ventilation
- Choosing one or the other depends on climate



Source: ENERGY STAR

Electrical Systems

- An inefficient electrical distribution system in a school can result in degraded power quality, the introduction of wasteful harmonics, line losses, and additional costs from the utility

Electrical systems

- Upgrades may be needed due to:
  - Addition of onsite renewables
  - Electrification of major building systems
  - Addition of EV charging infrastructure

Source: Electric School Bus Initiative

Electrical system upgrades

- When considering projects that may impact the electrical system:
  - ❑ Talk to utility representative, qualified electricians
  - ❑ Know meter location(s) and number(s), panels and circuit breakers
  - ❑ Make sure panel box directories are up to date

Source: PreFast

Electrical system best practices

- Oversized equipment adds to peak electrical loads and does not operate as well at part-load conditions.
- Use high-efficiency motors and, where appropriate, variable frequency drives.
- Select fans and pumps for the highest operating efficiency at the typical operating conditions.
- Use timers to limit the duty cycle of heaters when they are not in full use.
- Select energy-efficient appliances.

Lighting Systems

- Tunable LED lighting has been shown to increase reading speed and reduce errors during testing, in addition to providing benefits to teachers

[Source: https://doi.org/10.1016/j.physbeh.2011.09.020](https://doi.org/10.1016/j.physbeh.2011.09.020)

Lighting: efficiency tips

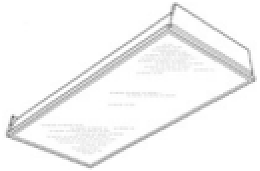
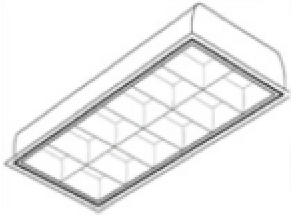
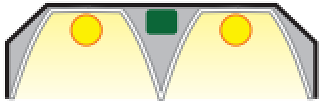
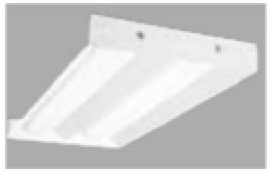
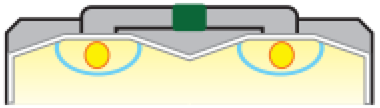
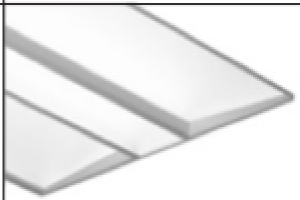
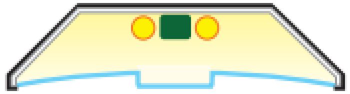
Ways to reduce lighting energy use:

1. Minimize the need for electric lighting by using daylighting strategies
2. Replace older lights with LEDs
3. Utilize controls
4. Educate and engage occupants

Discovery Elementary School | Arlington, VA
Credit: VMDO

Installing LEDs

Depending on the existing fixture, retrofit options such as a retrofit kit or tubular LED (TLED) may be an option

Description	Troffer Image	Troffer Cross Section View	Retrofit	
			TLED	Kit
Prismatic Lensed – This was the original troffer design. It utilizes a flat lens and is required in clean rooms, food processing areas, and some healthcare applications.			●	●
Parabolic Louvers – The vast majority of troffers in offices are parabolic louvers. The louvers act to reduce glare from fluorescent lamps. When TLEDs are installed, there might be more glare because of differences between the light distribution of the TLEDs and fluorescent lamps.			▲	●
Recessed Indirect – These are "softer" in appearance. The perforated metal reduces light output and addresses glare. However, these fixtures are very inefficient. More than 50% of the light generated by the fluorescent lamp can be absorbed by the perforated metal.			▲	▲
Volumetric – These are lensed troffers where the lenses contour around the fluorescent lamps. The term volumetric was coined because these troffers light high on the wall, making the space feel brighter while managing potential glare.			●	●
High Performance – These are next-generation volumetric troffers. The optical system has been maximized for light output while the distribution has been optimized to properly light the space.			●	●

Color key to components:
- ● = lamp
- ■ = housing
- ■ = ballast
- = reflector
- = louvers
- = lens

● = few limitations

▲ = proceed with caution

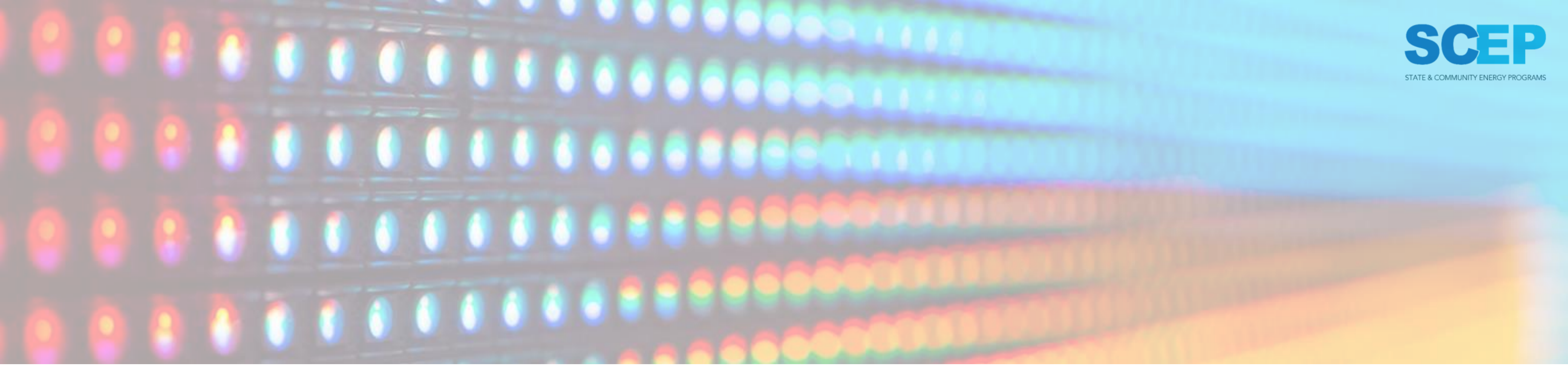
Source: *DOE*

Sports field LEDs

- The projected savings for moving to LED lighting over a 10-year period are **$133,000** for a typical sports complex
- LEDs offer a variety of non-financial benefits:
  - ✓Reduced glare
  - ✓No warm-up time
  - ✓No hazardous waste
  - ✓Remote monitoring

Lighting controls

- So many options!
  - Manual controls
  - Dimmer switches
  - Timers
  - Occupancy sensors
  - Vacancy sensors
  - Voice-controlled technology
  - Photosensors
  - Daylighting controls
- Best choice will depend on:
  - Cost
  - Complexity
  - Electrical considerations

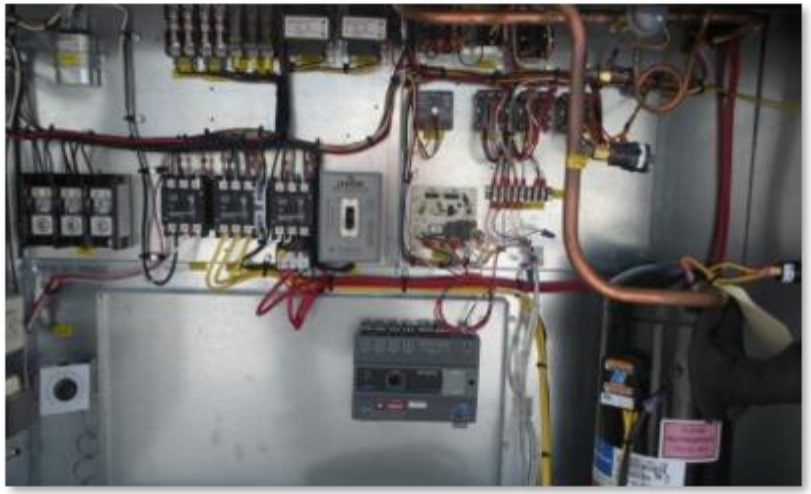


Controls & Integration Systems

- Building controls are an easy way to minimize energy use while maintaining building operations and occupant comfort.

Controls – guiding principle

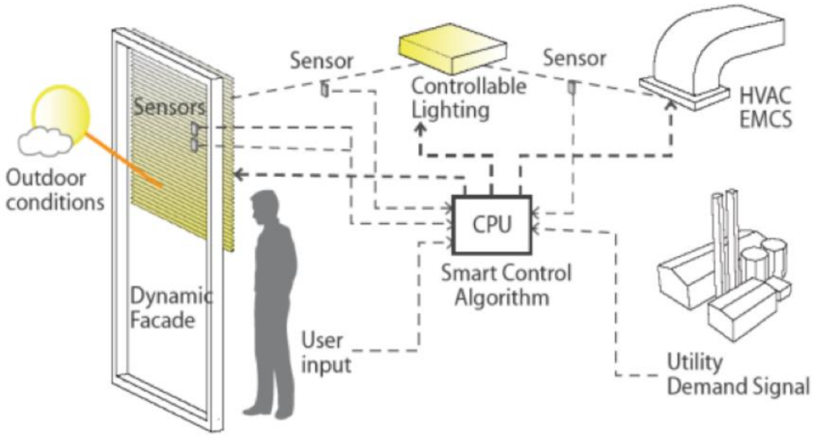
Keep it simple.



Controls

- Systems that can be controlled:
  - Windows & shading
  - HVAC
  - Lighting
  - Security
  - Plug loads
- Controls can enable communication with utility to participate in demand response
- Follow ASHRAE Guideline 36 standards

- Sensors may include:
  - Temperature
  - Humidity
  - Light levels
  - Occupancy
  - Scheduled hours



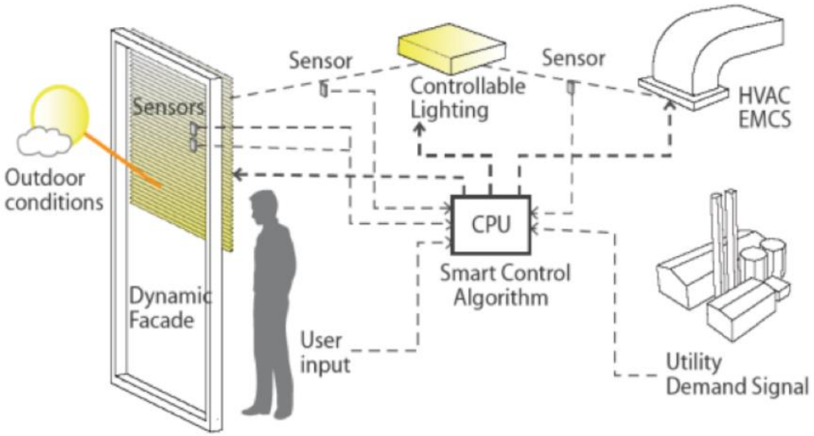
Source: NREL

Controls

- Systems that can be controlled:
  - Windows & shading
  - HVAC
  - Lighting
  - Security
  - Plug loads

Integrate to maximize efficiency!

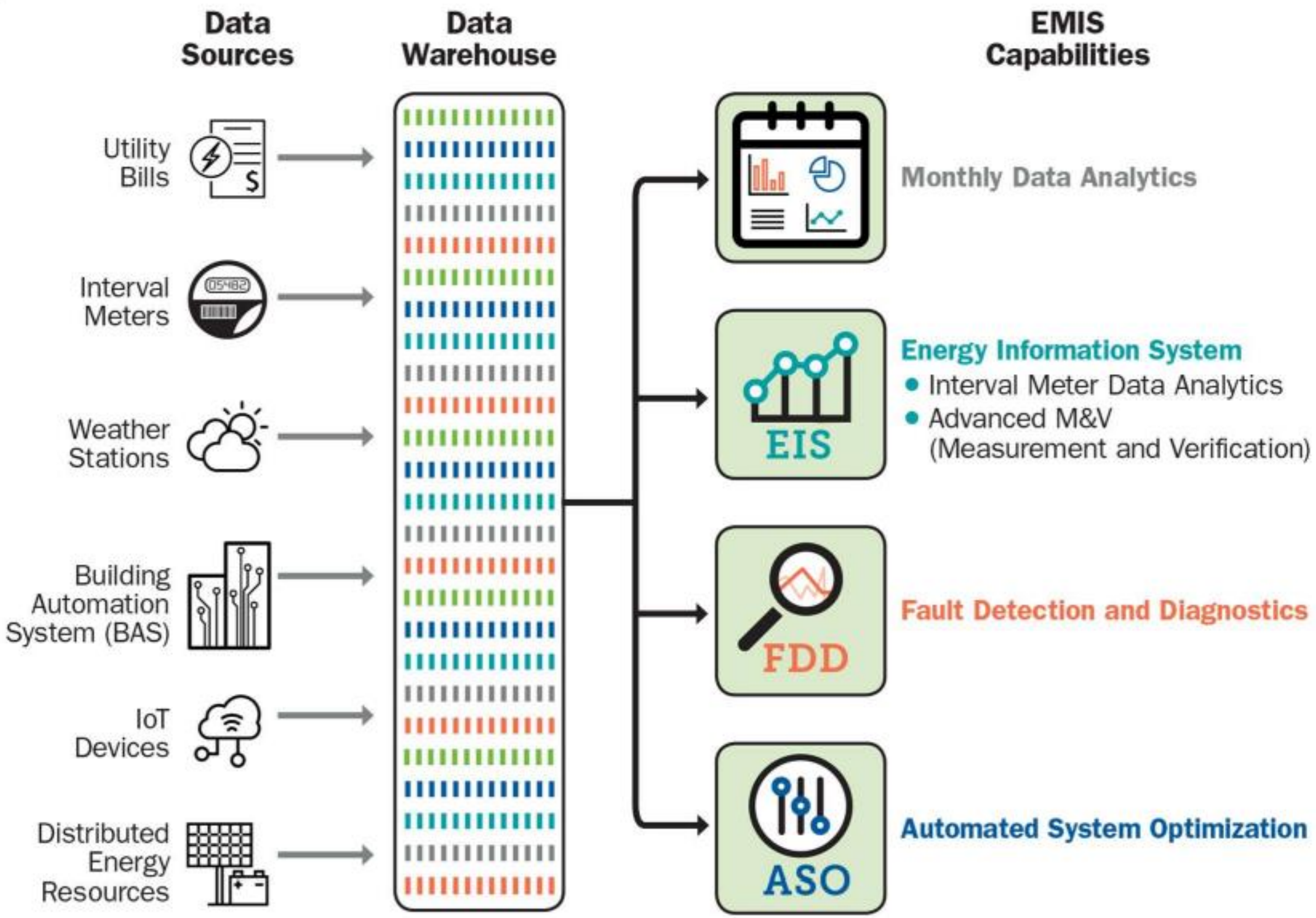
- Lighting + ventilation
- HVAC + room reservation system



Source: NREL

Controls recommendations: EMIS

- Gathers data from a variety of sources to monitor, analyze and control building energy use



Source: DOE Better Buildings

Controls recommendations: HVAC

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)

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Primary_School_BB_Carbon_Strategies.pdf

Water Heating

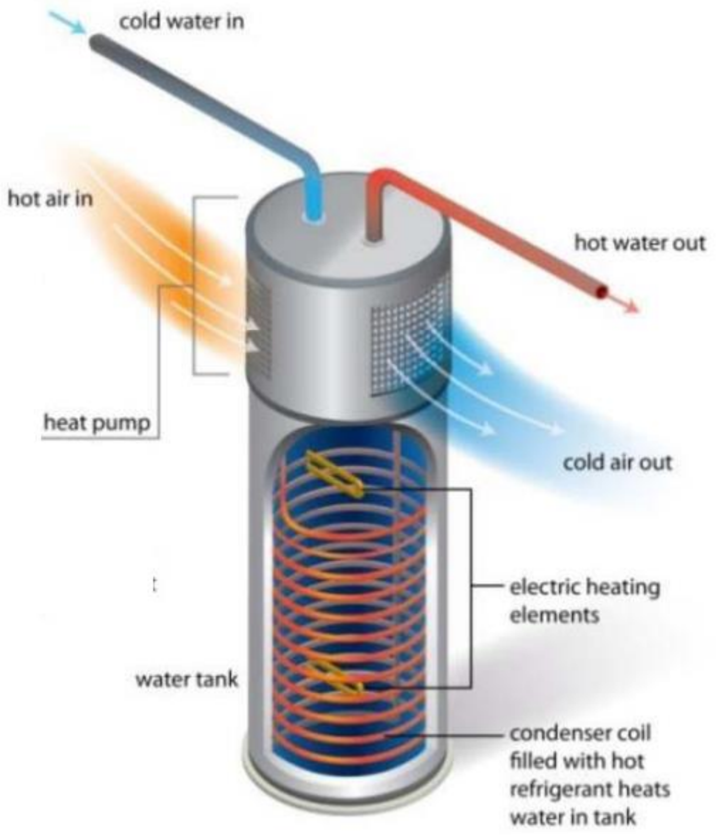
Water heating

Ways to reduce water heating energy use:

1. Lower hot water needs overall
   - Low-flow handwash sinks, kitchen fixtures, and showerheads (if applicable)
   - Fix leaks
2. Right size or evaluate system use
3. Install a more efficient water heater
4. Insulate piping and storage tanks
5. Evaluate the efficacy of recirculation systems
   - If a pump is necessary, install a timer

Water heating: selecting a system

- ✓ Size to meet the peak hot water load
  - DOE provides sizing guidance: https://www.energy.gov/energysaver/sizing-new-water-heater
- ✓ System placement: closer to fixtures = better
- ✓ System type:
  - **Tank-style water heaters:** best for centralized, higher volume draws (typically stores 30 to 80 gallons)
  - **Tankless "point-of-use":** best for placing close to fixtures that only need a small amount of hot water at a time (typically 2 to 5 GPM)



Source: NREL

Water heating: key metrics

- **Uniform Energy Factor (UEF):** amount of hot water produced per unit of fuel consumed. Higher = better

Water Heater Type	Typical UEF
Electric tankless	0.80 - 0.99
Electric HPWH	2.8 – 4.0

- **First Hour Rating:** amount of hot water produced per hour (gallons)
  - Applies only to tank-style water heaters
- Select an ENERGY STAR Certified water heater!

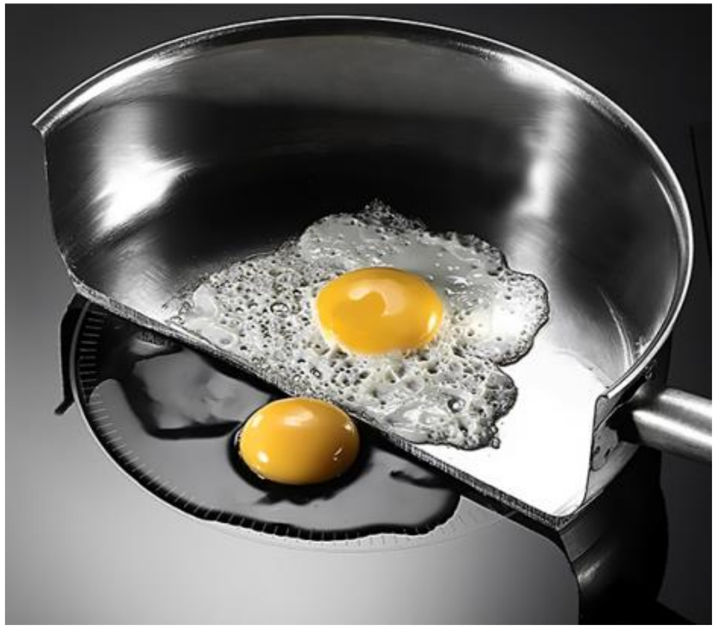
Kitchens

The pathway to perfectly cooked eggs

Kitchens: efficiency tips

Ways to reduce school kitchen energy use:

- ✓ Improve efficiency
  - Select ENERGY STAR appliances for available categories
  - Transition to high-efficiency induction cooktops
  - Evaluate menu options to reduce cook times
- ✓ Review your exhaust system
  - Upgrade exhaust ventilation systems
  - Reposition appliances to minimize exhaust rates
- ✓ Keep up on appliance maintenance



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Kitchens: strategies

- US DOE's Better Buildings offers comprehensive low-carbon kitchen recommendations for equipment, ventilation, refrigeration, and water heating

Better Buildings®
U.S. DEPARTMENT OF ENERGY

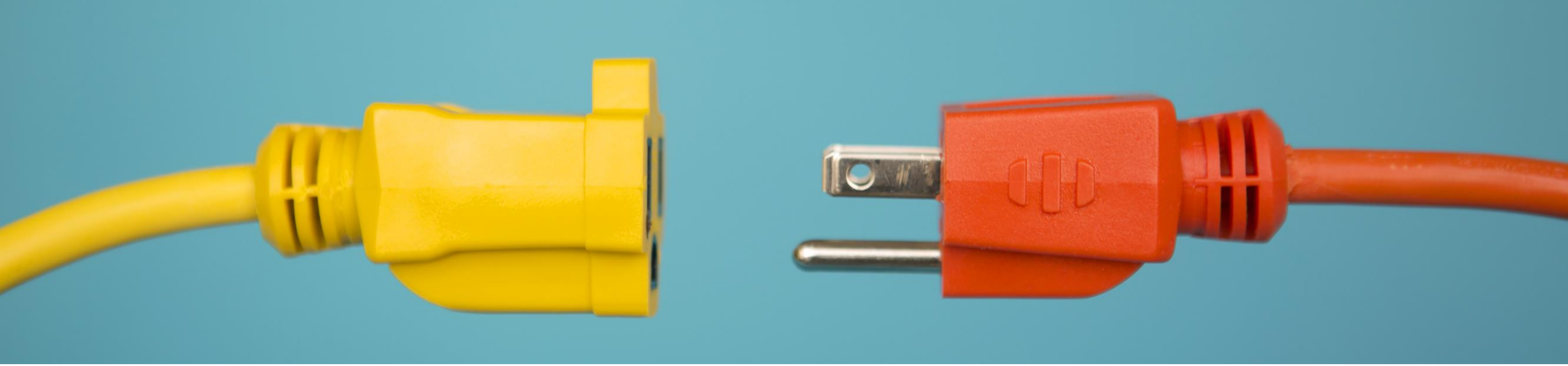
Low Carbon Technology Strategies

COMMERCIAL KITCHEN

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 commercial kitchens. This document was created as a supplement to Low Carbon Technology Strategies for building types that typically include commercial kitchens: Primary School, Secondary School, Supermarket, Hospital, and Small Hotel. Assess current conditions in your commercial kitchen against the simple, intermediate, and advanced options to begin planning your next steps to reduce carbon emissions.

Technology	Simple	Intermediate	Advanced
Equipment	• Institute a start-up and shutdown schedule for all cooking and holding equipment • Install ENERGY STAR® rated or better kitchen equipment • Replace conventional ovens with convection ovens • Replace high-temperature	• Install a time clock or plug load controller on ice machine and set schedule to make the amount of ice that is needed at minimum energy use and cost • Replace gas equipment with electric, if possible (if not, purchase most efficient gas equipment)	• Upgrade the building's eletrical system to allow high-power and high-voltage equipment to come online

https://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/Kitchen_Resource_BB_Carbon_Strategies.pdf



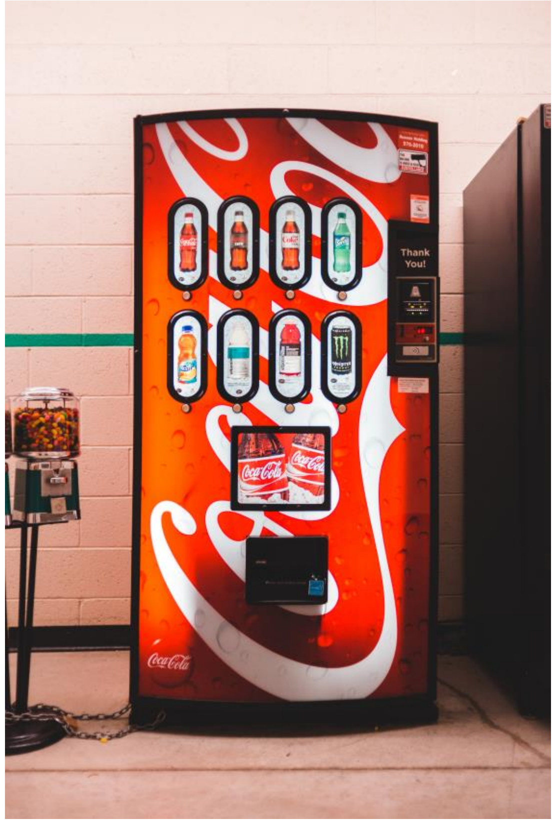
Plug Loads & Load Management

- Loads that are not associated with HVAC, lighting, water heating or other basic building operation needs

Plug & Process Loads (PPL)

Ways to reduce PPL energy use:

1. Inventory all devices & consolidate where possible
2. Purchase energy efficient equipment
3. Require low-energy/power saving modes when not in use
   - Beware of phantom loads!
4. Use control strategies
5. Incorporate education & awareness



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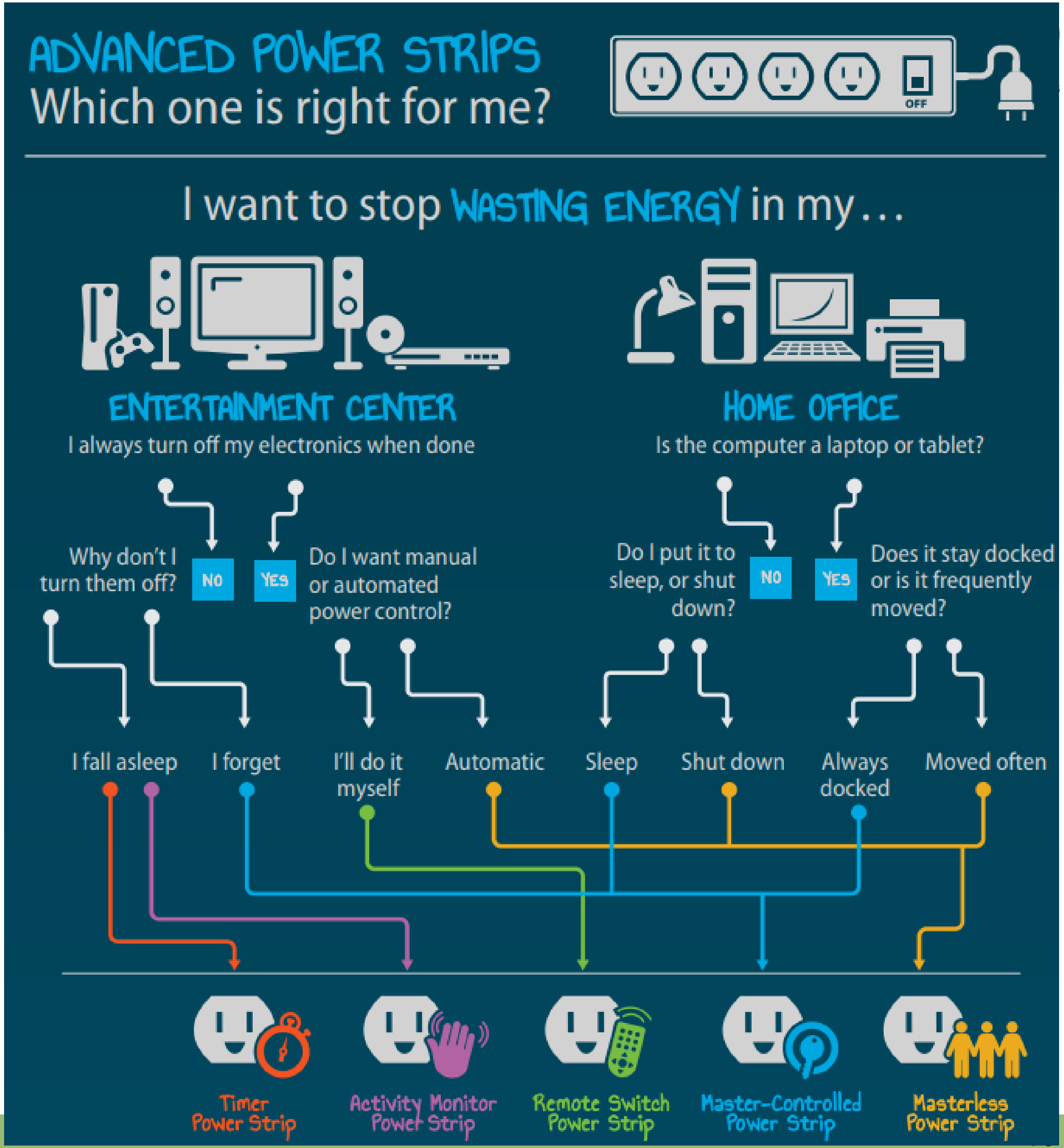
PPL control options

- Smart outlets
- Automatic receptacle controls
  - Time switch controls
  - Occupancy controls
- Control through Building Automation System (BAS)
- Integrate with other building system controls (e.g., lighting)

Source: NREL

PPL control options

- Smart power strips (aka advanced power strips)



Source: NREL

PPL education & awareness

- Establish a policy
- Engage & educate:
  - ✓ Why to take action
  - ✓ What actions to take
  - ✓ When to take action
  - ✓ Who to contact for help
- Hold competitions (schools or classes)

https://www.nrel.gov/docs/fy20osti/76994.pdf

Operations & Maintenance (O&M)

- Maintaining and monitoring equipment properly will ensure equipment reaches its expected useful life and issues are resolved promptly.

Importance of O&M Planning

- Electrification and high efficiency upgrades are difficult to execute in an emergency replacement

53%

of school districts in 2019 said they need to replace multiple building systems

41%

of districts said more than half their schools need HVAC upgrades

40%

of schools don't have a facilities plan for long-term maintenance and upgrades

31%

of school systems have portable facilities, and 45% of those portables are in poor or fair condition

16%

of districts have not assessed their building needs in more than 10 years

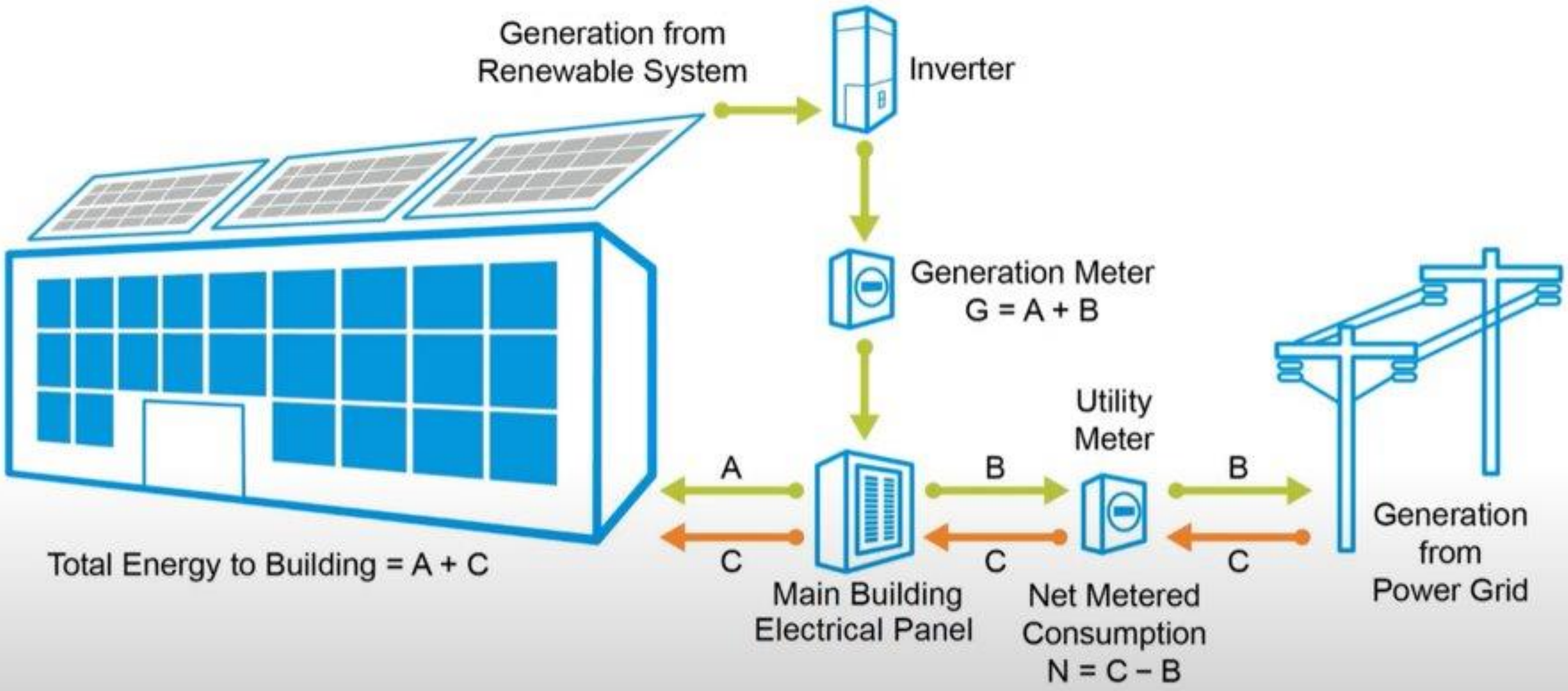
https://www.edweek.org/leadership/the-dismal-state-of-school-infrastructure-in-charts/2021/04

O&M best practices

- Create a long-term maintenance and replacement plan for major equipment
- Regularly service HVAC equipment and refrigeration units
- Educate
  - Training for operators, manuals
  - Education to teachers and staff
- Monitor performance
  - Follow M&V plans for specific projects
  - Review and update building controls as needed

Renewable Energy

Determining ZE Potential



Graphic credit: ENERGY STAR®

Estimating PV needs

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- "Backcast" to create a solar budget
  - What is the maximum area of PV you could have?
    - Consider location, shading
  - How much energy would this generate?
    - How does this compare with your anticipated energy consumption?
    - Have building efficiency issues already been addressed?
  - Does the cost justify the savings?
- Use NREL's PVWatts® Calculator

RESULTS

Print Results

100,514 kWh/Year*

System output may range from 97,679 to 102,011 kWh per year near this location.
*Click **HERE** for more information.*

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	4.36	6,423
February	4.90	6,470
March	5.98	8,620
April	6.78	9,330
May	6.89	9,743
June	6.88	9,411
July	7.44	10,356
August	7.44	10,330
September	6.62	8,928
October	5.74	8,094
November	4.80	6,753
December	4.06	6,056
Annual	5.99	100,514

PVWatts results for 60 kW system in Anaheim, CA

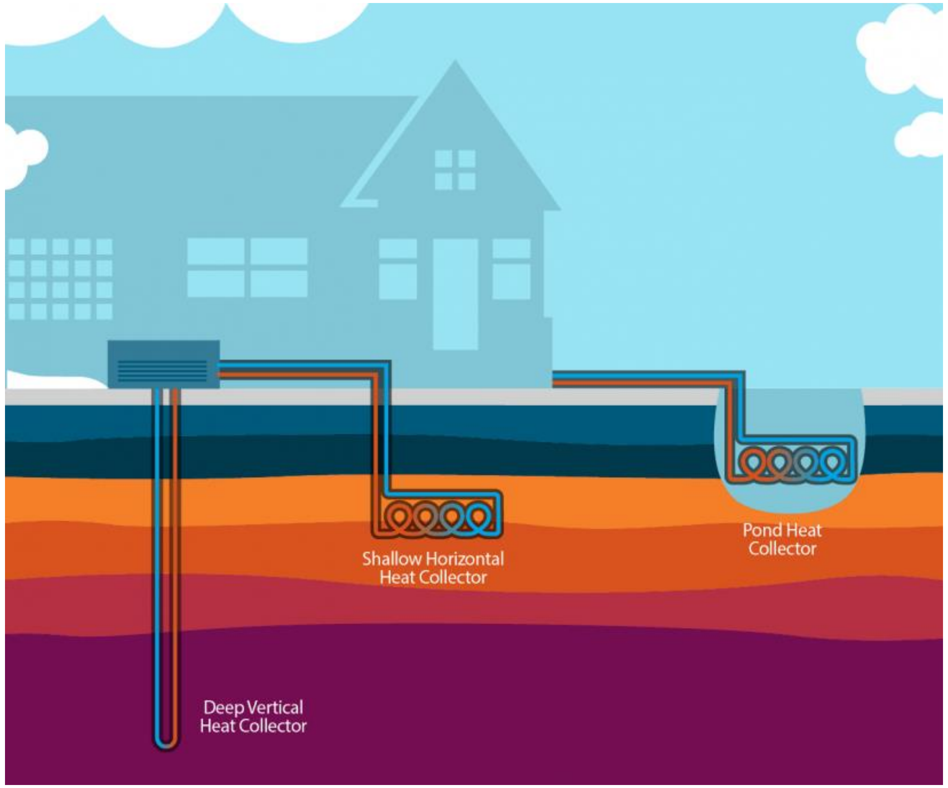
PV – other considerations

- Equipment: own vs. lease (PPA)
- Work with a professional!
  - Electrical system upgrades may be needed
  - Roof may not have capacity to bear the weight of a solar system
- Talk to the utility
- Storage is essential
  - Optimize cost savings
  - Emergency backup
  - Allows for easier EV integration

https://simpliphipower.com/deployments/commercial/schools/hawaii-schools-deploy-solar-simpliphi-microgrids-to-affordably-power-hvac/

Geothermal heat pumps

- Used for space conditioning and sometimes water heating
- Net energy benefit: For every unit of electricity used in operating the system, the heat pump can deliver as much as 5x the energy from the ground
- Easiest in temperate climates



https://www.energy.gov/eere/geothermal/geothermal-heat-pumps

Discussion

Putting together a district-level plan

1. What topics covered this week changed or was additive to your project plans?
2. What ways do you see building systems directly impacting your staff and students?
3. What aspects or systems of your building have been the most successful? Most challenging?
4. What topics covered this week do you want to/need to learn more about?

Thank you!

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