

Welcome to the waiting room (AKA your kitchen, home office, couch, etc.). Make yourself at home, grab a drink, and we'll begin shortly.



Reminder: Today's webinar will be recorded and a copy will be emailed you.



Zero Energy Schools: Exemplar and Toolkit

5/20/20

John Balfe, Kai Palmer Dunning, Carolyn Sarno Goldthwaite

Gary Brock, Julia Nugent

Northeast Energy Efficiency Partnerships



“Assist the Northeast and Mid-Atlantic region to reduce building sector energy consumption 3% per year and carbon emissions 40% by 2030 (relative to 2001)”

Mission

We seek to accelerate regional collaboration to promote advanced energy efficiency and related solutions in homes, buildings, industry, and communities.

Vision

We envision the region's homes, buildings, and communities transformed into efficient, affordable, low-carbon, resilient places to live, work, and play.

Approach

Drive market transformation regionally by fostering collaboration and innovation, developing tools, and disseminating knowledge



Allies Network



State Partners



Connecticut

State Partners: CT DEEP, CT Energy Efficiency Board, Eversource Energy, United Illuminating Company, Southern Connecticut Gas and Connecticut Natural Gas

Partners in 2017/2018/2019/2020

District of Columbia

State Partners: Department of Energy and Environment and DC Sustainable Energy Utility

Partners in 2017/2019/2020

Massachusetts

State Partners: Massachusetts Department of Energy Resources

Partners in 2019

New Hampshire

State Partners: NH Office of Strategic Initiatives, NH Public Utilities Commission, Eversource Energy, NH Electric Coop, Unitil and Liberty Utilities

Partners in 2017/2018/2019/2020

New York

State Partners: NYSERDA

Partners in 2017/2018/2019/2020

Rhode Island

State Partners: RI Office of Energy Resources, National Grid RI, RI Department and Education and RI Energy Efficiency & Resource Management Council

Partners in 2017/2018/2019/2020

Vermont

State Partners: Efficiency Vermont

Partners in 2017/2018/2019/2020

West Virginia

State Partners: West Virginia Office of Energy

Partners in 2020

Agenda


- ZE Schools Toolkit
- Fales Elementary School Exemplar
- Q&A
- Short-Takes
- Adjourn



ZE Toolkit: Background

Project Overview







ABOUT NEEP [INITIATIVES](#) EVENTS BLOG/ NEWS ROOM NETWORK RESOURCES

Northeast Energy Efficiency Partnerships


MASSACHUSETTS ACHIEVING ZERO ENERGY (MAZE)




View Edit Revisions



Francis T. Bresnahan Elementary School-
Newburyport, MA



Division of Fisheries & Wildlife Field Headquarters-
Westborough, MA



Athol Public Library- Athol, MA

RESILIENT HIGH PERFORMANCE BUILDINGS AND COMMUNITIES

- CAPEE
- Energy Codes ▾
- Energy Rating ▾
- Green Real Estate Resources
- HELIX
- High Performance Communities
- High Performance Schools ▾
- [Massachusetts Achieving Zero Energy \(MAZE\)](#)
- Multifamily Building Efficiency and Retrofit Solutions
- Zero Energy Buildings

PROJECT BACKGROUND

Zero Energy Schools Toolkit Overview



- Benefits & Impact
- Project Team
 - OPM and Design/Construction team
- Establishing Goals & RFP Language
- Financing for ZE Schools
- New construction, renovations, and technology
- Operations & Maintenance
- Examples of ZE Schools



Definition of Zero Energy School

Zero energy school is defined as an ultra-low-energy, combustion-free building that sources 100 percent of its annual energy from additional renewable energy sources.

- An ultra-low energy building utilizes various techniques to maximize lower energy use before the application of renewables.



ZE Toolkit: The Why

Why Build Zero Energy Schools?

Zero energy schools benefit building occupants

- Healthy indoor environment lower student absenteeism & increase staff satisfaction
- Improved IAQ and thermal comfort
- Building used as education tool



Other benefits

- Long-term savings over the lifecycle of the school
 - Lower O&M costs
 - Lower energy costs and water consumption
- Exemplary community buildings that demonstrate community goals of carbon emission reductions



ZE Toolkit: The How

Toolkit Guidance: The Project Team

- Who should be involved?
 - Community stakeholders and external professionals
- Establishing a ZE champion?
- Selecting an OPM and Designer
 - Checklists
 - Questions to ask during the interview process



Belmont Middle & High School Building Committee
 October 10, 2019 Belmont, MA

Toolkit Guidance: Establishing Goals



**Focus on EE
First**

**Establish an
EUI Target**

**ZE Language
in RFPs**

NREL Guidance: 18-25 kBtu/ft²/yr

Additional Toolkit Guidance



- Financing
- Additional Resource Links
- Operations and Maintenance
- Technologies
- Exemplars
- Model RFS Documents



Technical Assistance Available Throughout the Region!



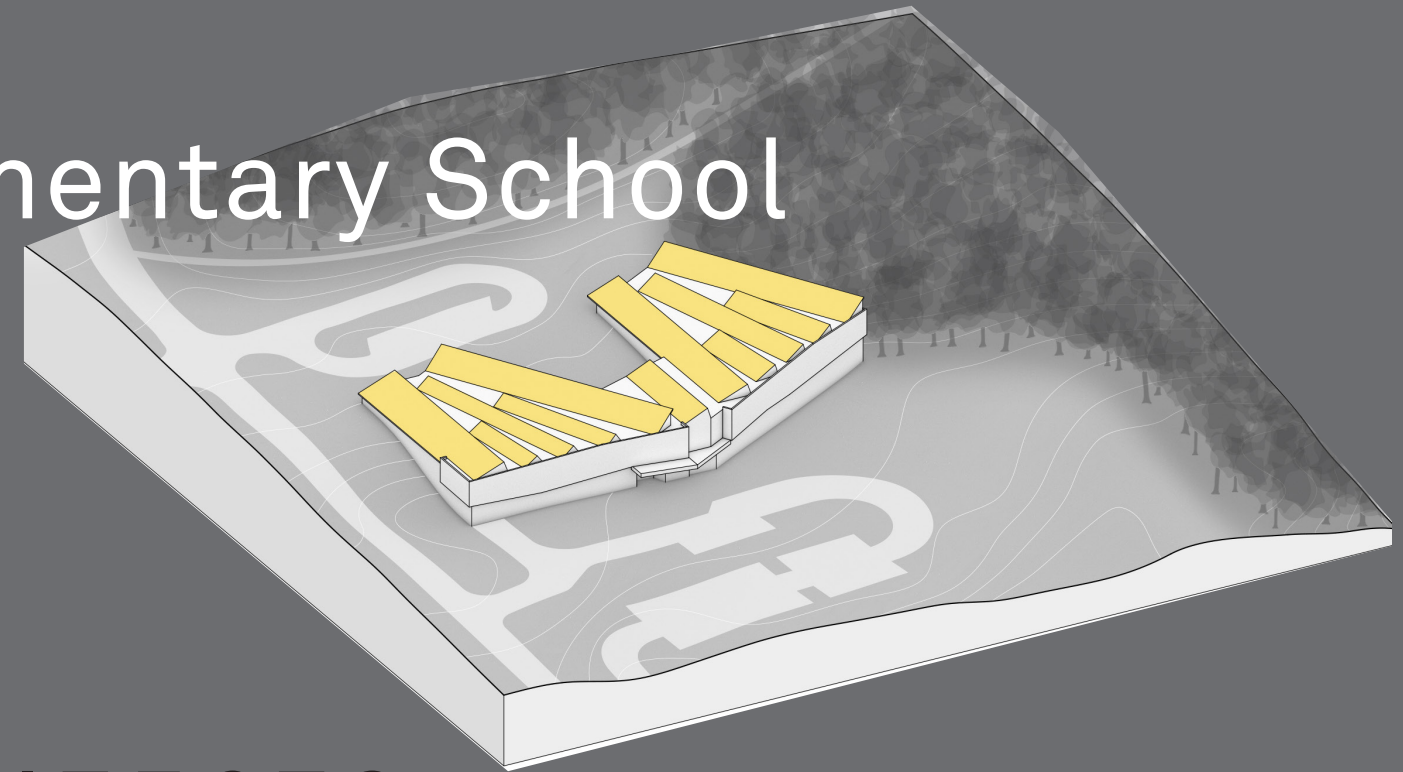
- NEEP is available to for:
 - Presentations
 - 1-on-1 meetings
 - Attending meetings
 - Reviewing project goals and plans
 - Providing fact sheets and additional resources



ZE Schools: Exemplar

Zero Net Energy

Annie E. Fales Elementary School
Westborough, MA



HM
FH

HMFH ARCHITECTS

What does it take to get to Zero Net Energy?

- Is there **community interest and advocacy**?
- Is it **financially feasible**?
- Is it **technically feasible**?

Set Project Goals, Establish Priorities

- **Budgets** (*financial and energy*)
- **Target EUI** (*kBTU/sf/yr*) *analogous to MPG for vehicles*
- **All-Electric Building** (*No Combustion*)
- **Owning a Solar PV System vs Power Purchase Agreement**

Is sustainability important?

2010: ***Zoning*** for Solar Farms

2016: ***Greener Option*** with NGrid

2017: ***Green Communities*** status

2019: ***Climate Action Task Force***

2019: ***Vote*** for municipal energy to be renewable by 2035



Do we have a champion?

Building Committee Chair

Superintendent

Will we get buy-in from facilities staff?

1998, first school in MA to use ***Geothermal Heating***

20 years of ***cost savings*** up to \$200,000 annually

Is Zero Net Energy Financially Feasible?

School #1

PV System Size:
192 kW (DC)

Est. Cost:
\$575,875

Simple Payback:
8 years to own

Savings over 20 yrs:
\$774,494 (owning)

Savings over 20 yrs:
\$291,594 (PPA)

School #2

PV System Size:
324 kW (DC)

Est. Cost:
\$972,000

Simple Payback:
9.7 years to own

Savings over 25 yrs:
\$1,592,840 (owning)

Savings over 25 yrs:
\$705,251 (PPA)

Fales Elementary

PV System Size:
508 kW (DC)

Est. Cost:
\$1,785,000

Simple Payback:
8.5 years to own

Savings over 20 yrs:
\$4,200,000 (owning)

Is Zero Net Energy Technically Feasible?

For this project, **Zero Net Energy** is defined as:

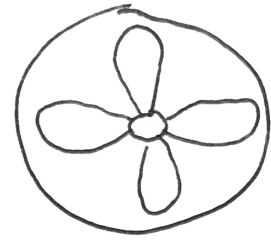
producing on-site renewable energy equal to the energy used to operate the building annually

How did we get there?

- **Reduce** energy use as much as possible
- **Produce** as much energy as possible

Components of Energy Use

Fales Total Energy Use Intensity (EUI) = 24.9



Ventilation: 4.30 17%



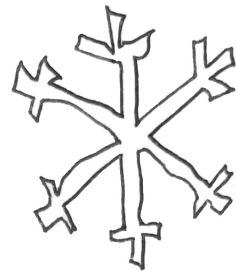
Hot Water: 0.28 1%



Heating: 2.35 9%



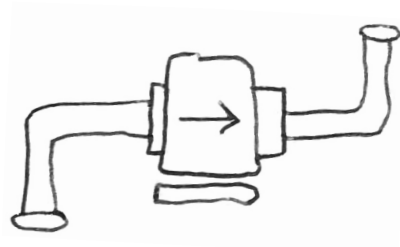
Lights: 3.13 13%



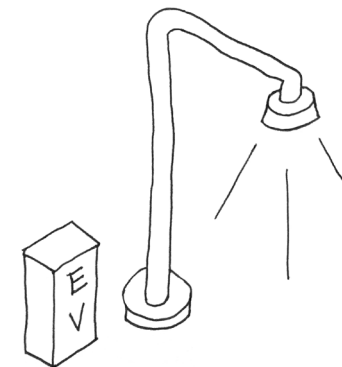
Cooling: 1.97 8%



Plug Load: 7.95 32%
including kitchen
equipment



Pumps: 4.44 18%



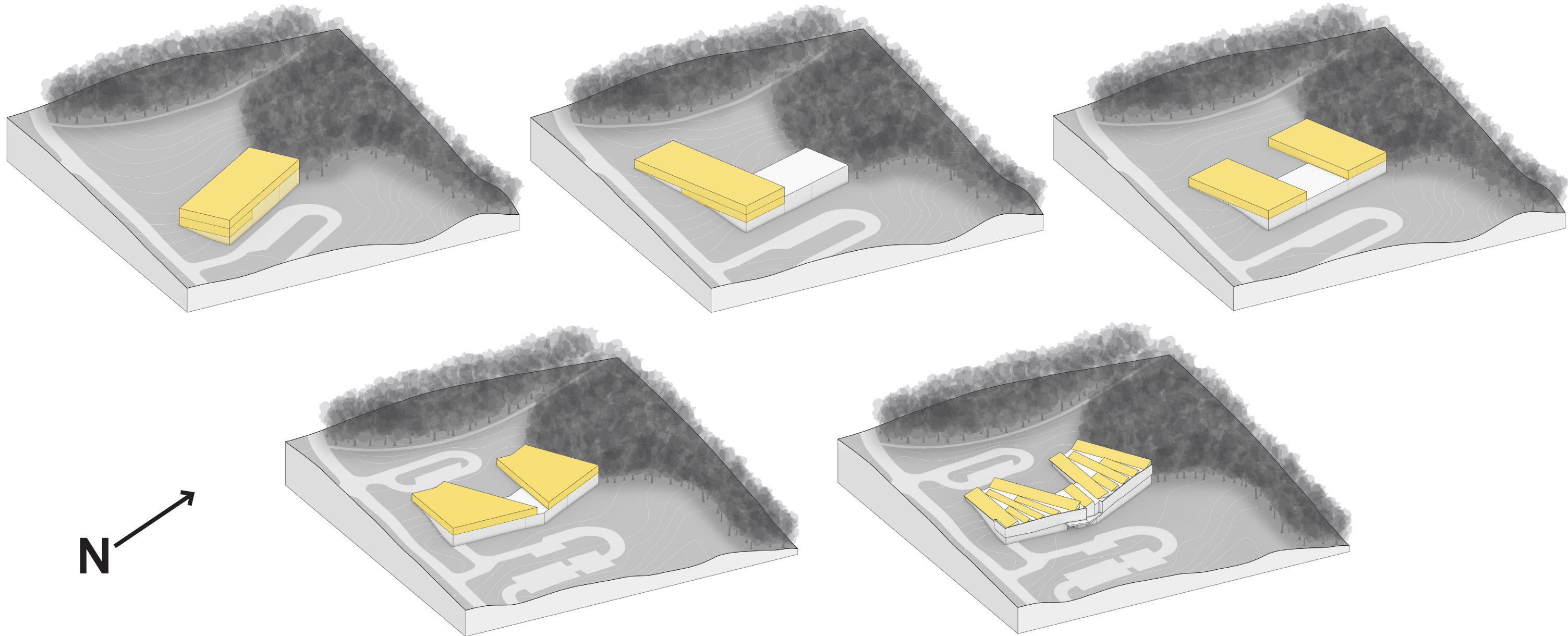
Exterior: 0.46 2%

HVAC: 52%

Other: 48%

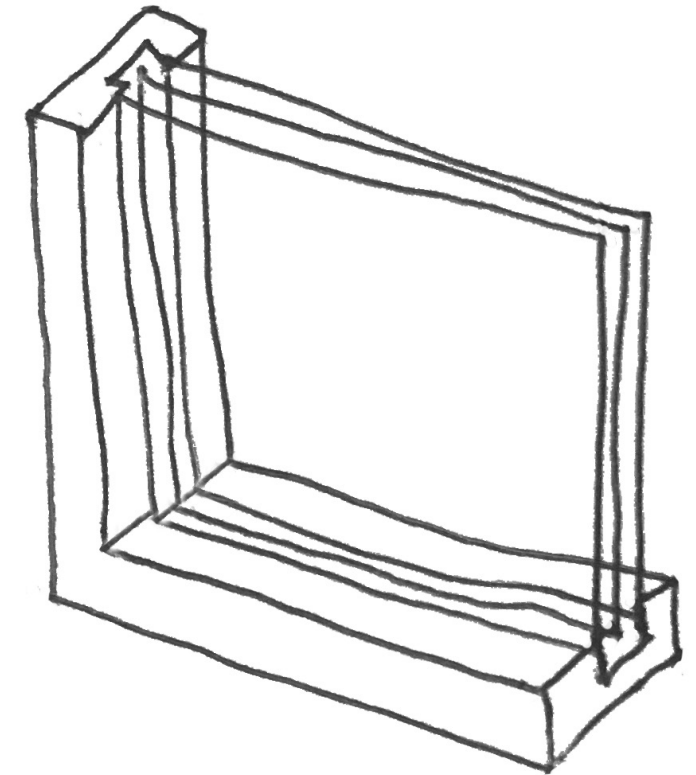
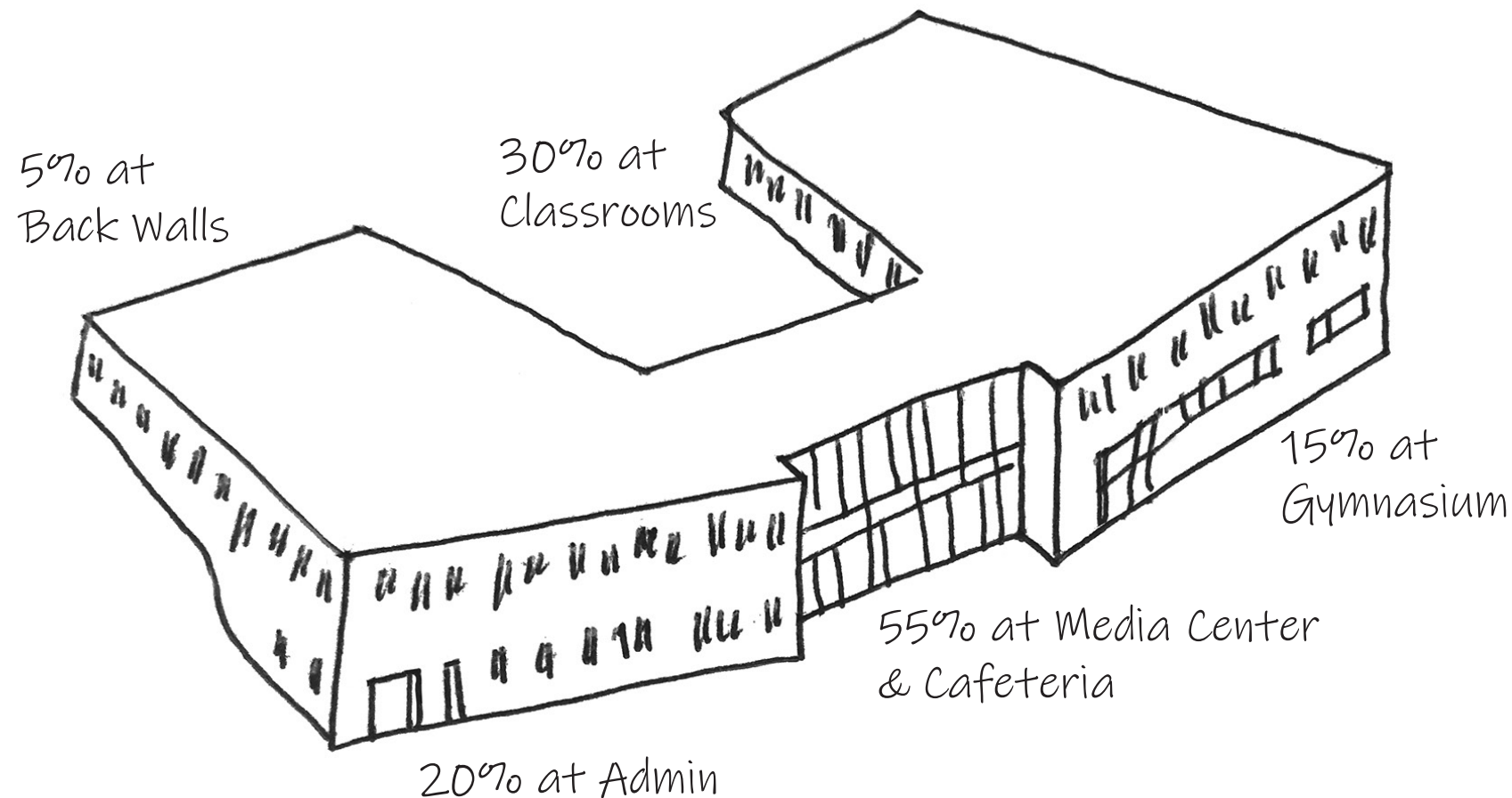
Energy Reduction: Orientation and Massing

- north-south orientation for upper floors
- lower levels buried in hillside



Energy Reduction: Building Envelope

- R30 for walls, R40 for roofs
- 25% window to wall ratio
- triple glazed windows & skylights
- balance solar heat gain & visible light



South, West, East Facades:

U-Value = 0.13

Solar Heat Gain = 0.23

Daylight Transmission = 54%

UV Transmission = 20%

North Facade:

U-Value = 0.13

Solar Heat Gain = 0.33

Daylight Transmission = 60%

UV Transmission = 28%

Energy Reduction: Lighting

Position glazing for *Daylight Autonomy (DA)*

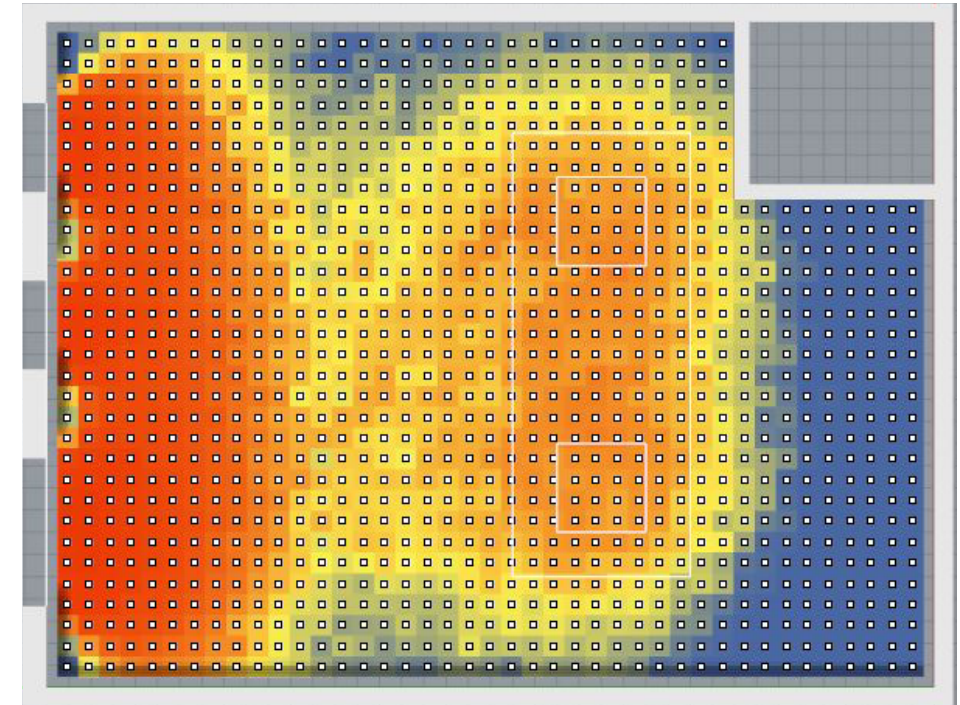
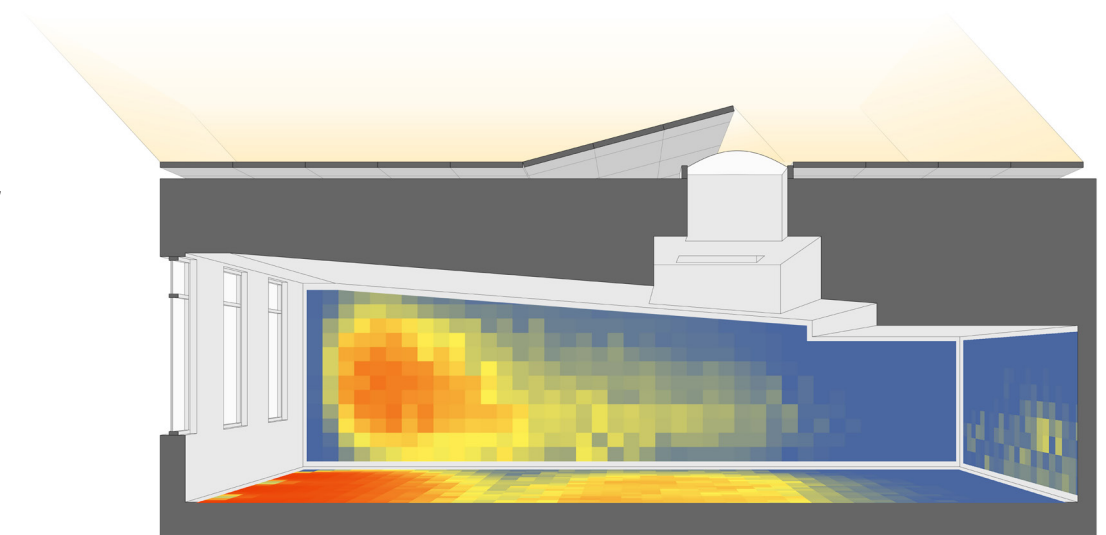
DA = percent of operating hours that an area can be lit exclusively with daylight

Control artificial lighting

- daylight and occupancy sensors
- fixtures zoned to balance daylight
- master controls linked to Building Management System

Low *Light Power Density (LPD)*

- benchmark LPD is 1.2 watts per sf
- target LPD is 0.43 watts per sf



Energy Production: back of the envelope math

Establish the target **Energy Use Intensity (EUI)**
multiply by the area of the building

EUI = the amount of energy per square foot to operate the building over the course of a year

- benchmark for US K-12 schools = **75 EUI**
- typical for a net-zero school = **20-25 EUI**
- Fales target = **27.5 EUI**

Projected Annual Energy Use = 2,178,000 kBTU

Building Area = 72,000 sf
x Target EUI = 27.5 kBTU/sf
+ 10% cushion

Annual Energy Use = 2,178,000 kBTU

Energy Production: back of the envelope math

Projected Annual Energy Use = 2,178,000 kBTU

Energy use for buildings is measured in **kBTU**,
but PV output is measured in **kW-hr**.

*Convert from **kBTU** to **kW-hr***

Projected Annual Energy Use = 638,154 kW-hr

Building Area = 72,000 sf
x Target EUI = 27.5 kBTU/sf
+ 10% cushion

Annual Energy Use = 2,178,000 kBTU

Convert from kBTU to kW-hr
2,178,000 kBTU x .293

Annual Energy Use = 638,154 kW-hr

Energy Production: back of the envelope math

How many kW does the solar array need to be for the projected annual energy use?

Annual yield is location and system specific:

- solar exposure
- weather data
- type of system

Westborough Annual Yield:

1 kW (~4 panels) yields 1,100 kW-hr per year

Building Area = 72,000 sf
x Target EUI = 27.5 kBTU/sf
+ 10% cushion

Annual Energy Use = 2,178,000 kBTU

Convert from kBTU to kw-hr
2,178,000 kBTU x .293

Annual Energy Use = 638,154 kw-hr

Annual Yield = 1,100 kw-hr/yr

638,154 kw-hr / 1,100kw-hr/kw

580 kW System Needed

Energy Production: back of the envelope math

How much PV area is needed?

- assume each panel is **320 watts (.32 kW)**
- each panel is **17.6 square feet**

~32,000 square feet of PV panels needed

Variables to consider

- EUI could be lower or higher
- PV technology is improving

Building Area = 72,000 sf
x Target EUI = 27.5 kBTU/sf
+ 10% cushion

Annual Energy Use = 2,178,000 kBTU

Convert from kBTU to kw-hr
2,178,000 kBTU x .293

Annual Energy Use = 638,154 kw-hr

Annual Yield = 1,100 kw-hr/yr
638,154 kw-hr / 1,100kw-hr/kw

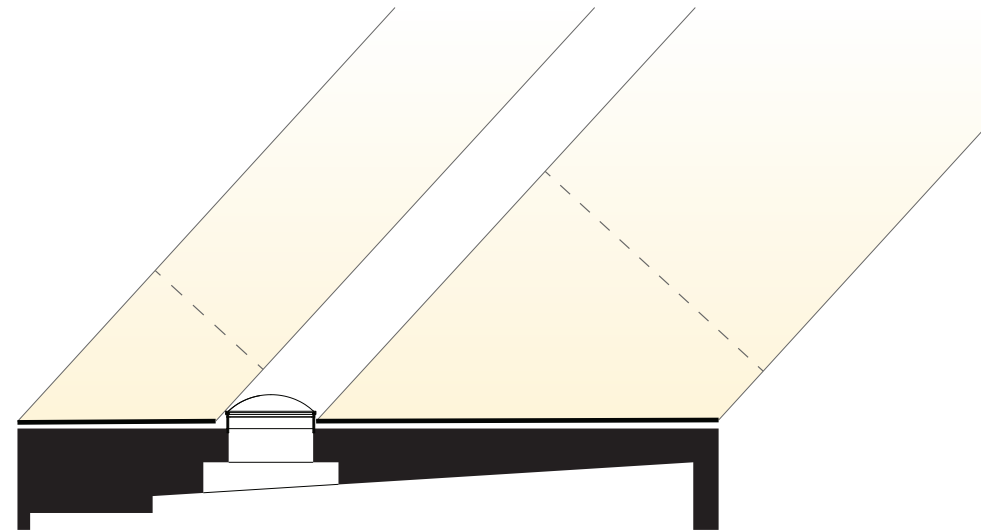
580 kW System Needed

584 kW / 320 w/panel = 1,813 panels
1,813 panels x 17.6 sf/panel

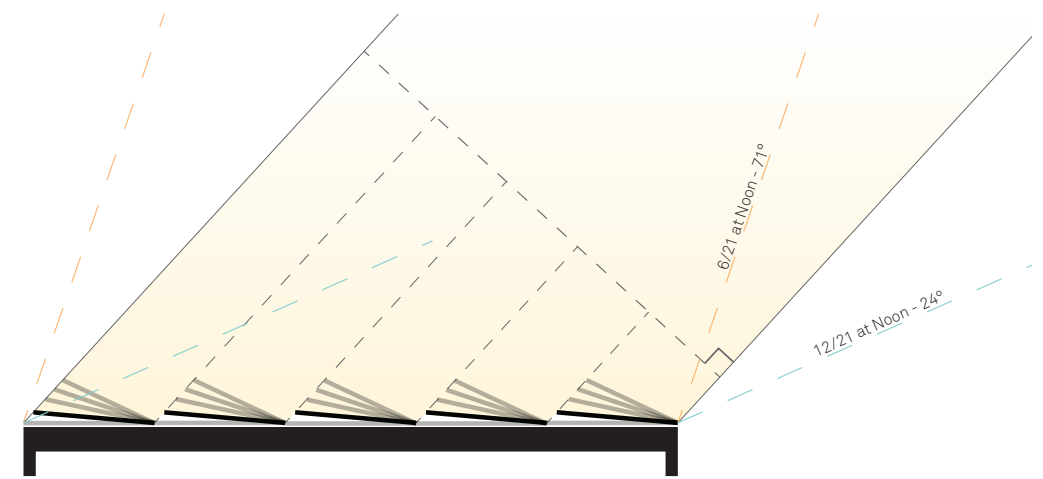
31,909 sf for the PV array

Conflicting Energy Production and Energy Reduction needs:

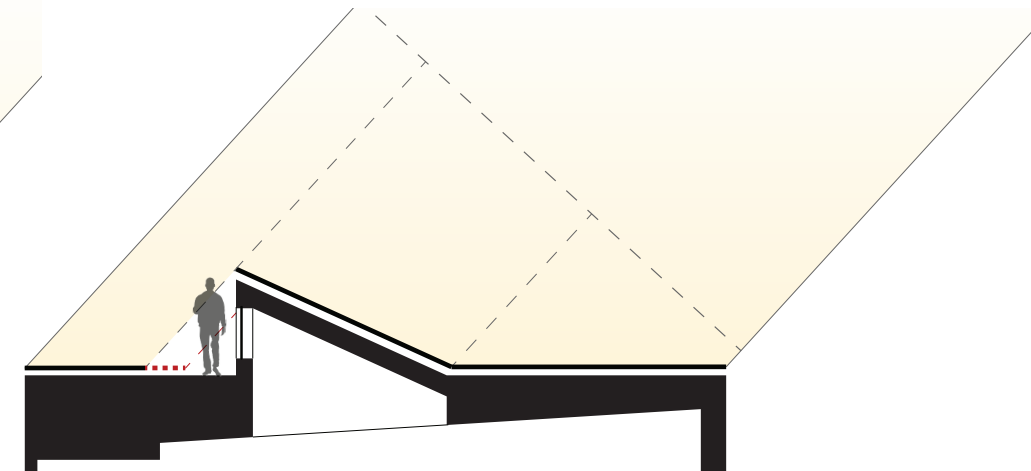
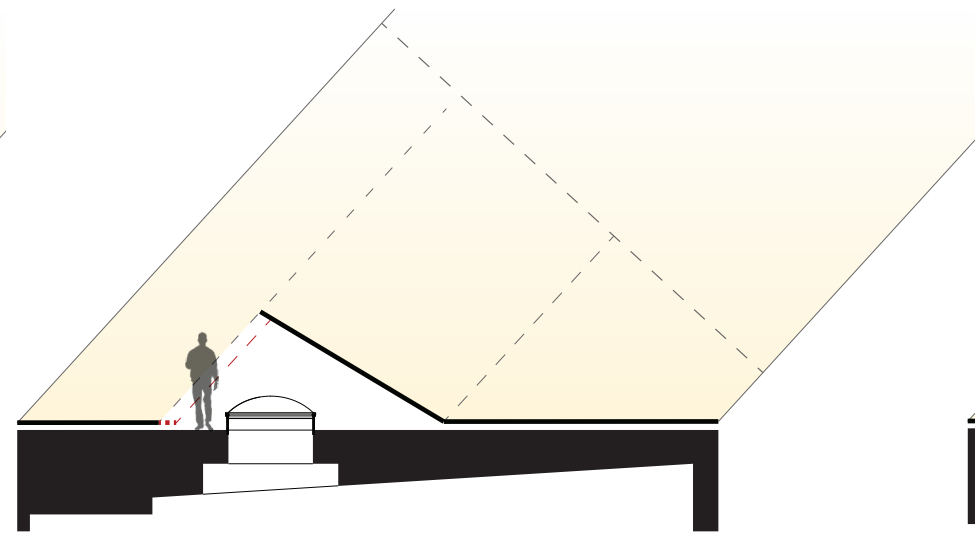
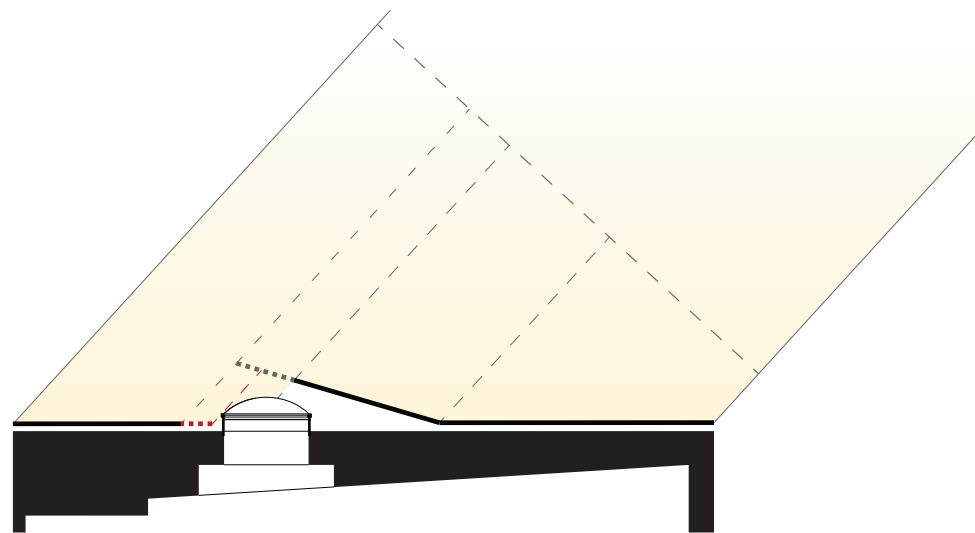
- skylights and solar PV competing for roof area
- traditional skylights have poor insulating value



optimal for daylight



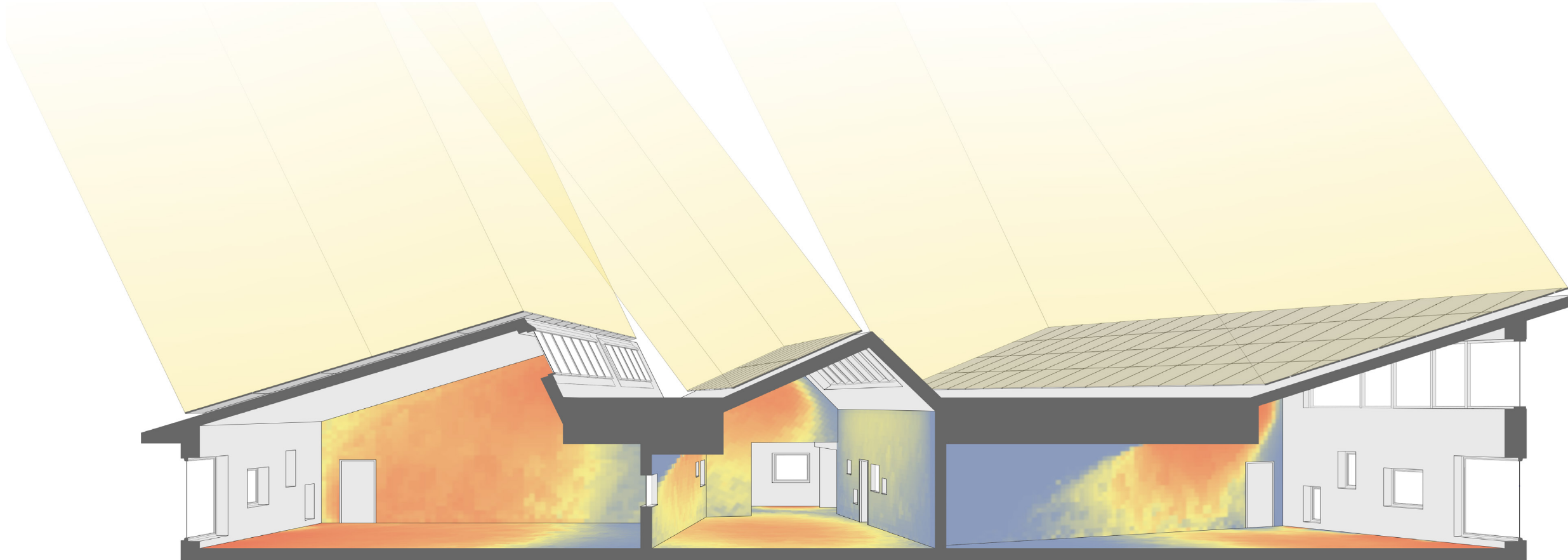
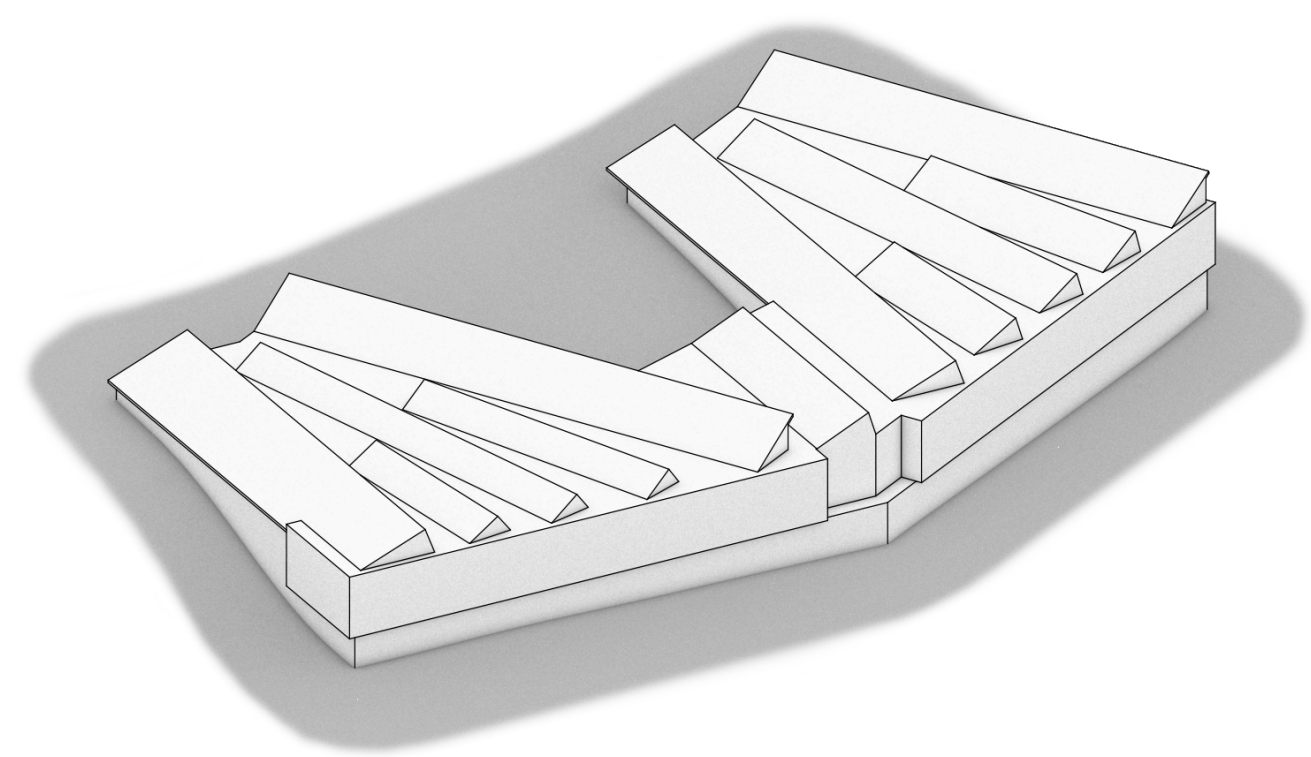
optimal for solar



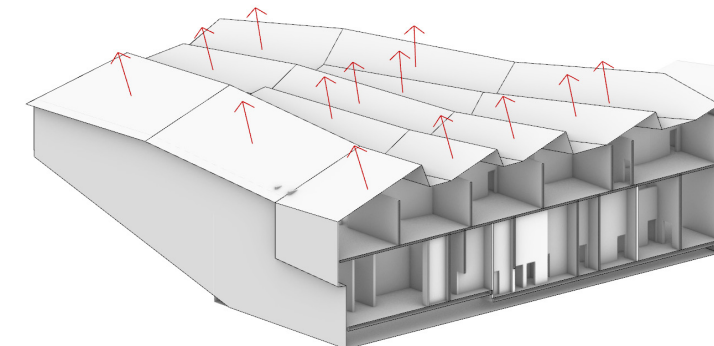
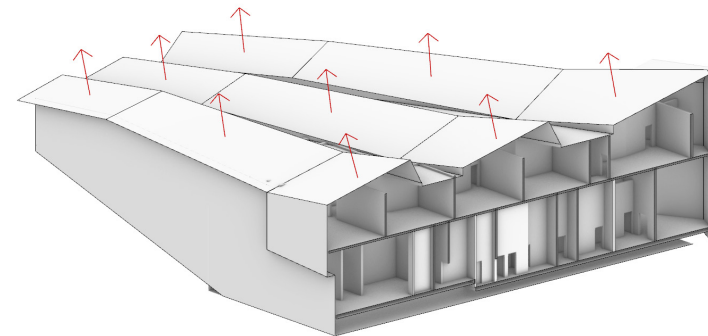
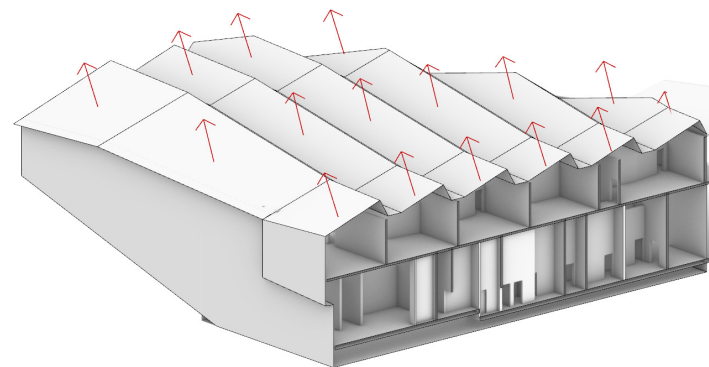
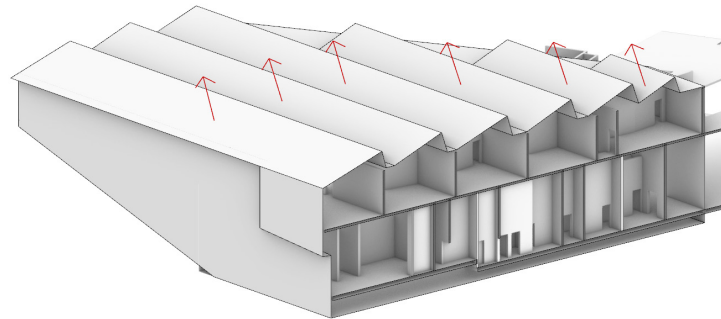
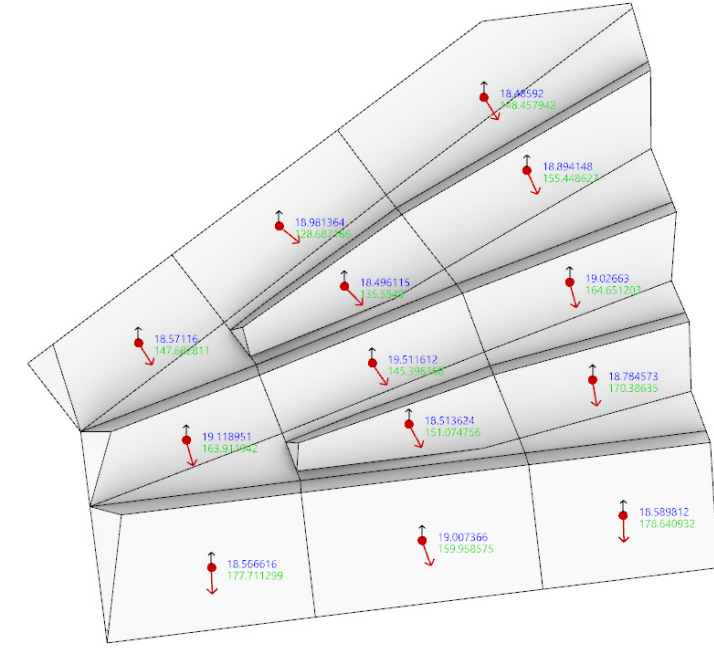
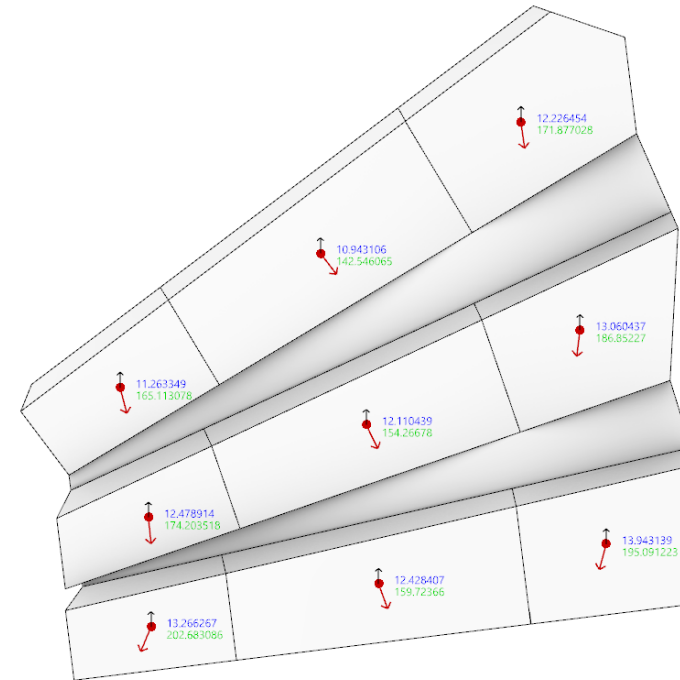
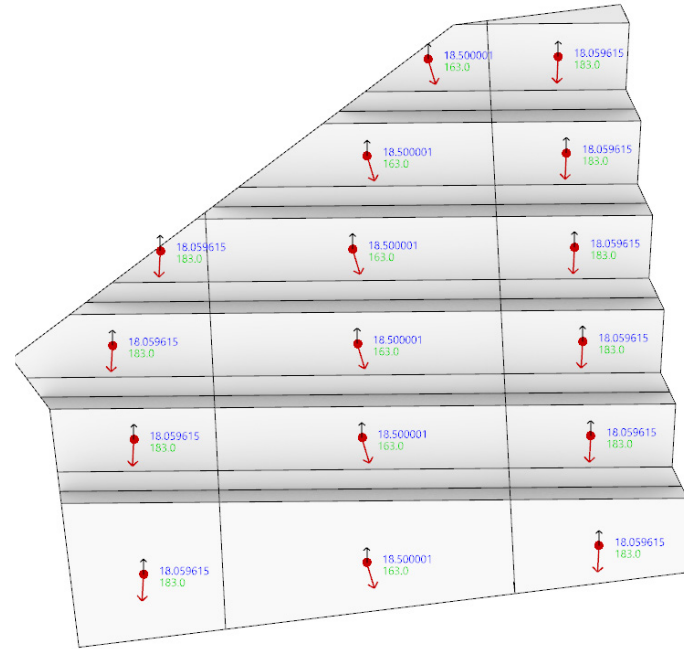
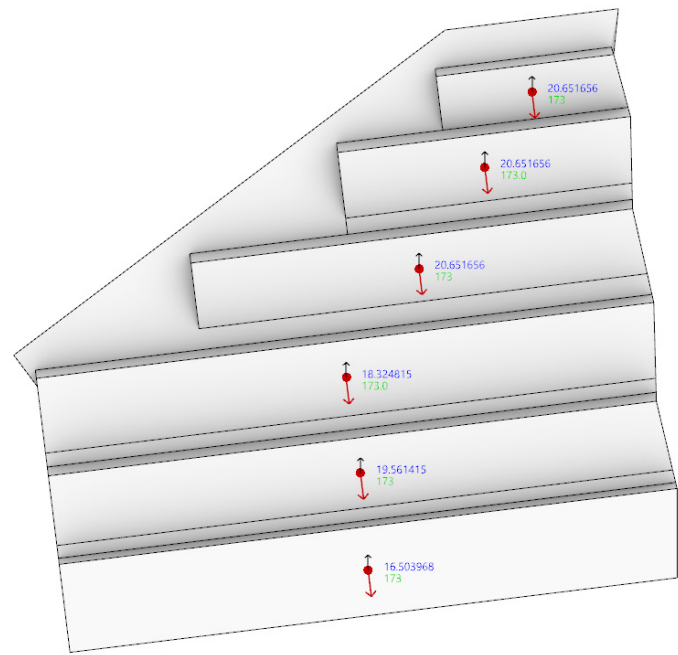
combined strategies

Sawtooth Roof

- *expands roof surface area by 18%*
- *brings natural light to interior spaces*
- *architectural expression of zero energy*



Roof Massing Options



Parallel

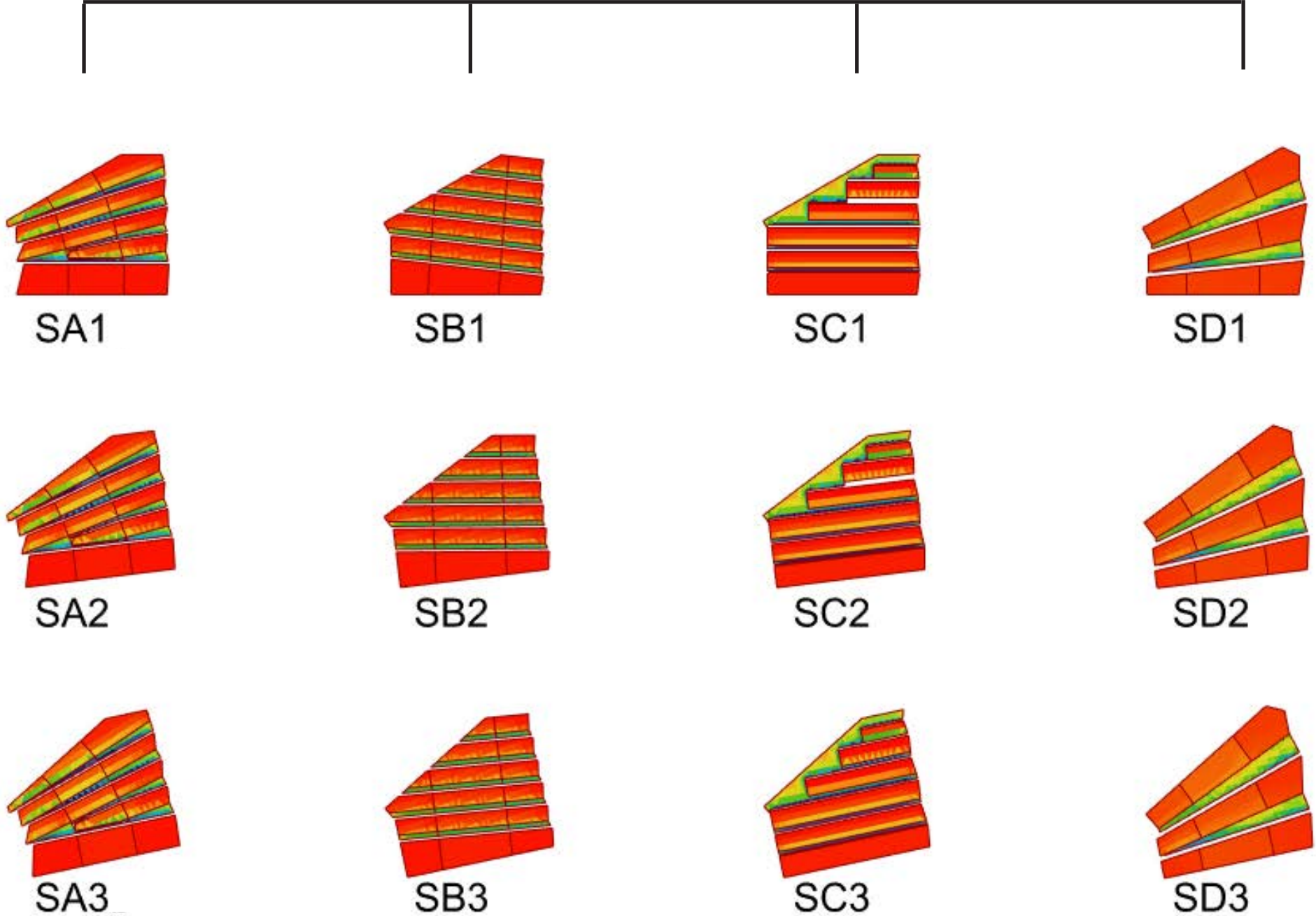
Rotated Parallel

Triple-Pleat

Quadruple-Pleat

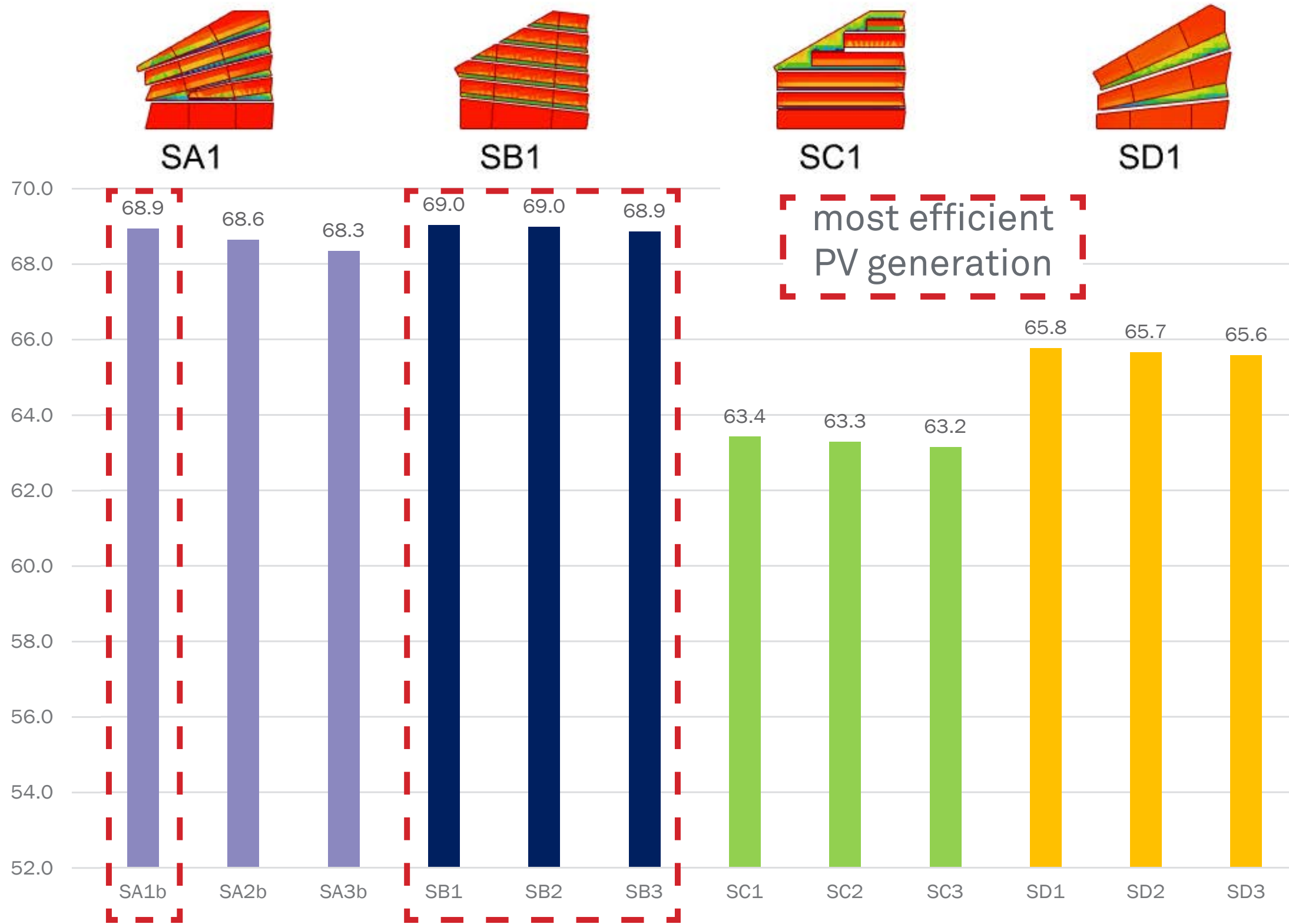
Radiance Analysis of Roof Options

4 roof shapes

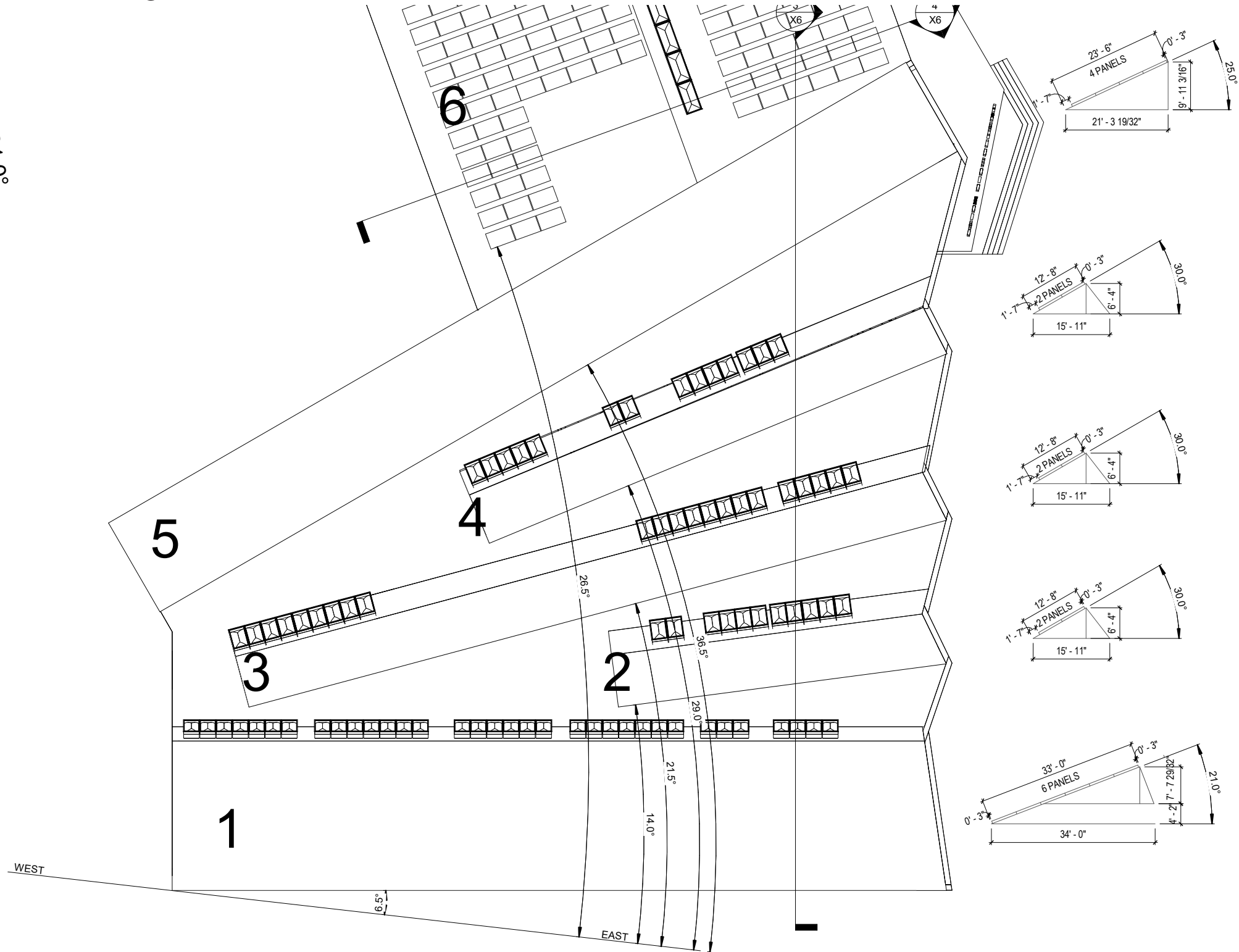
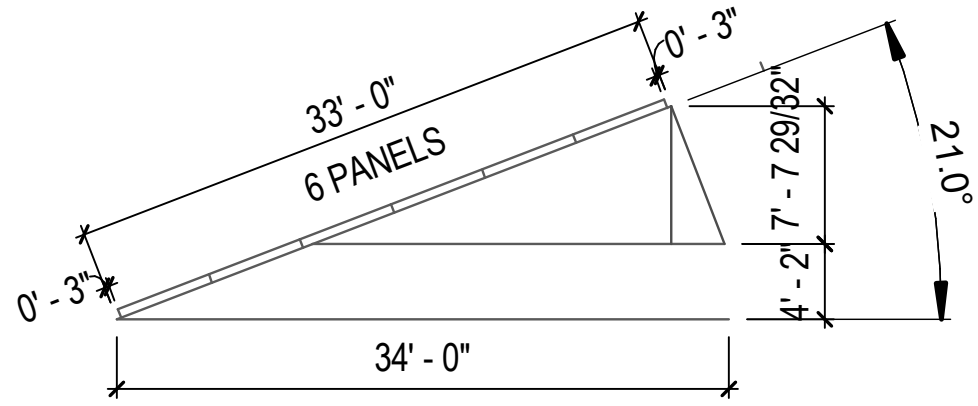


3 rotations

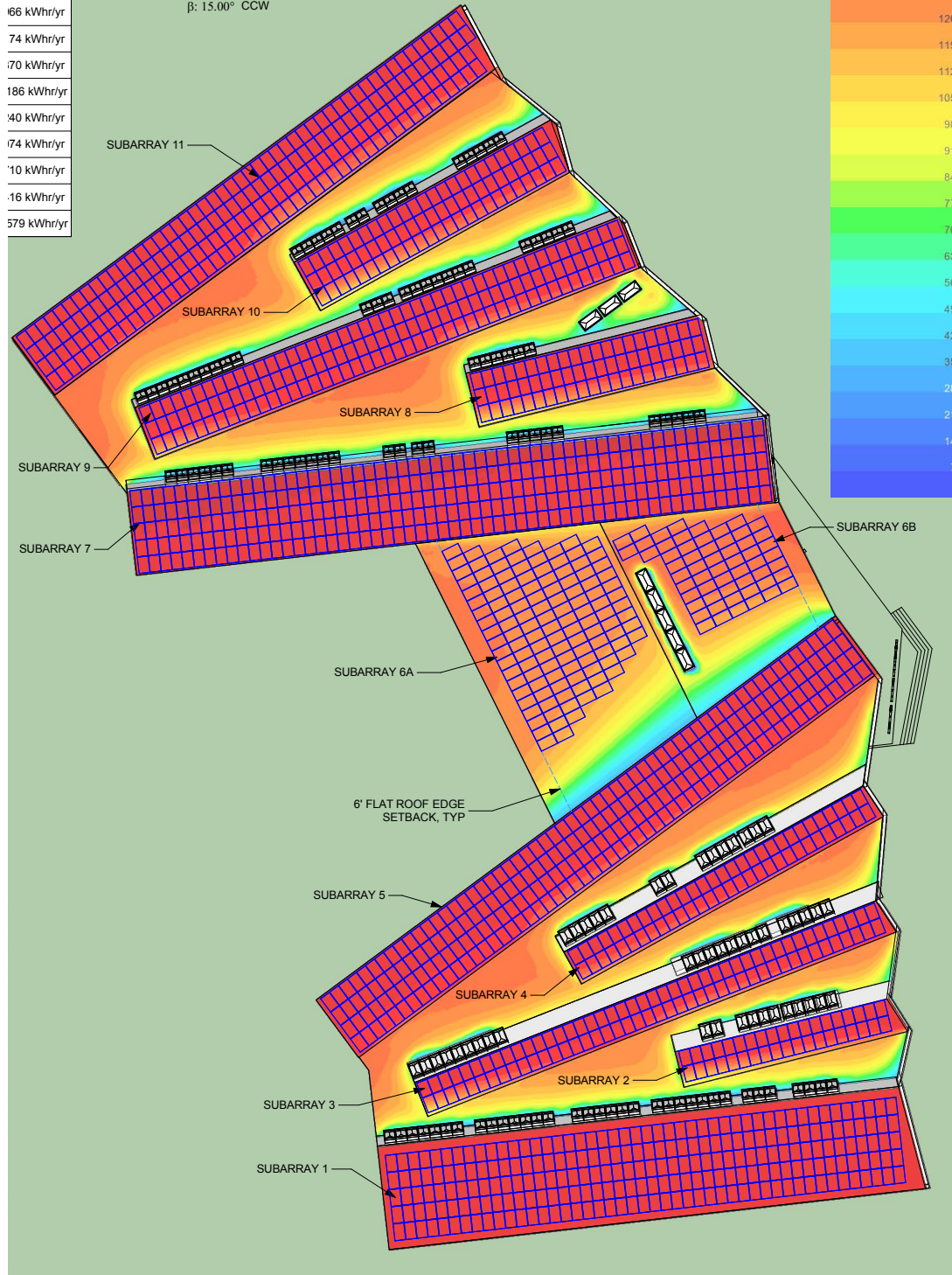
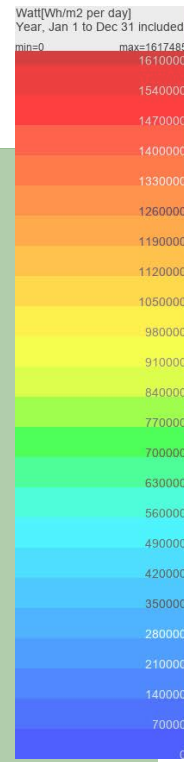
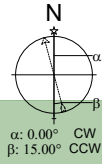
Radiance Analysis of Roof Options



Optimizing Roof Geometry

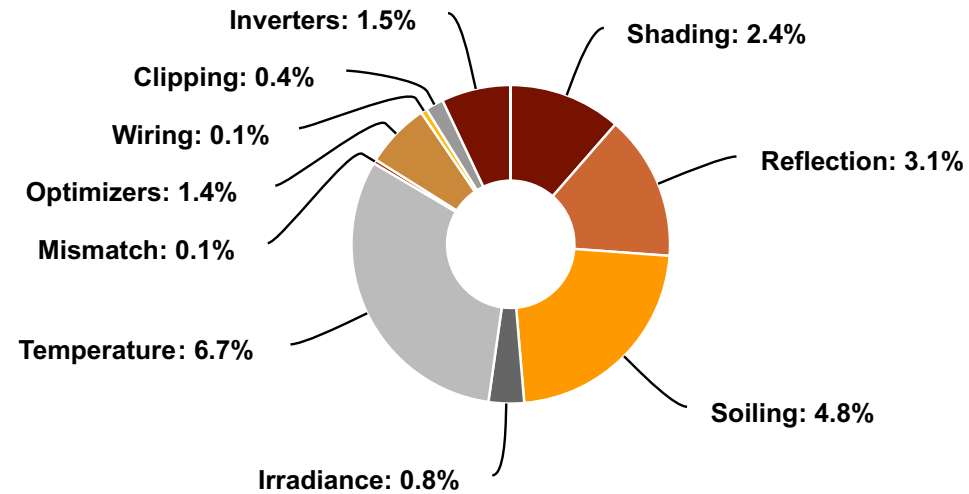


ANNUAL AC ENERGY
67 kWh/yr
24 kWh/yr
25 kWh/yr
27 kWh/yr
66 kWh/yr
74 kWh/yr
70 kWh/yr
186 kWh/yr
40 kWh/yr
74 kWh/yr
10 kWh/yr
16 kWh/yr
579 kWh/yr

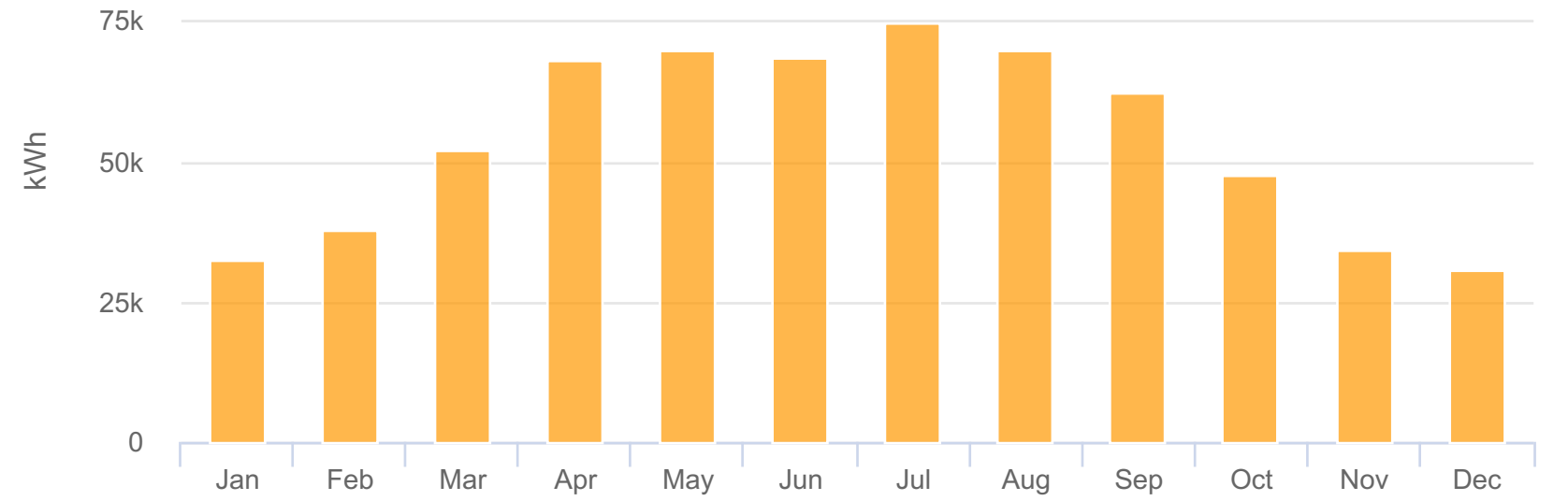


Design Development:

- 1,578 panels @ 320 w/panel = 504 kW
- 638,579 kW-hr per year



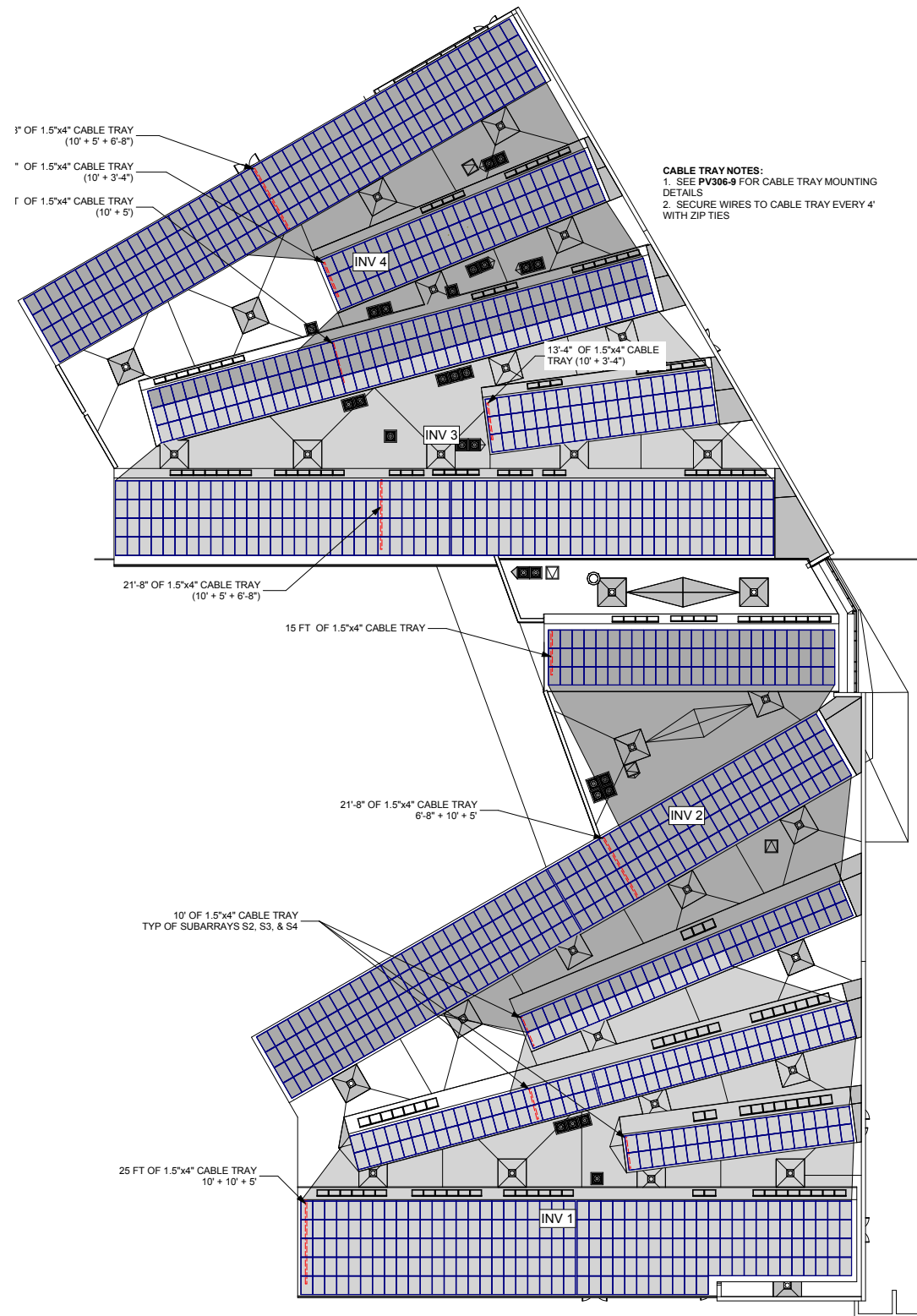
System Losses



Monthly Production

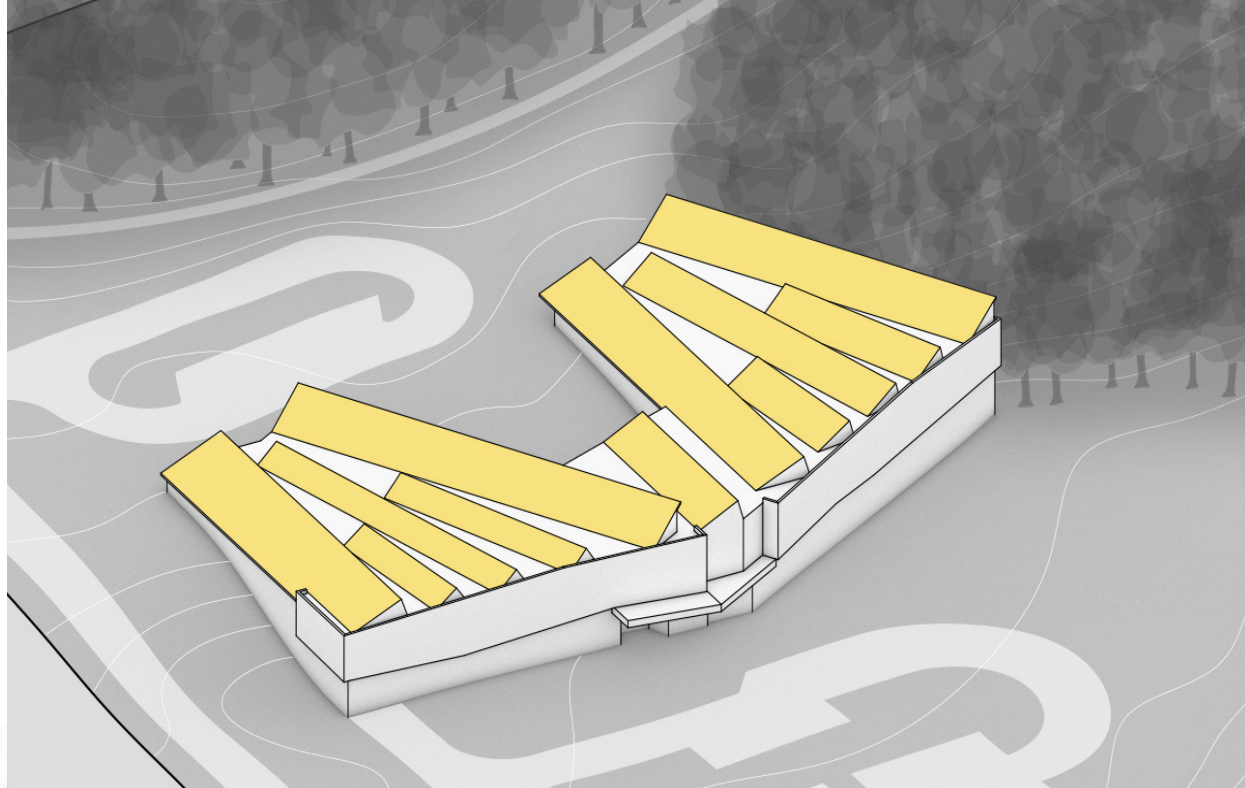
Final Design:

- 1,354 panels @ 375 w/panel = 508 kW
- 648,291 kW-hr per year

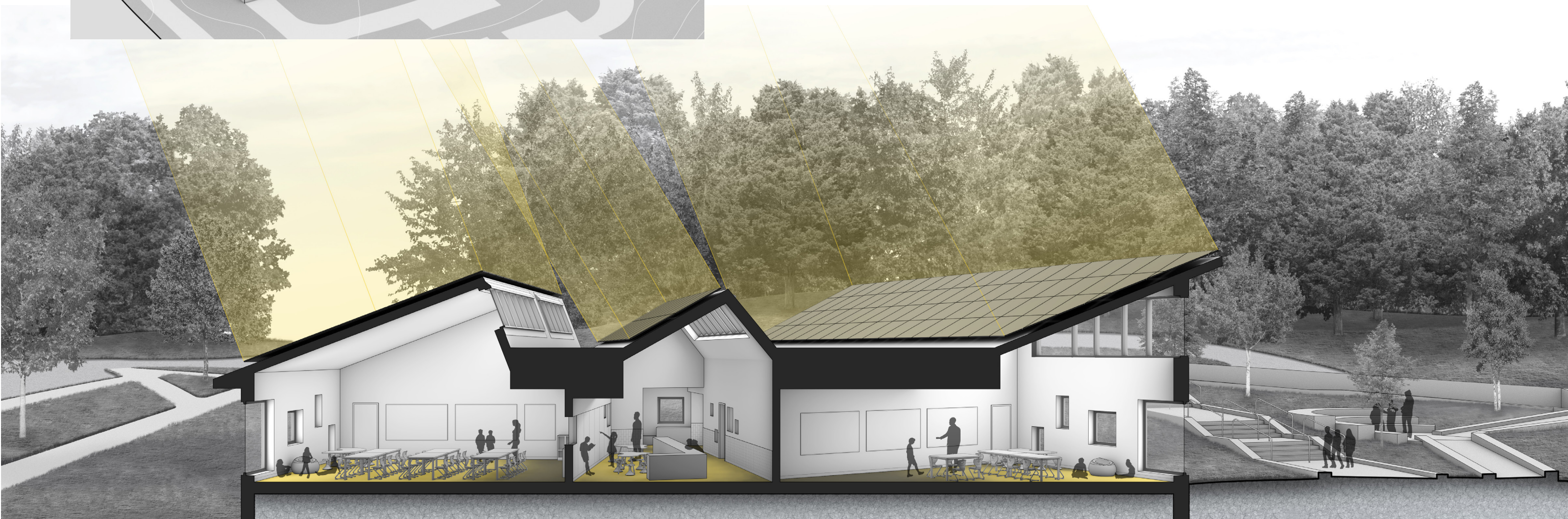


How did we do?

	<i>Back-of-the-Envelope</i>	Final Design
Energy Use Intensity:	<i>27.5 EUI</i>	24.9 EUI
Annual Energy Use:	<i>638,000 kW-hr</i>	585,000 kW-hr
Annual Energy Production:	<i>638,000 kW-hr</i>	648,000 kw-hr
		<i>Net Positive - 10% more energy produced than used</i>
Size of PV System:	<i>580 kW</i>	508 kW
Watts per Panel:	<i>320 W</i>	375 W
Size of Array	<i>32,000 sf</i>	24,000 sf



Questions?



A hand holding a white marker is writing the word "Questions?" in white chalk on a dark, textured chalkboard. The hand is positioned on the right side of the frame, with the index finger pointing towards the end of the word. The word "Questions?" is written in a casual, slightly cursive font. The background is a dark, almost black chalkboard with some faint, lighter-colored smudges and lines.

Questions?

Please type your questions into the chat box within the GoToWebinar panel.

Short-Takes

Building Decarbonization Public Policy Webinar Series!



Building Policies · June 18, 11:00 a.m. - 12:00 p.m.

EM&V · July 16, 11:00 a.m. - 12:00 p.m.

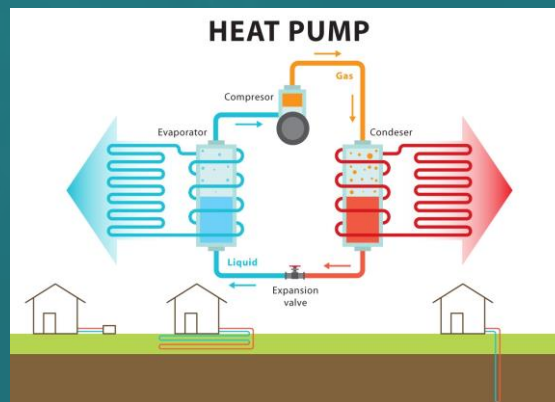
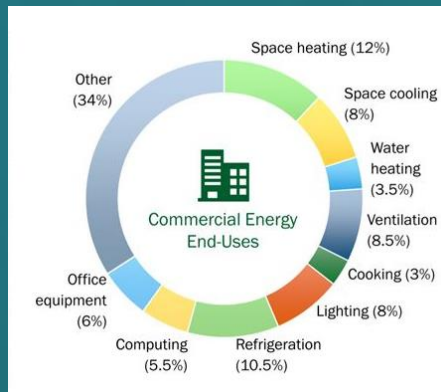
Register here: <https://neep.org/events/policy-framework-webinar-series>

Massachusetts Energy Zero Code (MA E-Z Code)



Overview:

- Energy efficiency
 - Prescriptive path focuses on deep energy efficiency (Passive House levels) beyond IECC 2021
- Electrification and decarbonization
- Renewable energy that meet additionality



ACE Project

Achieving Community Efficiency



Building
Benchmarking
Policies

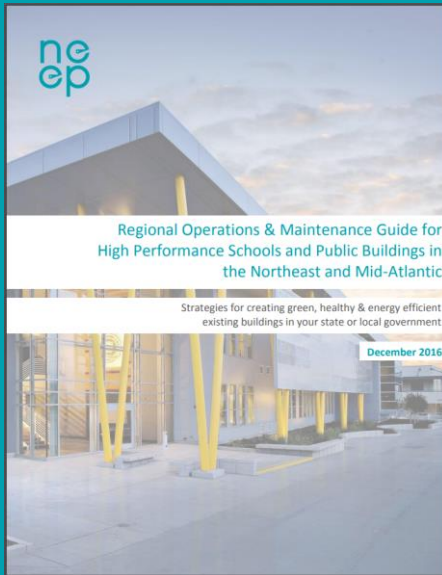
On-Site Energy
Manager

Accessible,
Useful
Resources

Credit: WVTourism.com

Meeting Communities Where They Are

Other Free NEEP Resources







CAPEE

COMMUNITY ACTION PLANNING FOR ENERGY EFFICIENCY

 **Step 1**
Complete Short Questionnaire

 **Step 2**
Receive Recommendations

 **Step 3**
Download Custom Action Plan

TRY IT OUT www.neep.org/capee

QUESTIONS? capee@neep.org



Christa McAuliffe Elementary School

Concord, NH

GENERAL INFORMATION

Location: 17 North Spring Street, Concord, NH 03301
Project Cost: \$10,545,834
Scope: 71,485 ft²
Cost Per Square Foot: \$205/ft²
Completion: September 2012
Enrollment: 484 students grades K-5
Architect: HMFH Architects, Inc.
Engineers: Rist-Frost-Shumway Engineering
Funding/Grant: N/A
NE-CHPS

PROJECT OVERVIEW

Christa McAuliffe Elementary School is one of a trio of high performance schools that opened in September 2012 in Concord, NH. The other two are Abbott-Stowling Elementary School and Mill Brook Primary School.

The new K-5 school honors its predecessor's character by reusing design element from the former school, like the ornate granite entryway. Inside, Christa McAuliffe's Learning Corridor functions as the heart of the school and supports various methods of teaching and learning. Throughout the interior, exposed HVAC lighting, and structural components are used as teaching tools to bring energy efficiency and building structure into the curriculum.

Community members were involved throughout the planning and design process, and their input and goals led to the creation of a neighborhood school with accessible walking and bicycle paths leading to the welcoming facade.

Student health was also a priority and was reflected in a variety of design choices. To maximize student wellbeing, the design team ensured that interior spaces received natural light, which improves overall health and circadian rhythm. High-reflectance white paint on many of the walls increases the efficiency of lighting while direct sunlight diffused with color panels and the school's north-south orientation minimizes glare. Exterior lighting features full cut-off ability, illuminating only the area below the fixture, which preserves the darkness of night sky.

The school's HVAC system also supports student health; the units use the same technology as units in medical operating rooms, featuring special diffusers that improve air quality and minimize the amount of airborne dust particles.

Acoustics were carefully incorporated into the new school, which fully meets ANSI Standard 12.60, the highest standard for classroom acoustics. Wall panels and ceiling tiles prevent background noise and reverberation and minimize noise and distractions. The impact of these changes shows through the new building's significant decline in absenteeism, which saw a 15-20 percent drop-off since McAuliffe's opening.



Air Source Heat Pumps – Renters Checklist – Home Energy Management Systems
NEEP Blog – Strategic Electrification – Building Energy Labeling

Visit us at **NEEP.org** for these resources and more

Thank You!

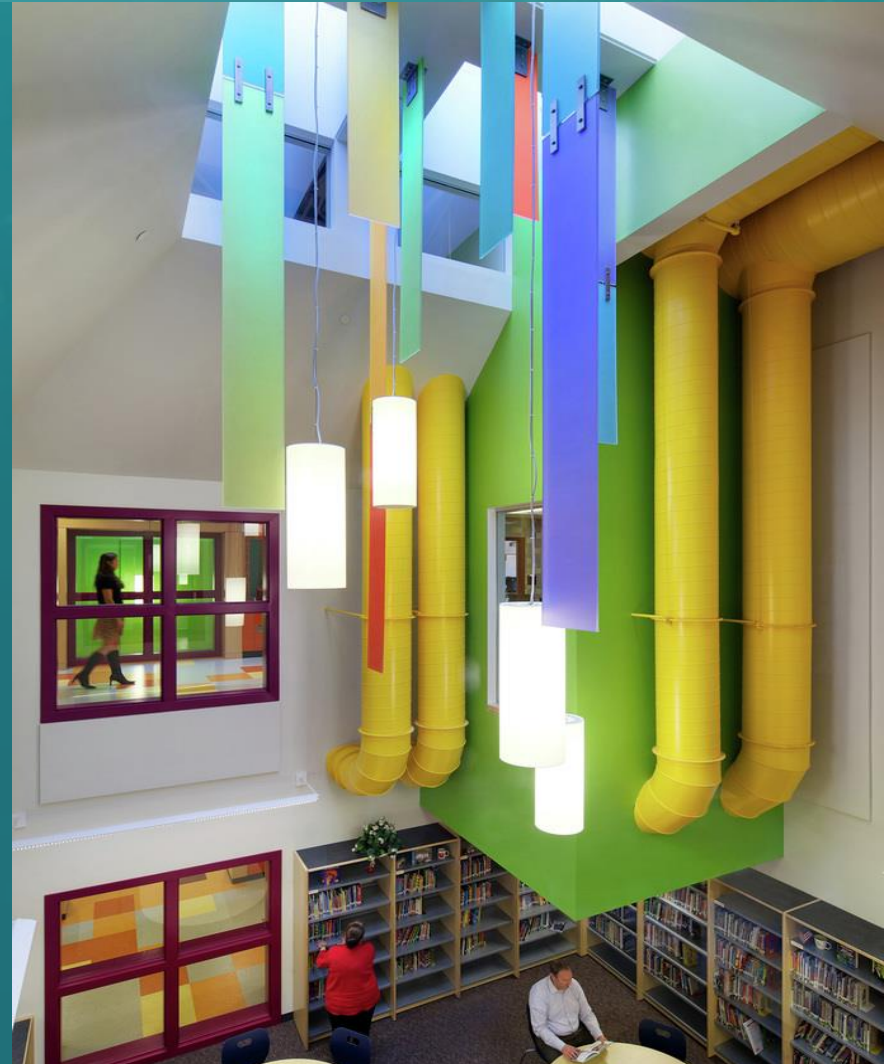


Kai Palmer Dunning

- kpunning@neep.org

John Balfe

- jbalf@neep.org



Credit: Ed Wonsek / HMFH Architects