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

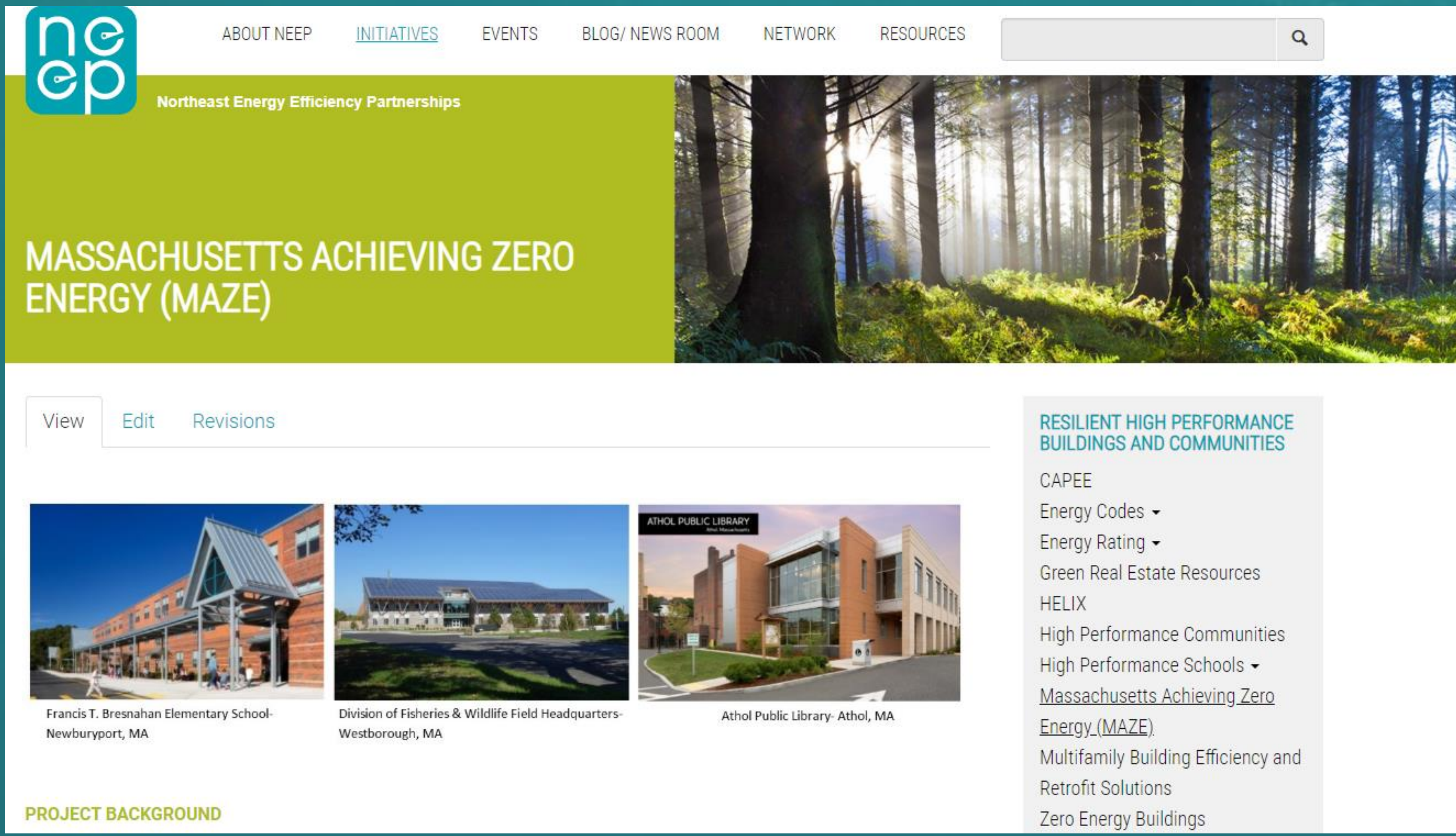
Partners in 2020

Agenda

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

ZE Toolkit: Background

Project Overview



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?

<u>Zero energy schools benefit building occupants</u>

- 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

Toolkit Guidance: Establishing Goals

Focus on EE First

Establish an EUI Target

ZE Language in RFPs

NREL Guidance: 18-25 kBtu/ft^2/yr

Additional Toolkit Guidance

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

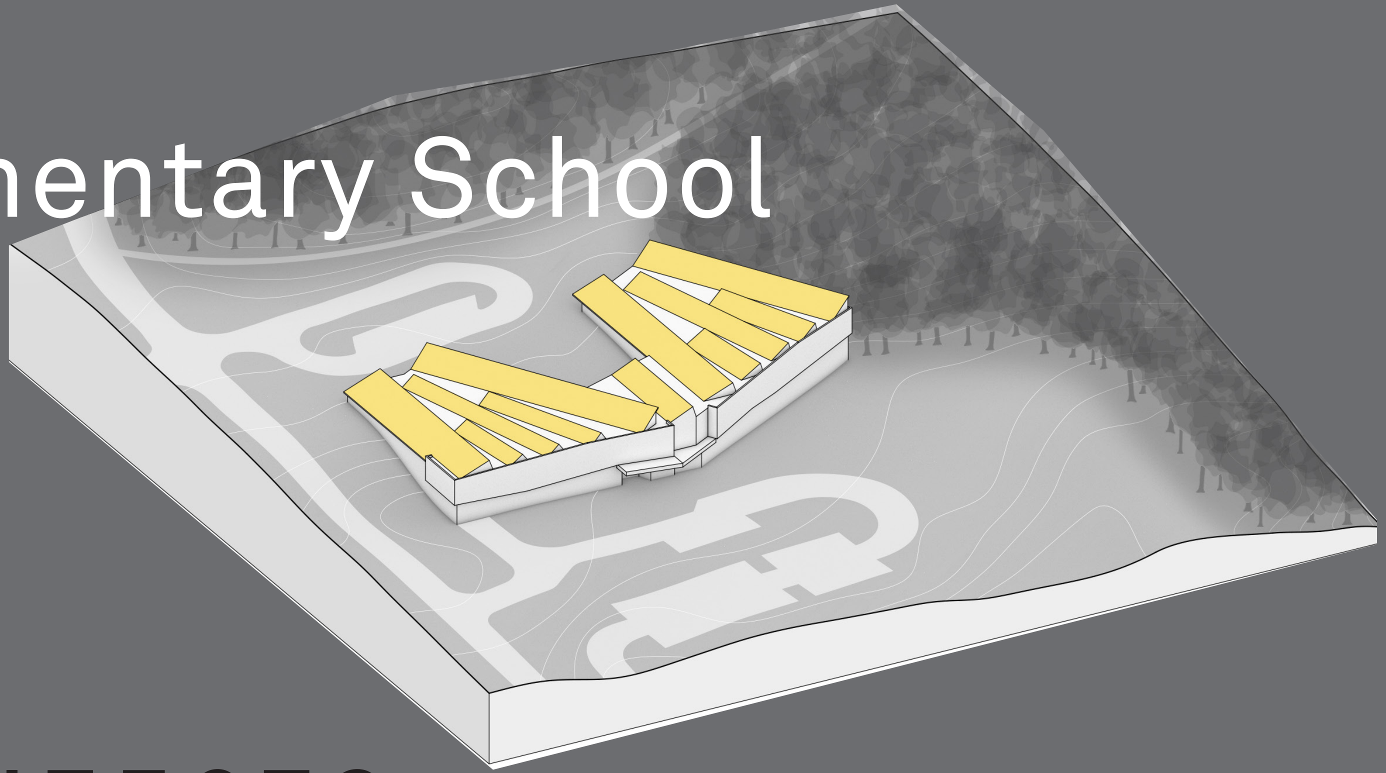
Technical Assistance Available
Throughout the Region!

- 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



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

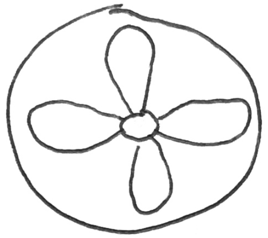
How did we get there?

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

- ***Produce*** as much energy as possible

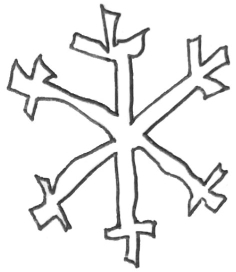
Components of Energy Use

Fales Total Energy Use Intensity (EUI) = 24.9

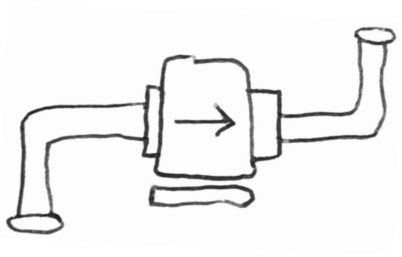


Ventilation: 4.30 17%

Heating: 2.35 9%

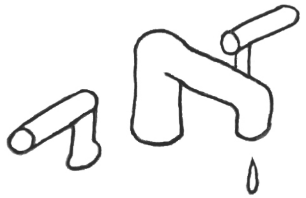


Cooling: 1.97 8%



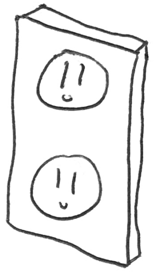
Pumps: 4.44 18%

HVAC: 52%

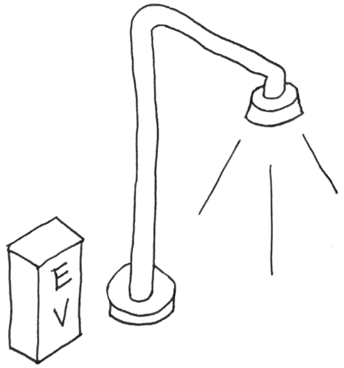


Hot Water: 0.28 1%

Lights: 3.13 13%



Plug Load: 7.95 32%
including kitchen equipment

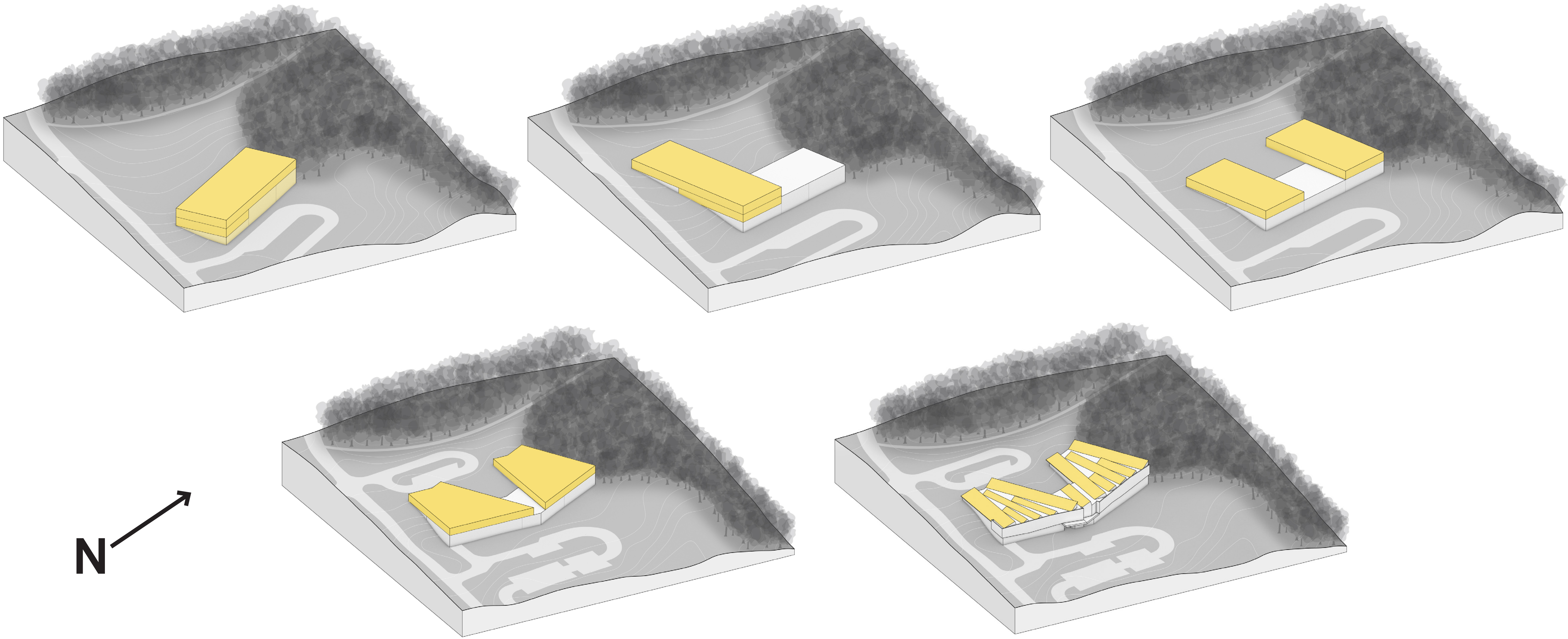


Exterior: 0.46 2%

Other: 48%

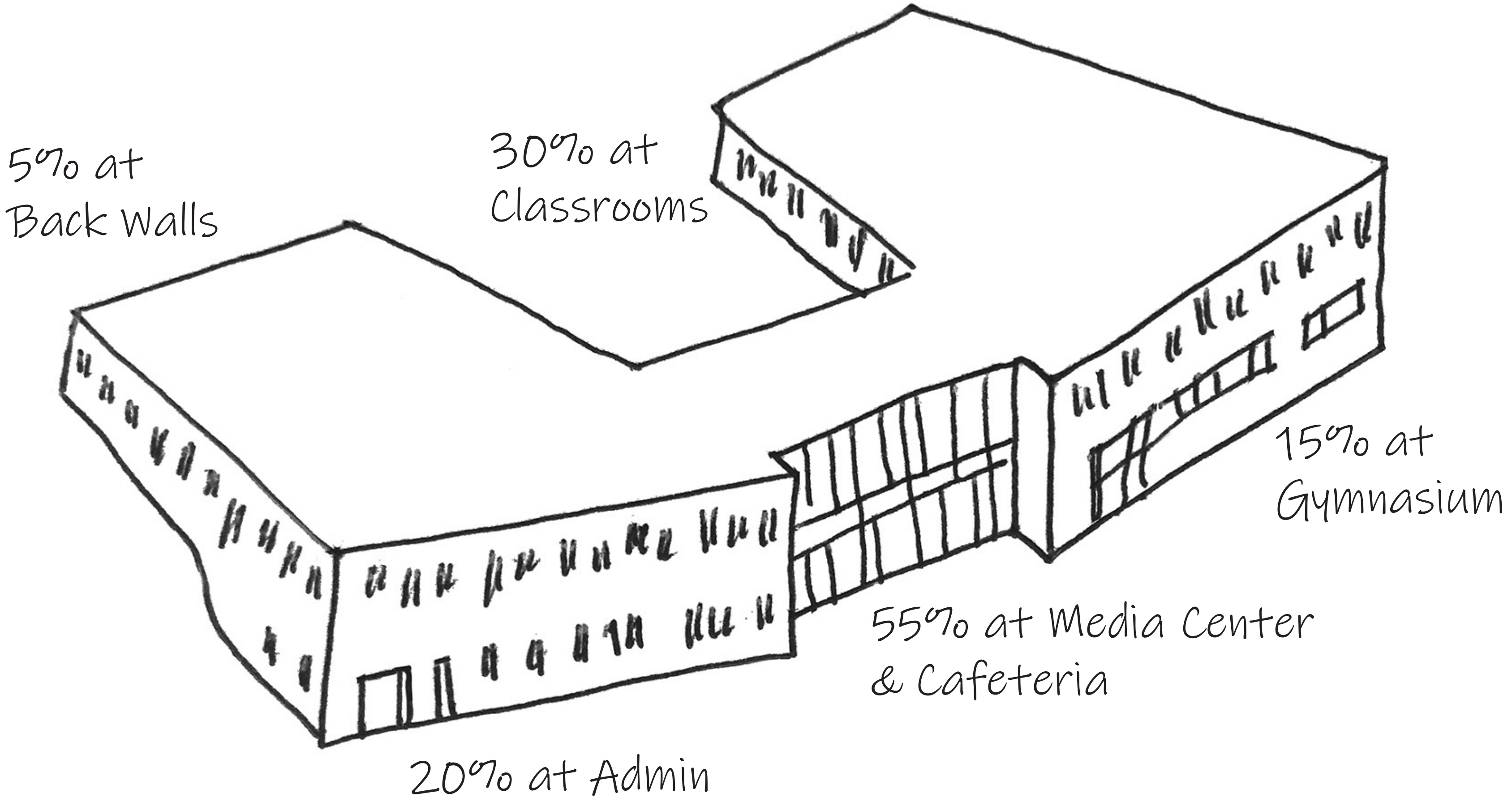
Energy Reduction: *Orientation and Massing*

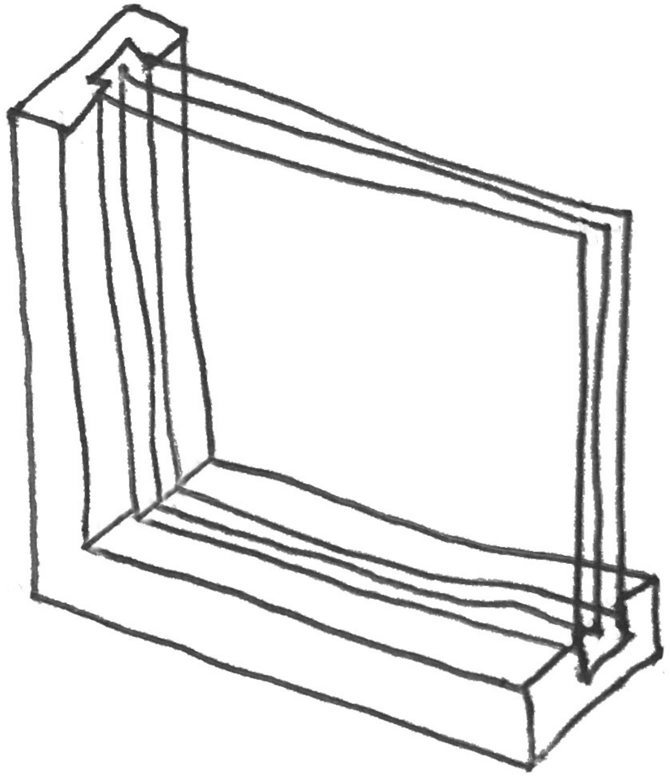
- north-south orientation for upper floors
- lower levels buried in hillside



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)*

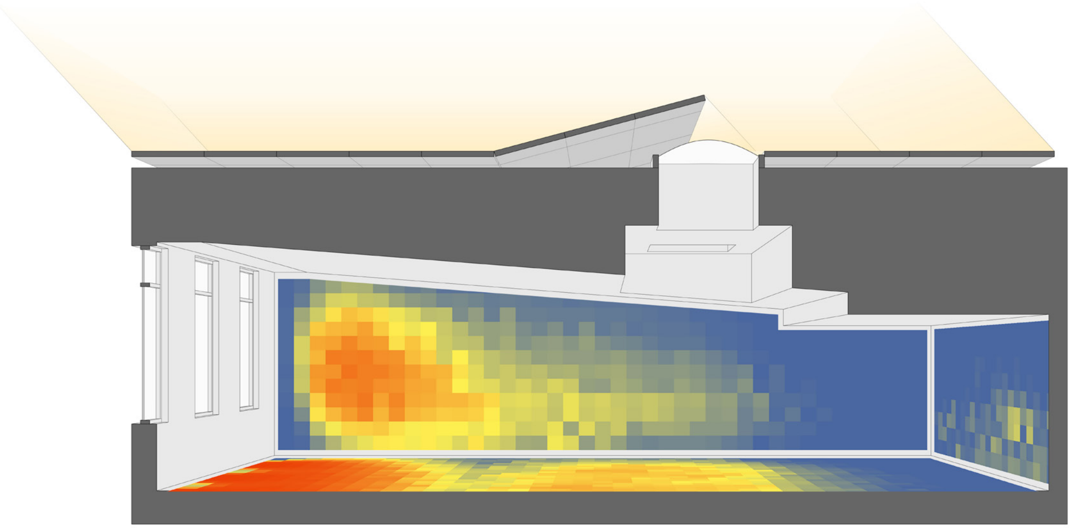
DA = percent of operating hours that an area can be lit exclusively with daylight

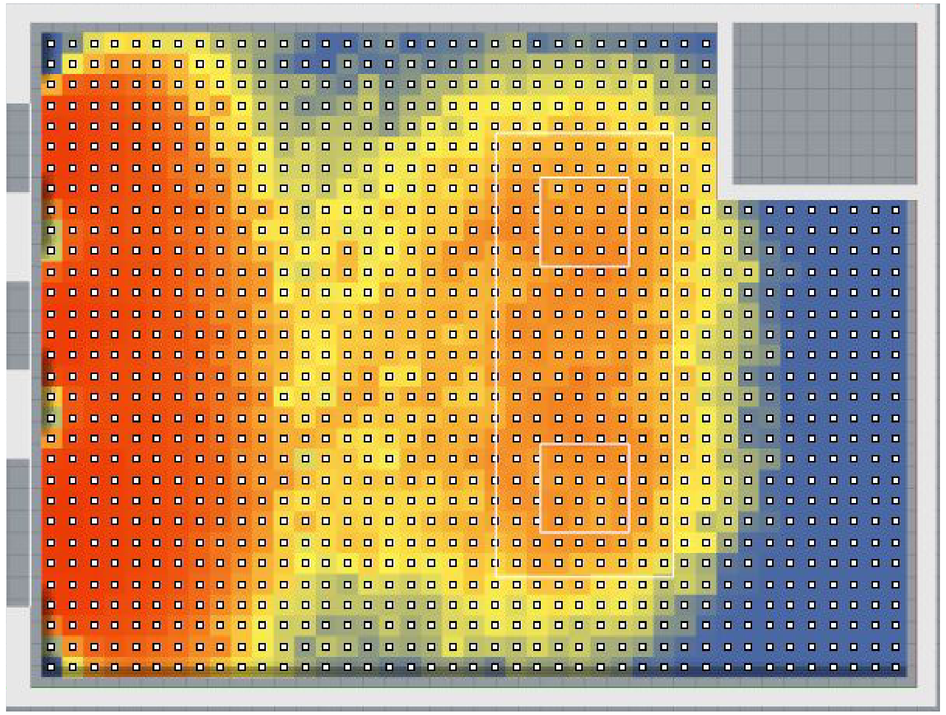
Control artificial lighting

- 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**





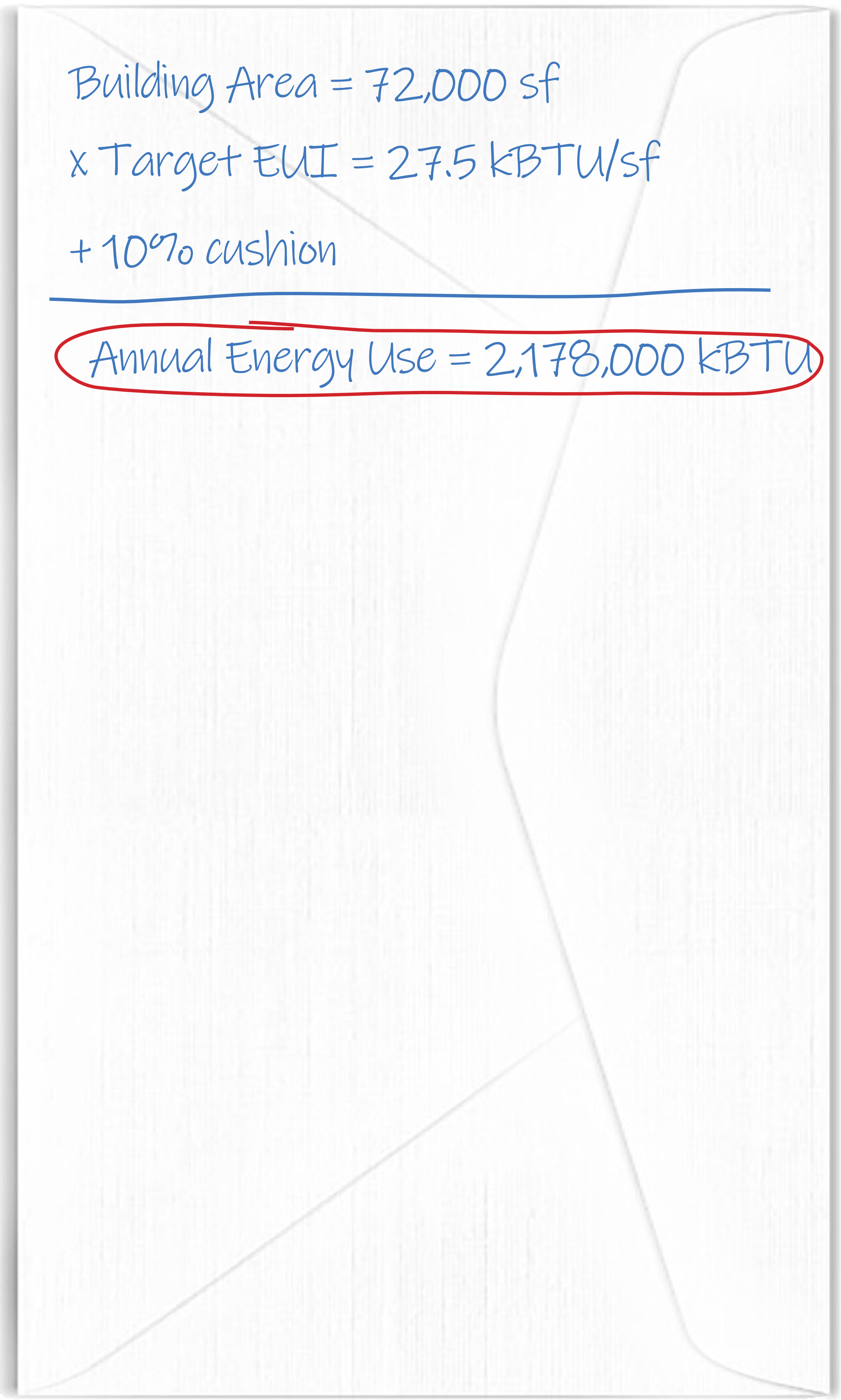
Energy Production: back of the envelope math

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



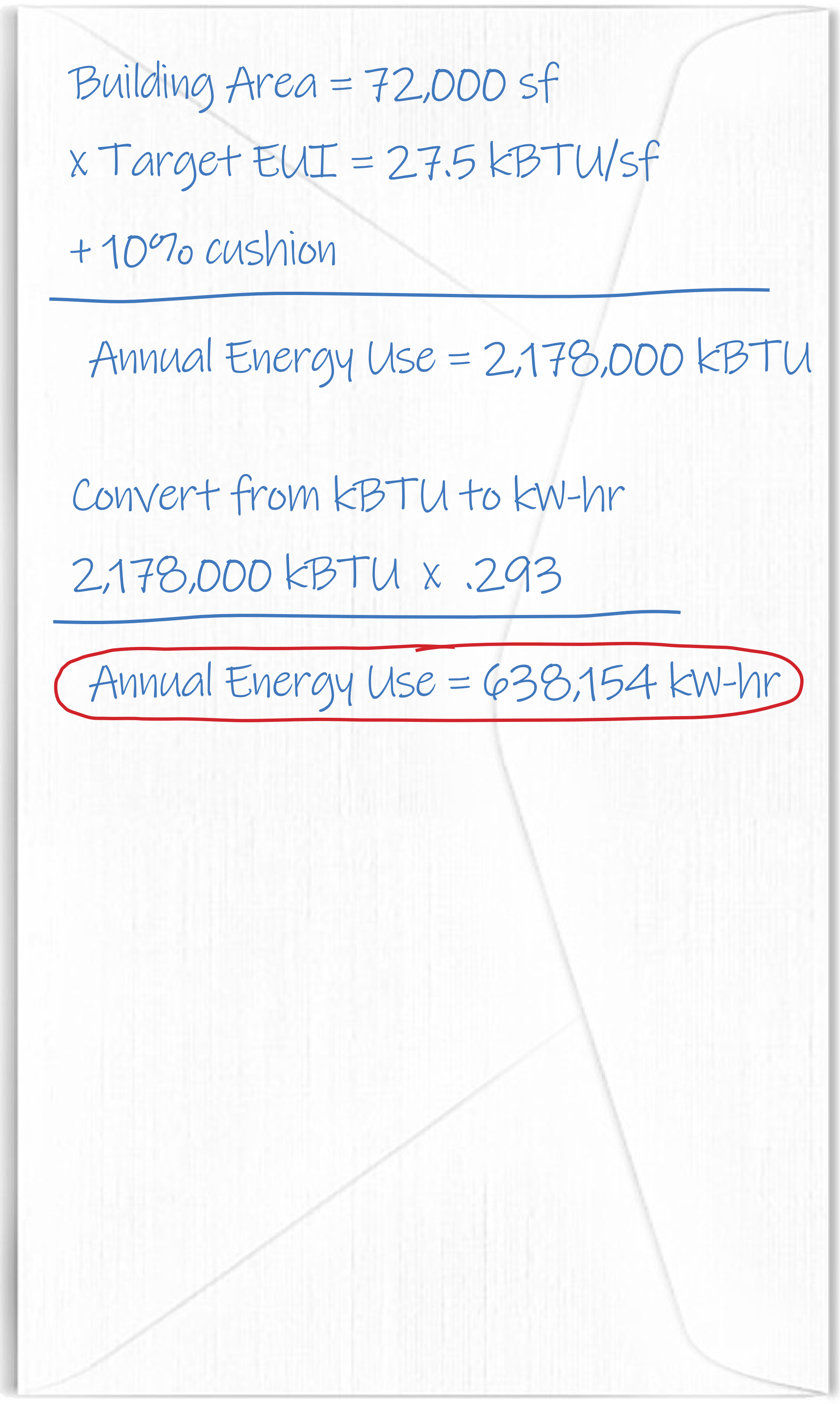
Energy Production: back of the envelope math

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



Energy Production: back of the envelope math

How many kWs 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

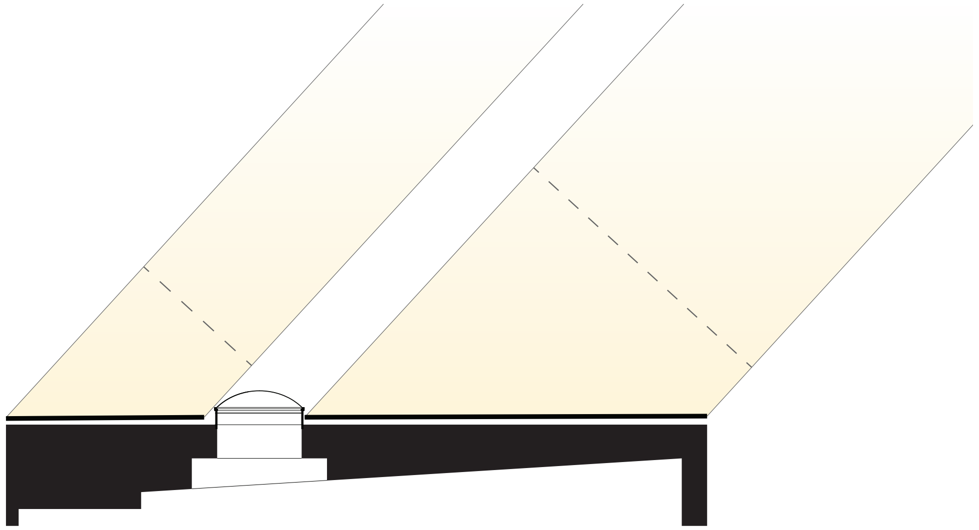
580 kW System Needed

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

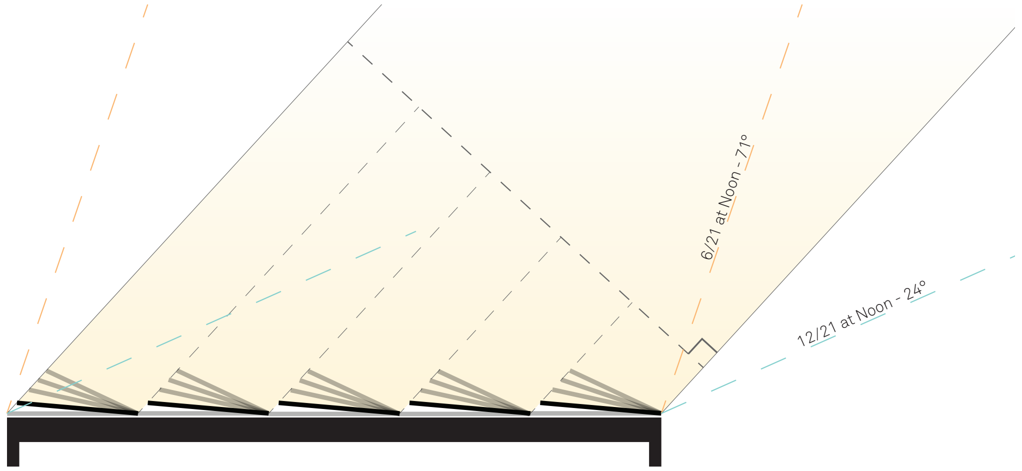
31,909 sf for the PV array

Conflicting Energy Production *and* ***Energy Reduction*** *needs:*

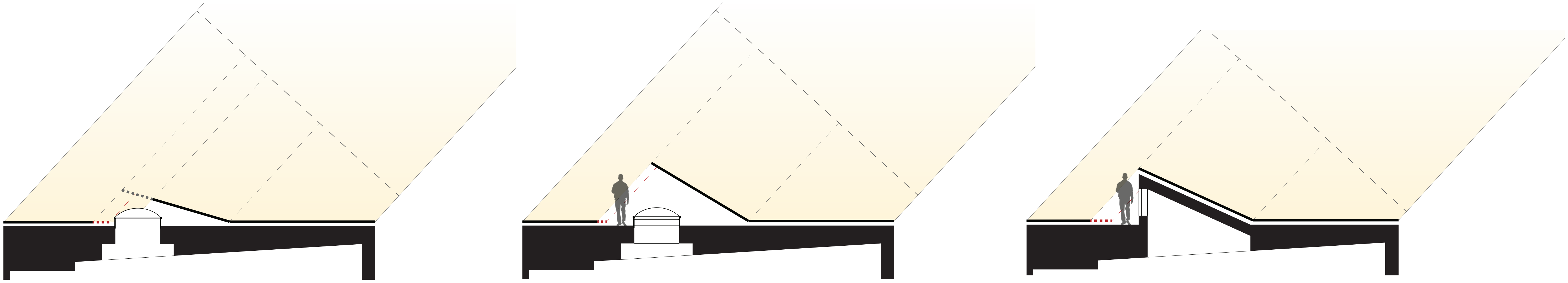
- *skylights and solar PV competing for roof area*
- *traditional skylights have poor insulating value*



optimal for daylight



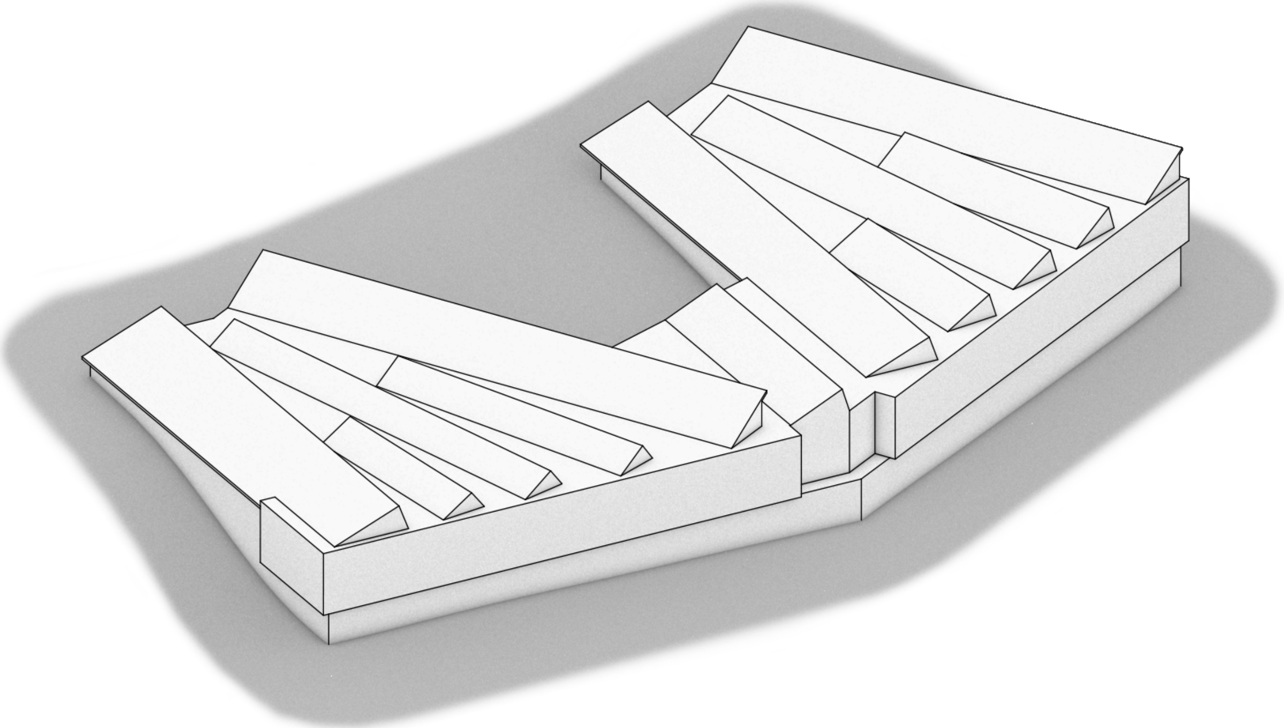
optimal for solar

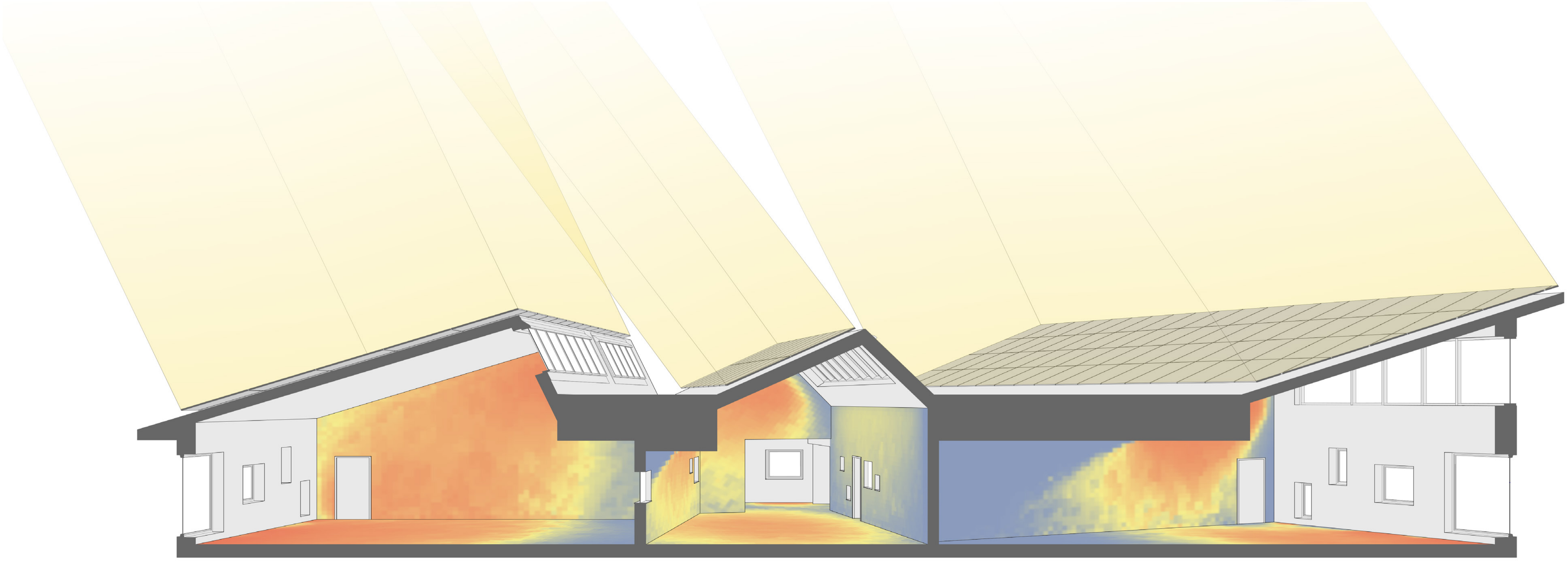


combined strategies

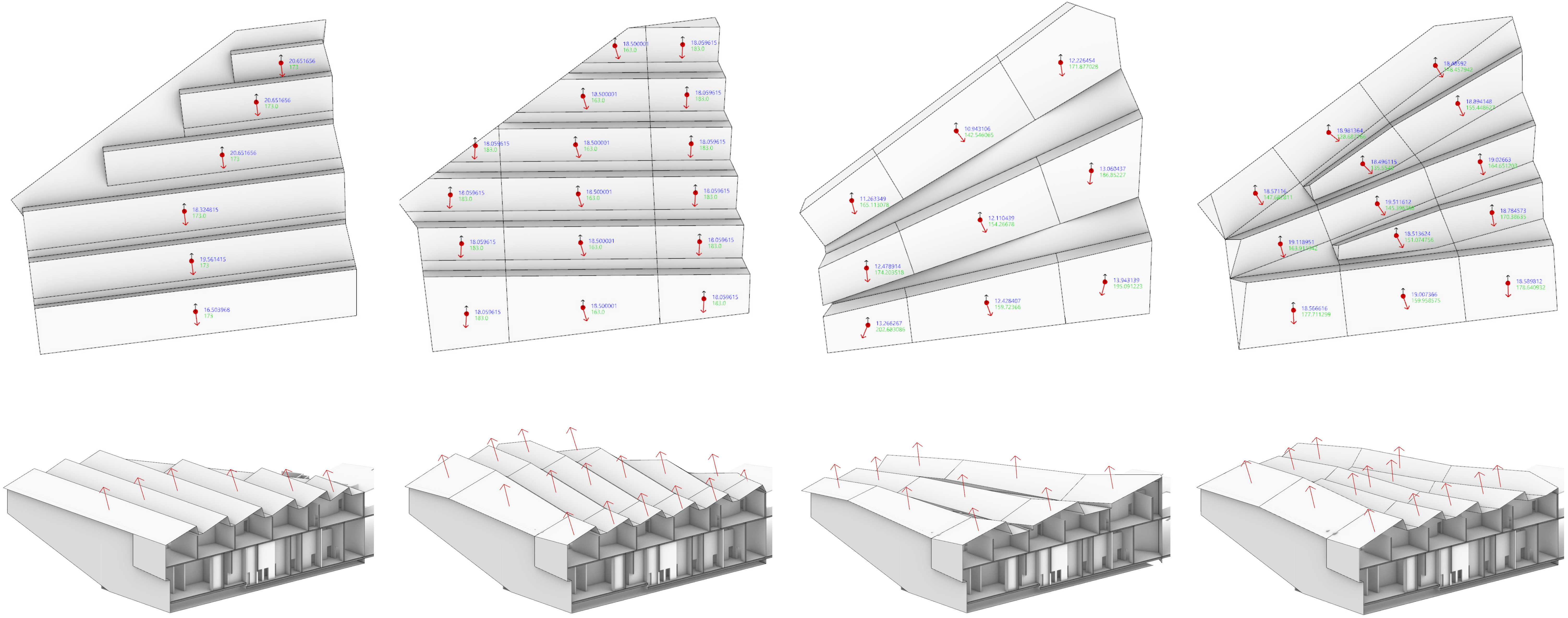
Sawtooth Roof

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



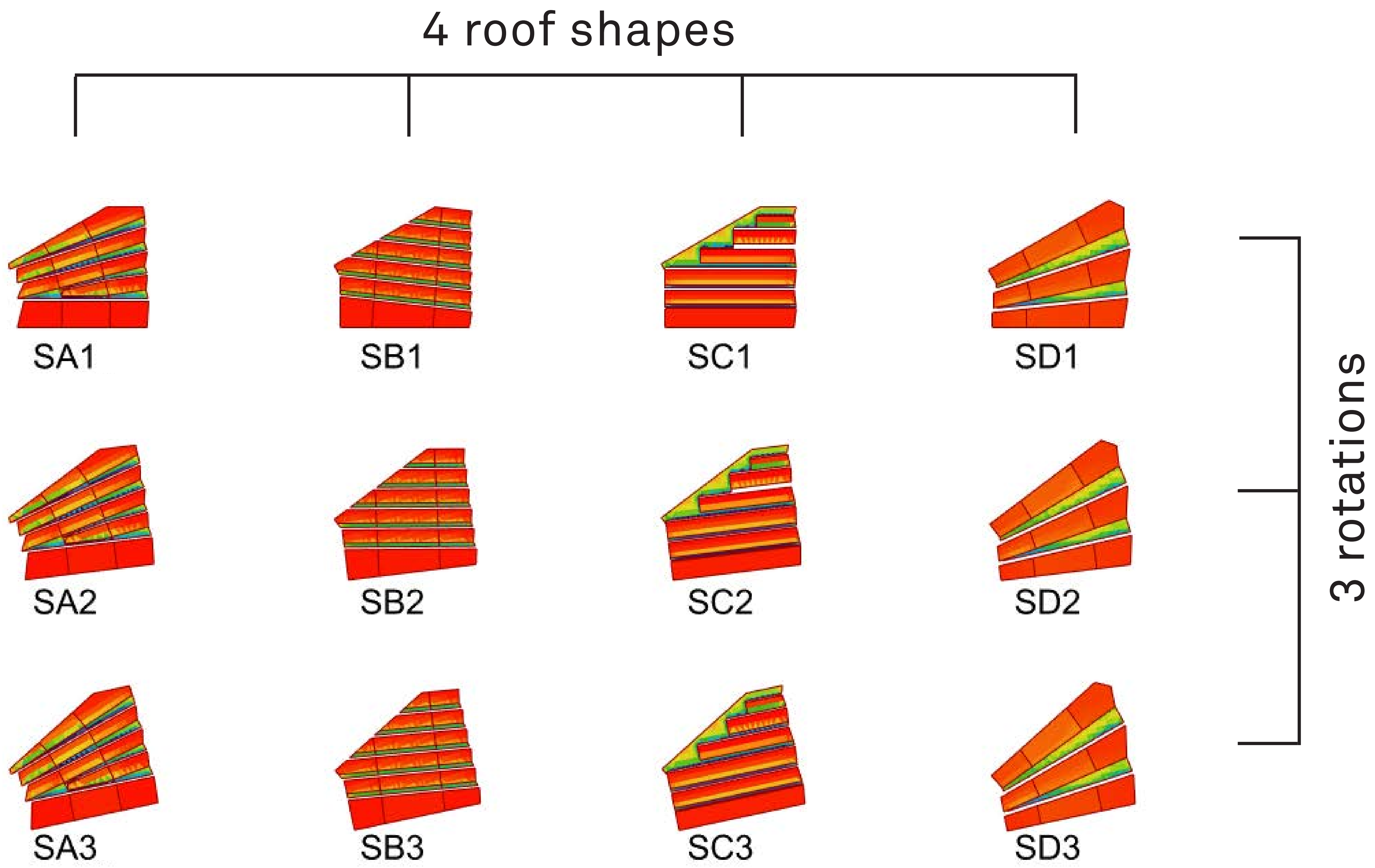


Roof Massing Options

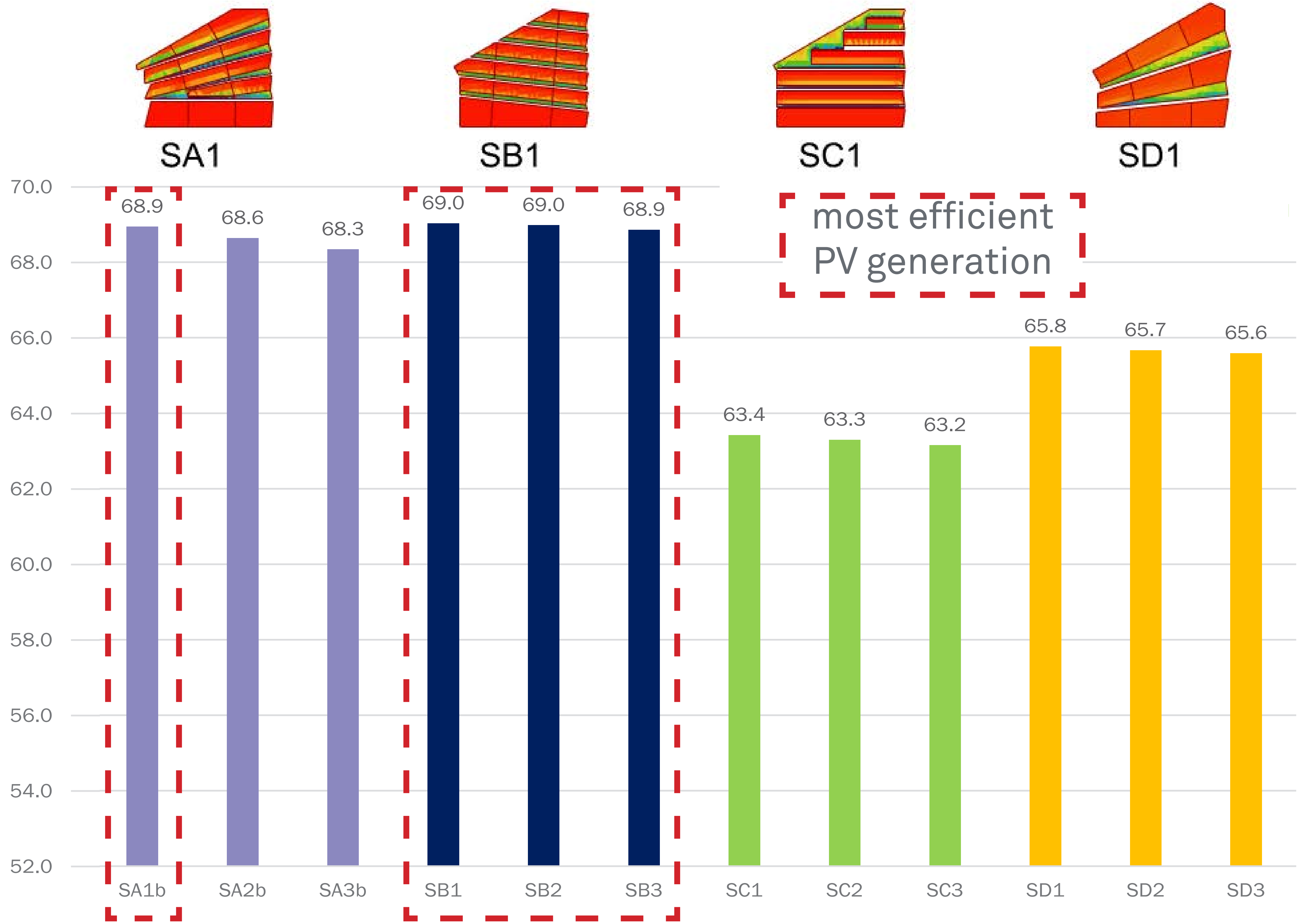


Parallel Rotated Parallel Triple-Pleat Quadruple-Pleat

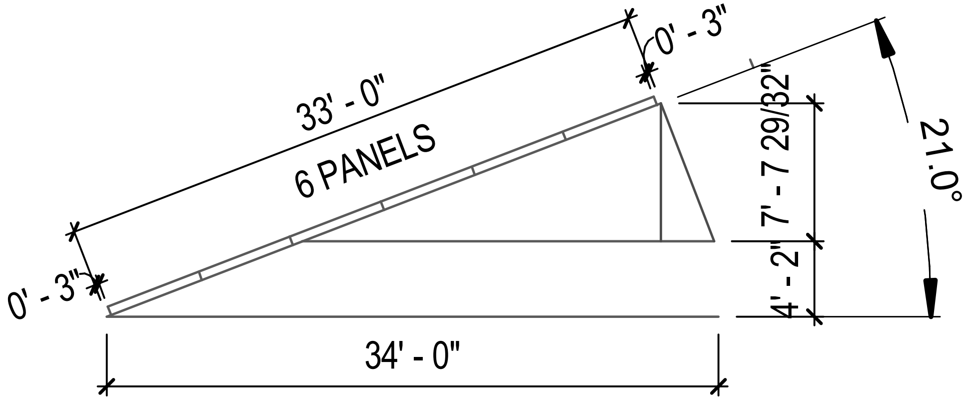
Radiance Analysis of Roof Options

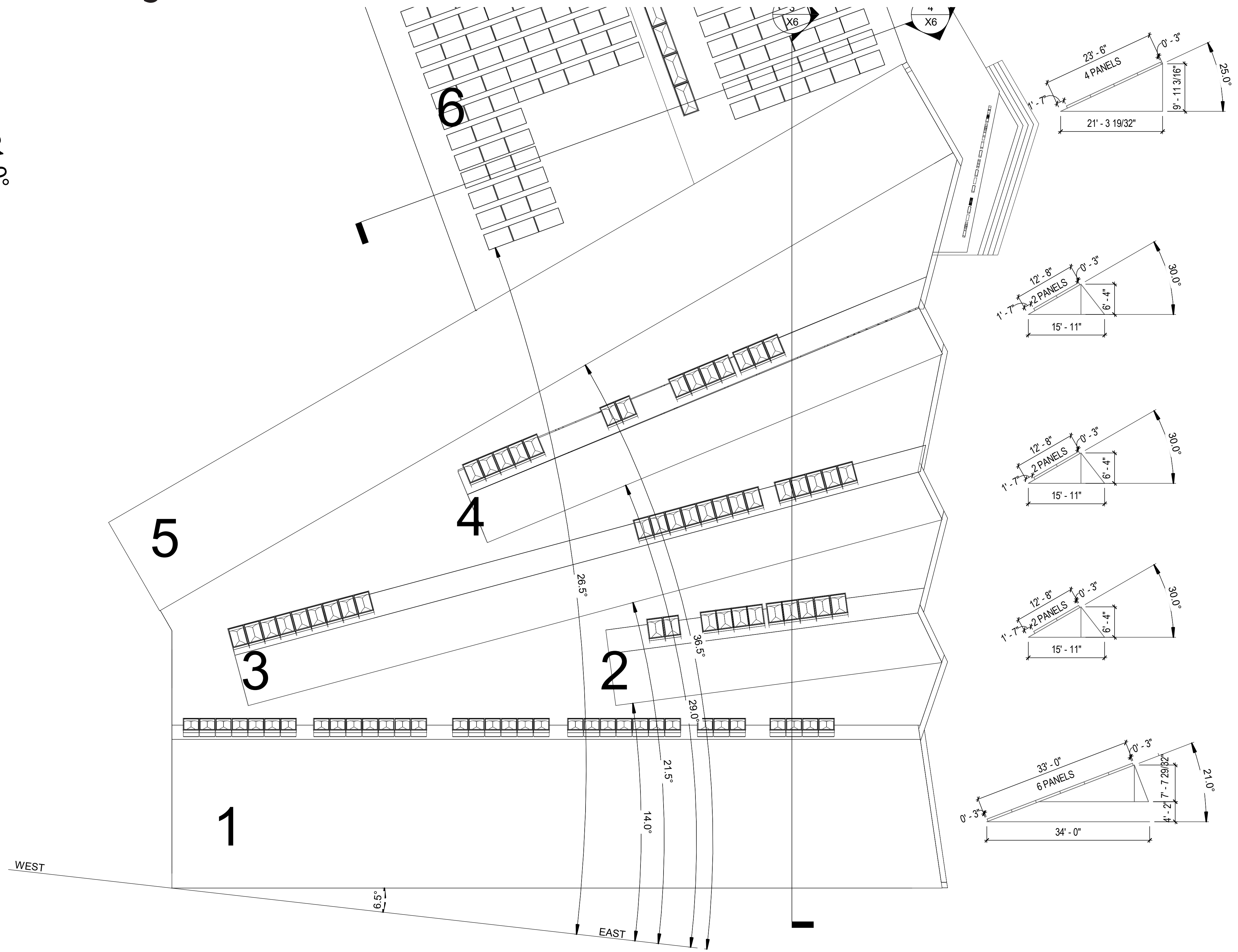


Radiance Analysis of Roof Options



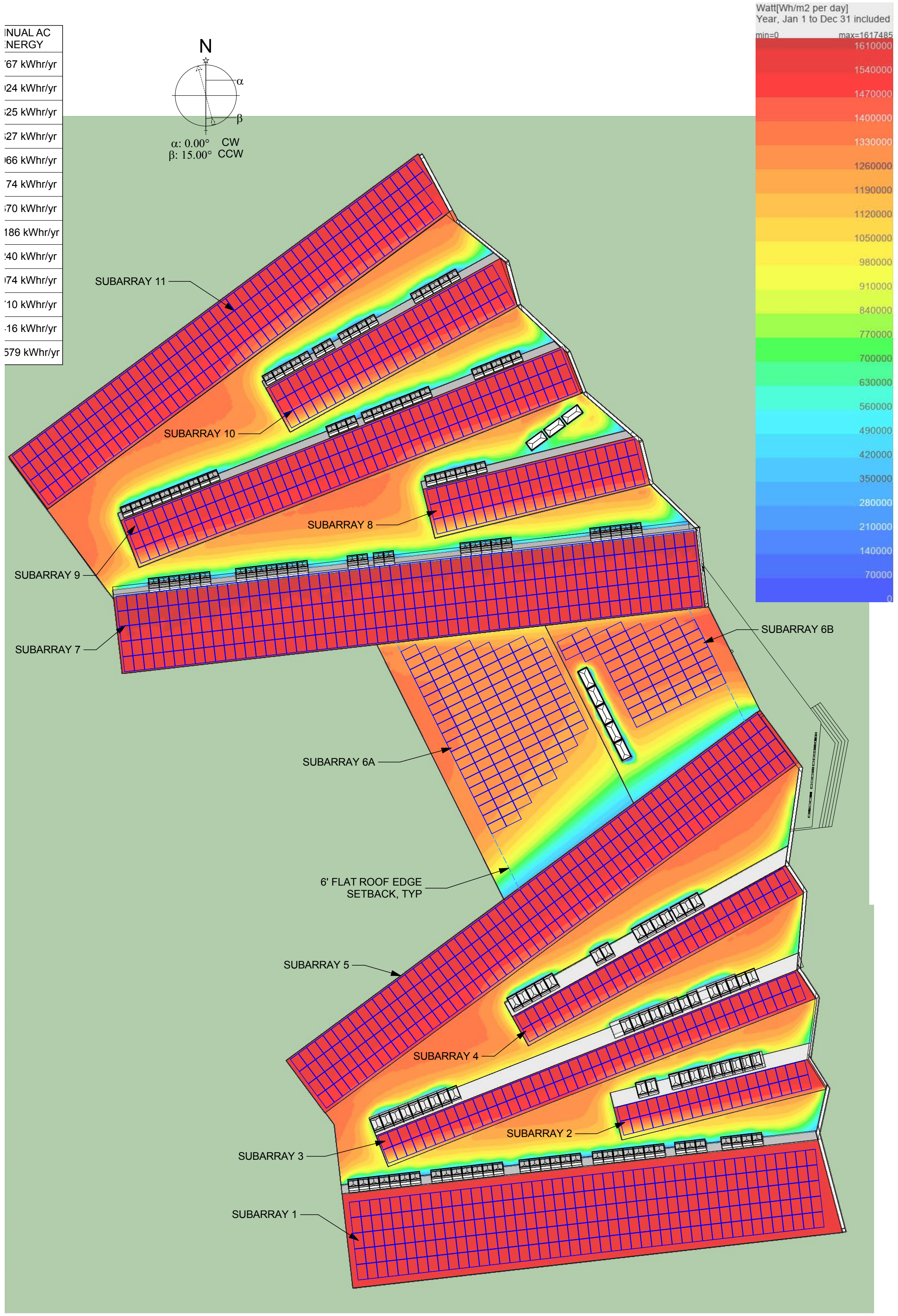
Optimizing Roof Geometry

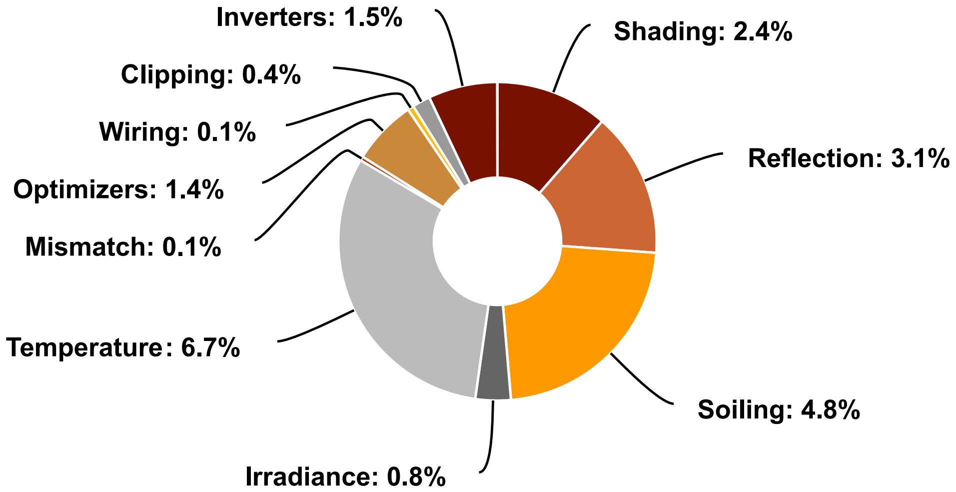




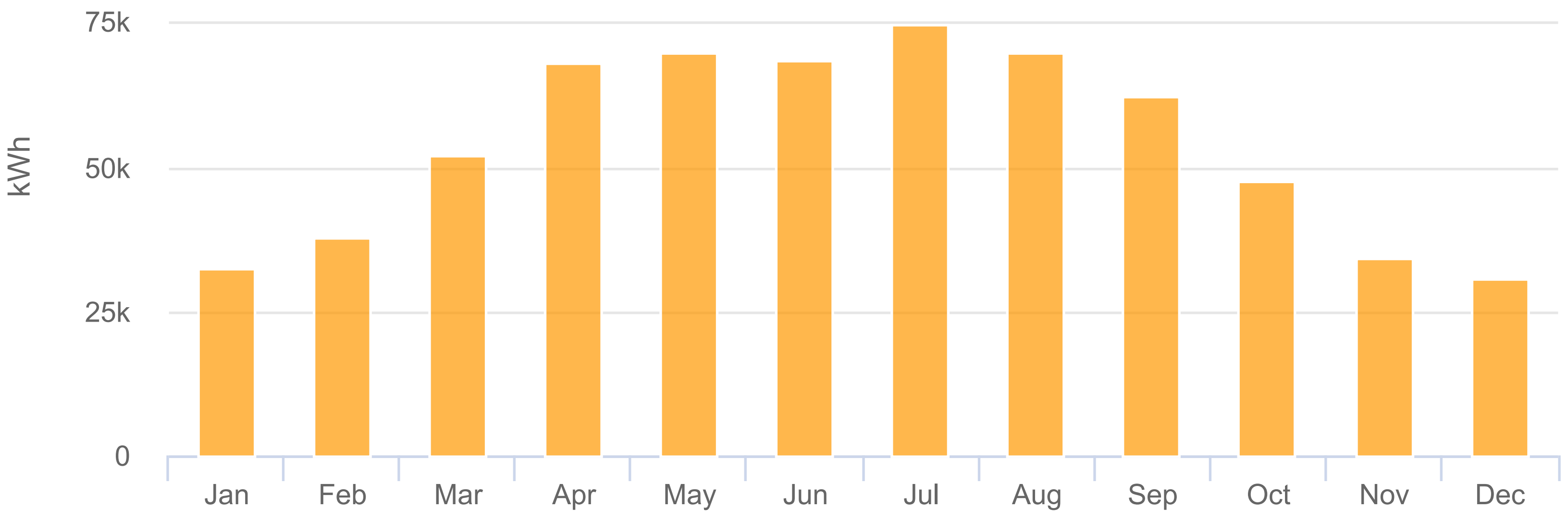
Design Development:

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





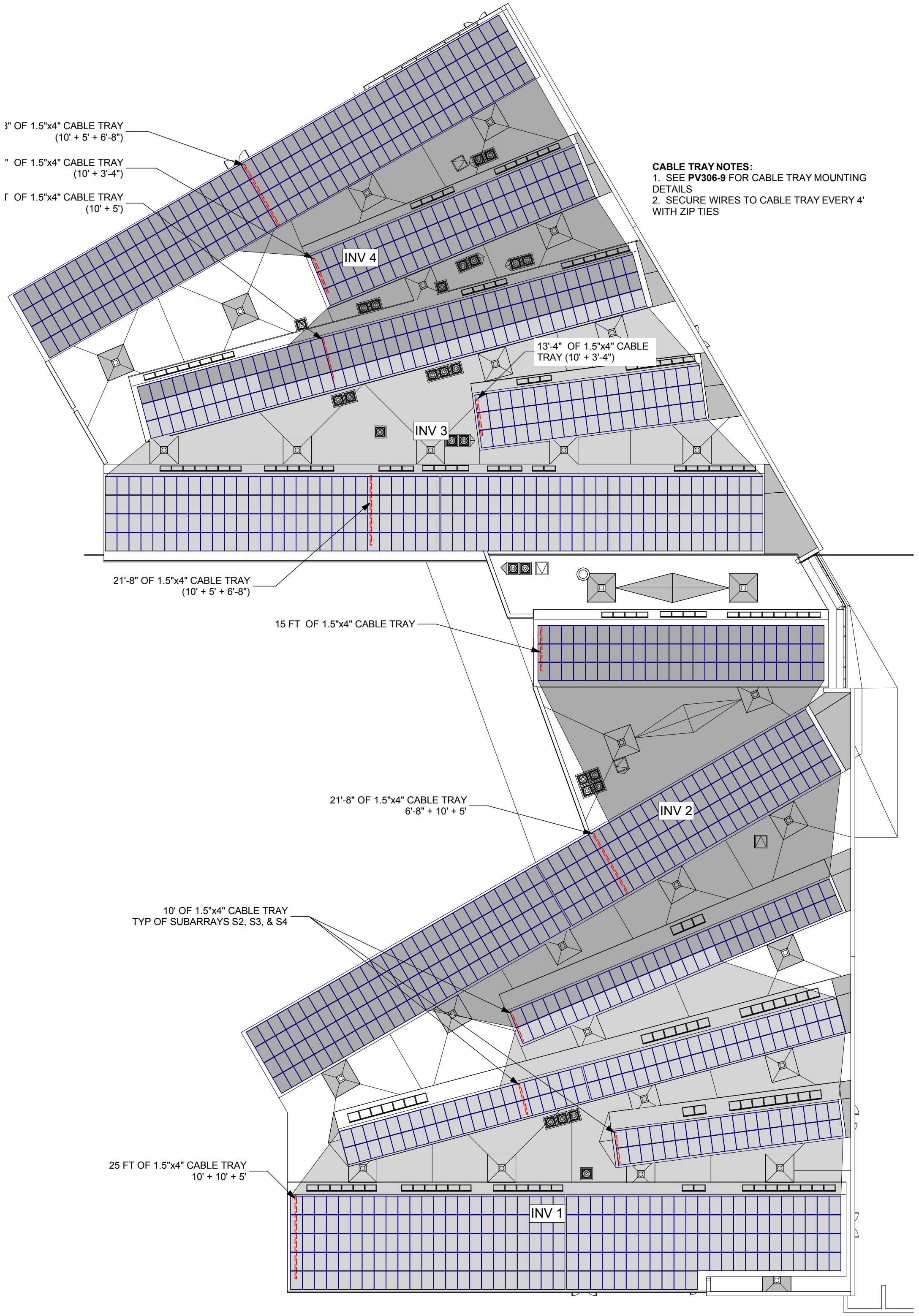
System Losses



Monthly Production

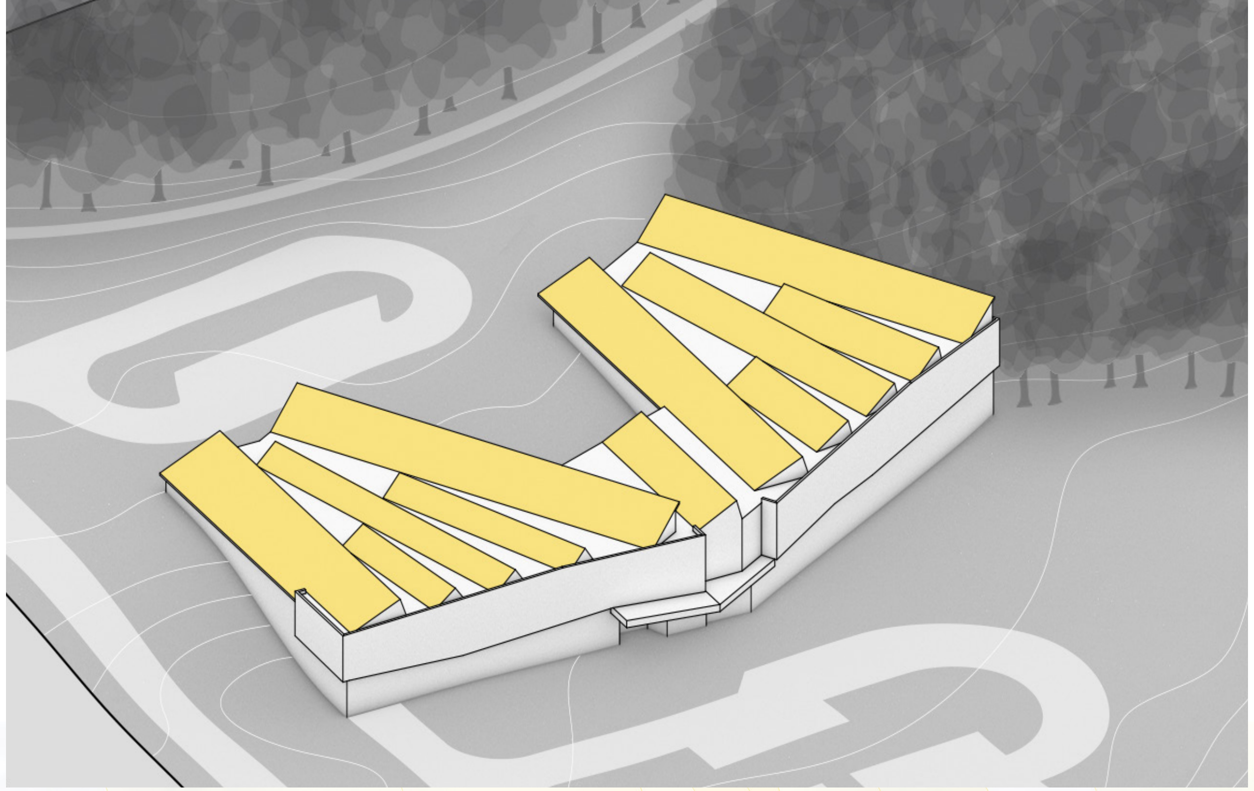
Final Design:

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

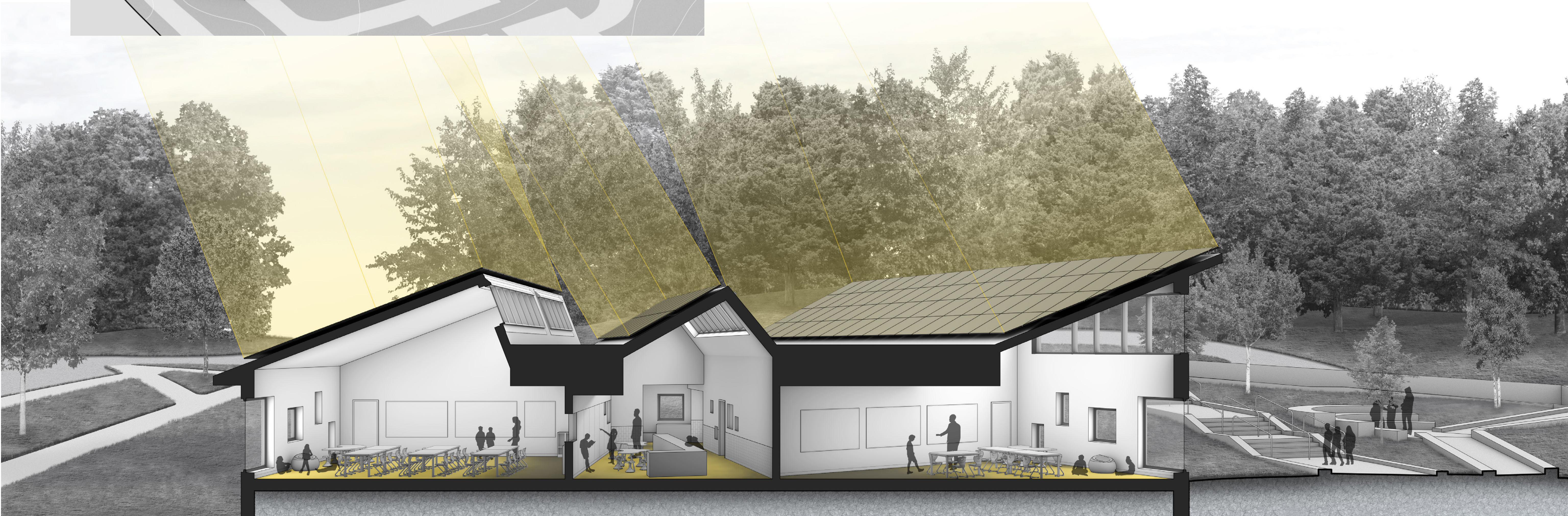


How did we do?

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



Questions?



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

Short-Takes

Building Decarbonization Public Policy Webinar Series!

neep

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

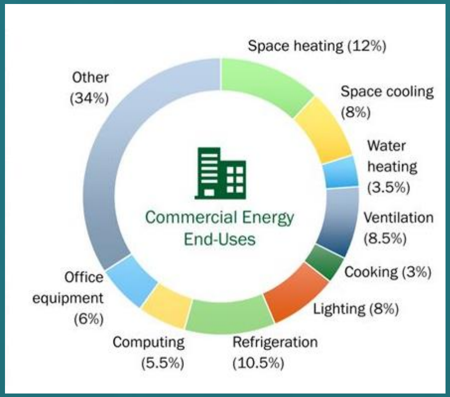
EM&V · July 16, 11:00 a.m. - 12:00 p.m.

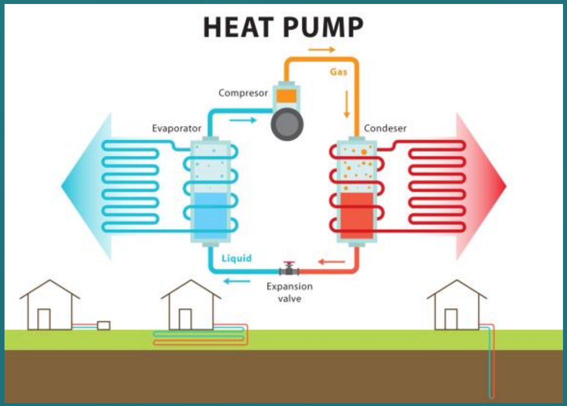
Register here: https://neep.org/events/policy-framework-webinar-series

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

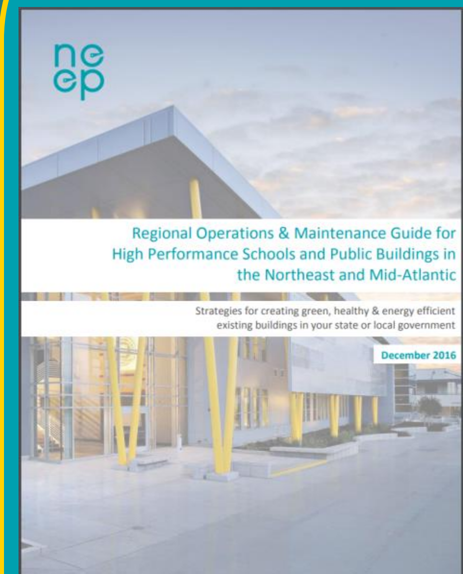
On-Site Energy Manager

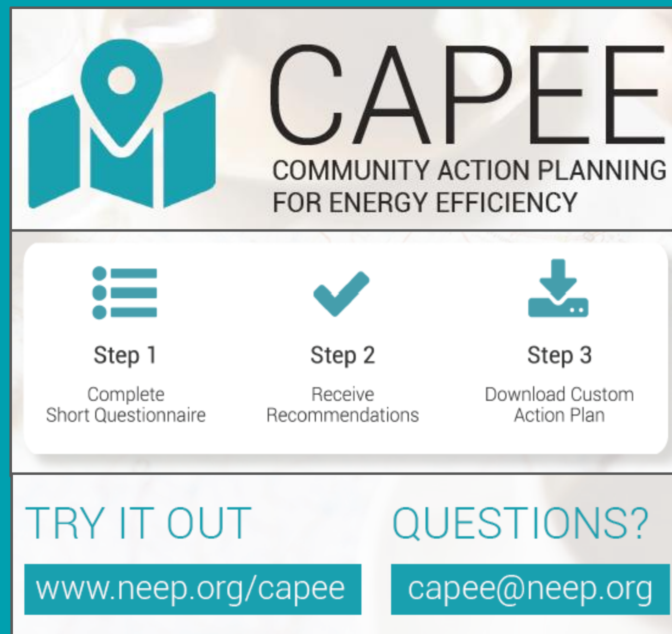
Accessible, Useful Resources

Credit: WVTourism.com

Meeting Communities Where They Are

Other Free NEEP Resources





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!

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Credit: Ed Wonsek / HMFH Architects