NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Strategies Workshop for RetrofitNY Awardees

Urban Futures Lab, Brooklyn

July 11, 2018

Lieko Earle, Paul Torcellini, Shanti Pless, and Michael Deru

NREL/PR-5500-72067

Agenda

8:00 – 10:00	**Opening & Introductions**
10:00 – 11:00	**Decision-making**
11:00 – 11:15	Break
11:15 – 12:15	**Façade & Windows**
12:15 – 1:15	Lunch break
1:15 – 2:15	**HVAC & DHW systems**
2:15 – 3:15	**Appliances & Lighting**
3:15 – 3:30	Break
3:30 – 4:30	**PV & Metering**
4:30 – 5:00	**Closing**

Opening & Introductions

Who are we and why are we here?

Who are we?

Paul Torcellini

Commercial Buildings

Michael Deru

Building Energy Science

Shanti Pless

Commercial Buildings

Lieko Earle

Residential Buildings

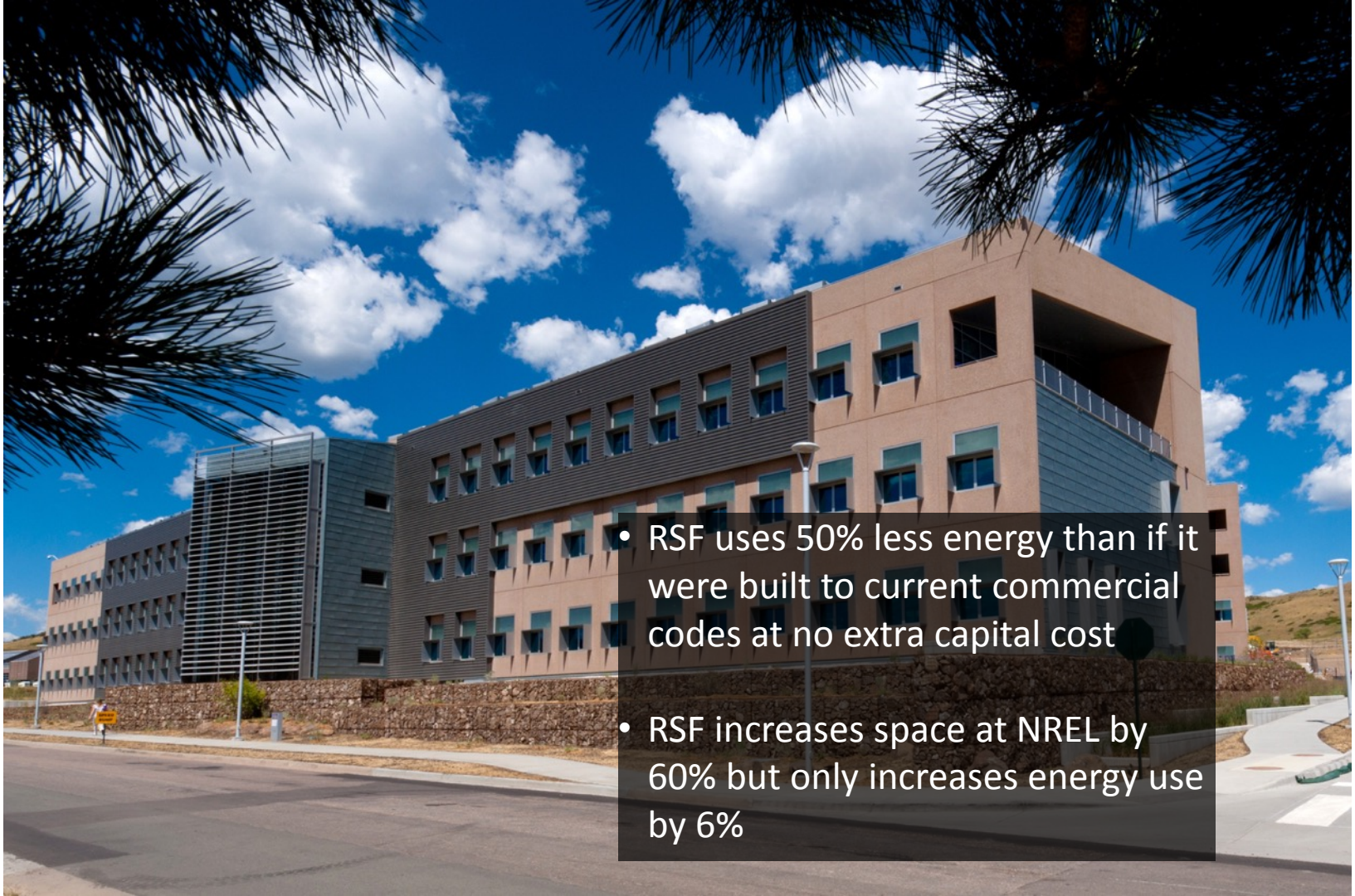
Awardee Round-Robin Introductions

In 10 minutes or less per project team:

- **What is your project (describe building, overall scope)?** (<3 min)
- **What keeps you up at night related to achieving success?**
- **What are the biggest barriers in achieving the target EUI?**
- **What do you want to get out of today?** (<1 min)

Decision-making

Key elements for achieving integrated, state-of-the-art retrofit design



- RSF uses 50% less energy than if it were built to current commercial codes at no extra capital cost
- RSF increases space at NREL by 60% but only increases energy use by 6%

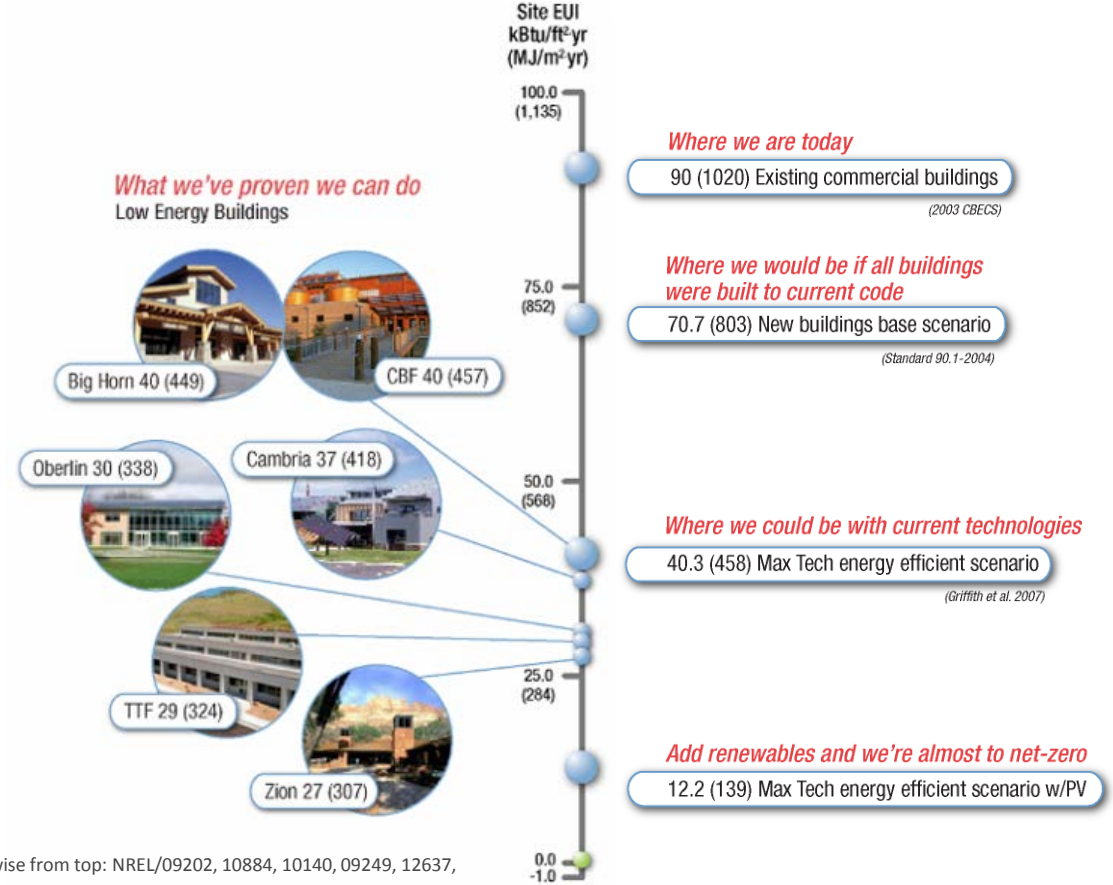
NREL/17825

Many Pieces

- So many ways to assemble the pieces
- Design is about making decisions – need motivation to make the right decisions
- Who are the decision makers?

Used by permission: Paul Torcellini/NREL

Great Potential in Buildings



Clockwise from top: NREL/09202, 10884, 10140, 09249, 12637, 11097

Setting Goals

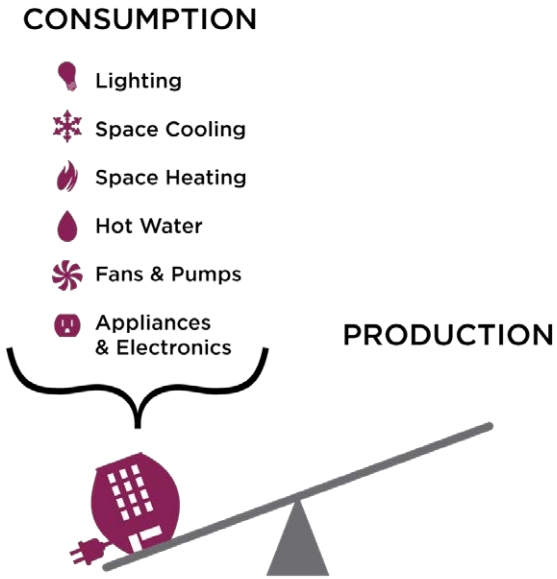
- Measurable goals are better
- From bad to good…
  - I want a green building
  - Design a LEED <rating> building
  - Design a building to use 30% less energy than ASHRAE 90.1-2013
  - Design a building to use less than 25,000 BTU/sqft
  - Design a ZERO ENERGY BUILDING

- Influencing purchasing decision—the owner

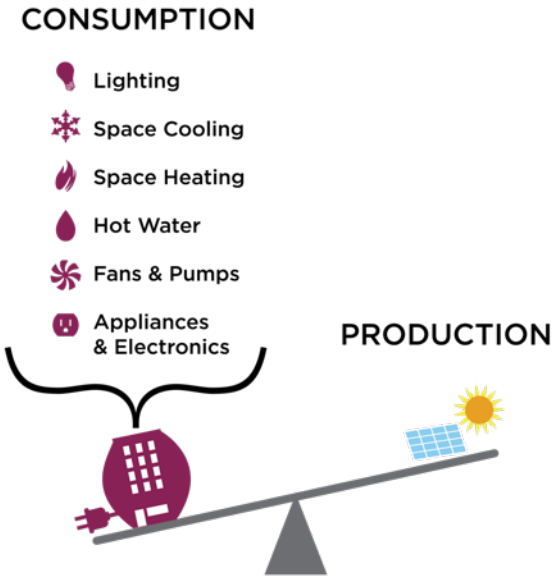
What are **Zero Energy Buildings**?

- Conceptually, a building that has no adverse energy [or environmental] impact [because of its operation]
- Energy consumption has been a long-term surrogate for environmental impact
- Boundaries and metrics
- What energy flows to measure

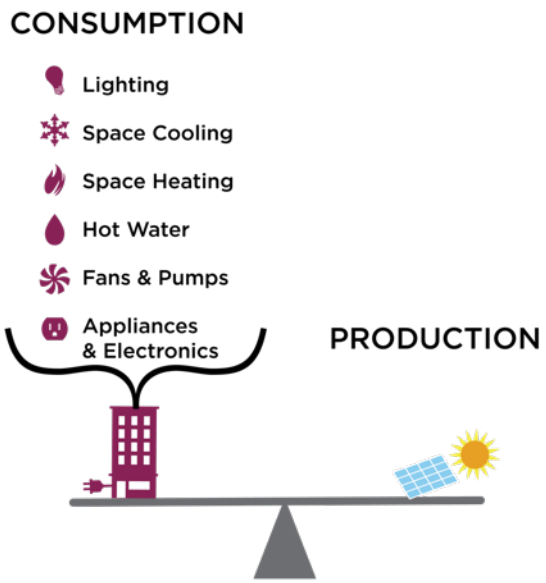
Zero Energy Building



Adding Renewables



Building on a Diet

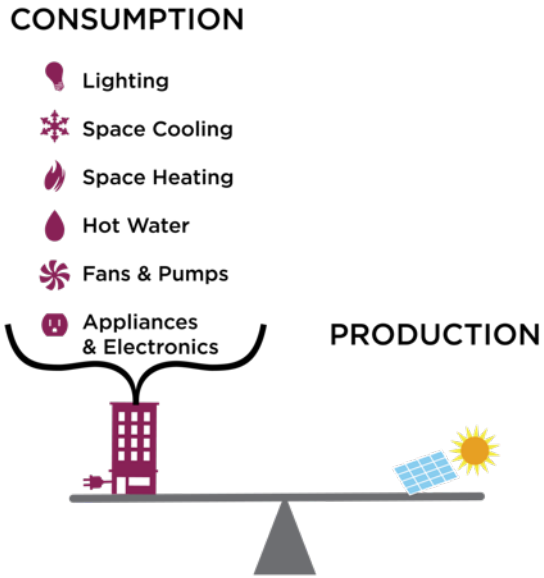


ZEB Concept

Goal 1:
Reduce Consumption

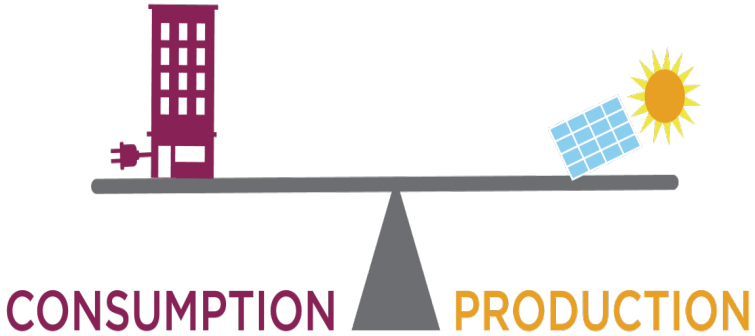
Goal 2:
Apply On-site Renewable Energy

BALANCE!



Zero Energy Building (ZEB) Definition

An energy-efficient building, where on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.



Adding Value

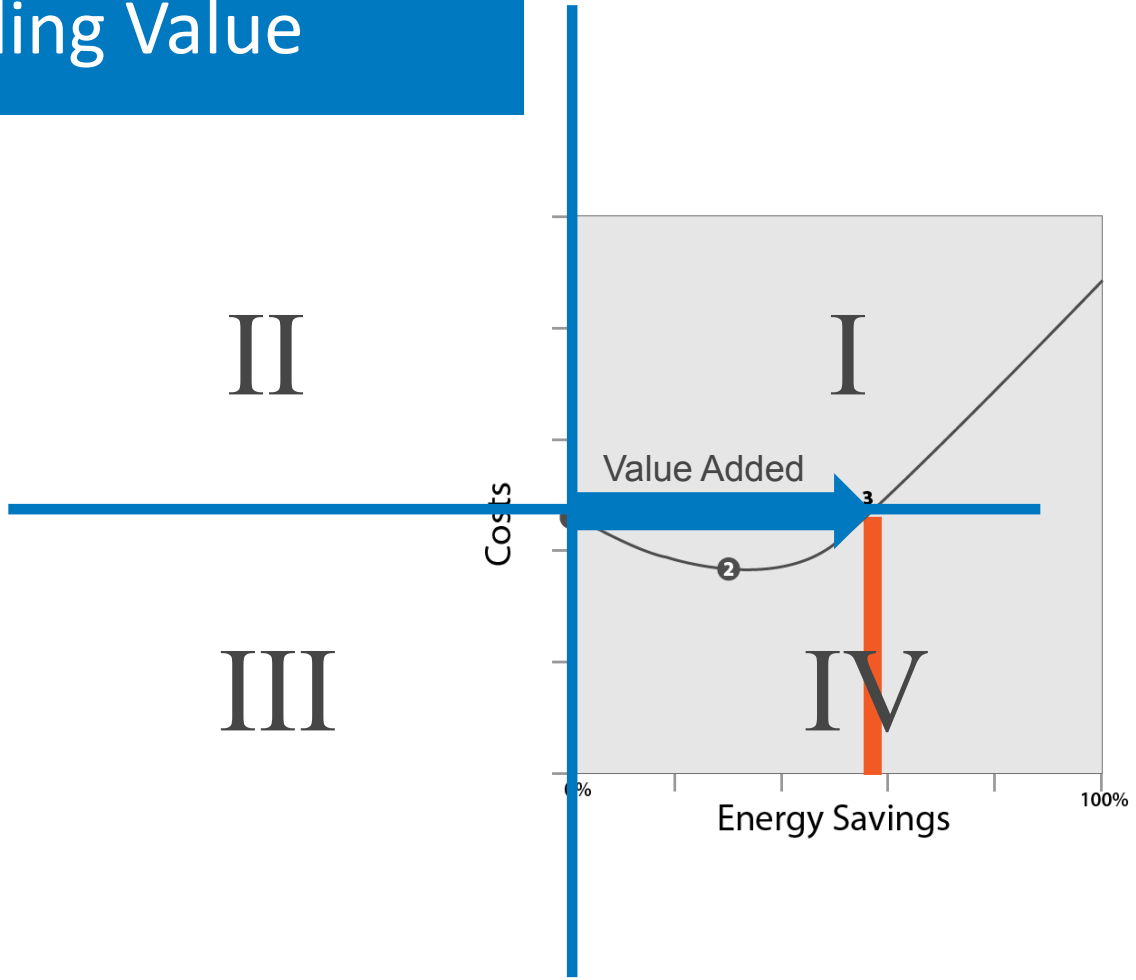


Photo credit: Paul Torcellini/NREL

NREL/17826

Problem Definition: RFP Objectives

MISSION CRITICAL

Attain safe work performance/Safe Design Practices

LEED Platinum

Energy Star “Plus”

HIGHLY DESIRABLE

800 staff Capacity

25 kBTU/sf/year

Architectural integrity

Honor future staff needs

Measurable ASHRAE 90.1

Support culture and amenities

Expandable building

Ergonomics

Flexible workspace

Support future technologies

Documentation to produce a “How to” manual

“PR” campaign implemented in real-time

Allow secure collaboration with outsiders

Building information modeling

Substantial Completion by 2010

IF POSSIBLE

Zero energy design approach

Most energy efficient building in the world

LEED Platinum Plus

ASHRAE 90.1 + 50%

Visual displays of current energy efficiency

Support public tours

Achieve national and global recognition and awards

Support personnel turnover

RFP also required maximum use of natural ventilation and 90% of floor space fully daylit

The Process

- Owner made tough decisions up-front
  - Set budget
  - Sought maximum value for that budget
  - Prioritized goals
- Design-Build procurement process
  - Managed the team to the RFP and its substantiation criteria
  - Rewards
- Allowed design-build team to use creativity to maximize value--innovation
- Owner did not solve the problem (but knew the technical solution existed)

Innovation as a result of the process

Process drove creativity of solutions by providing appropriate constraints

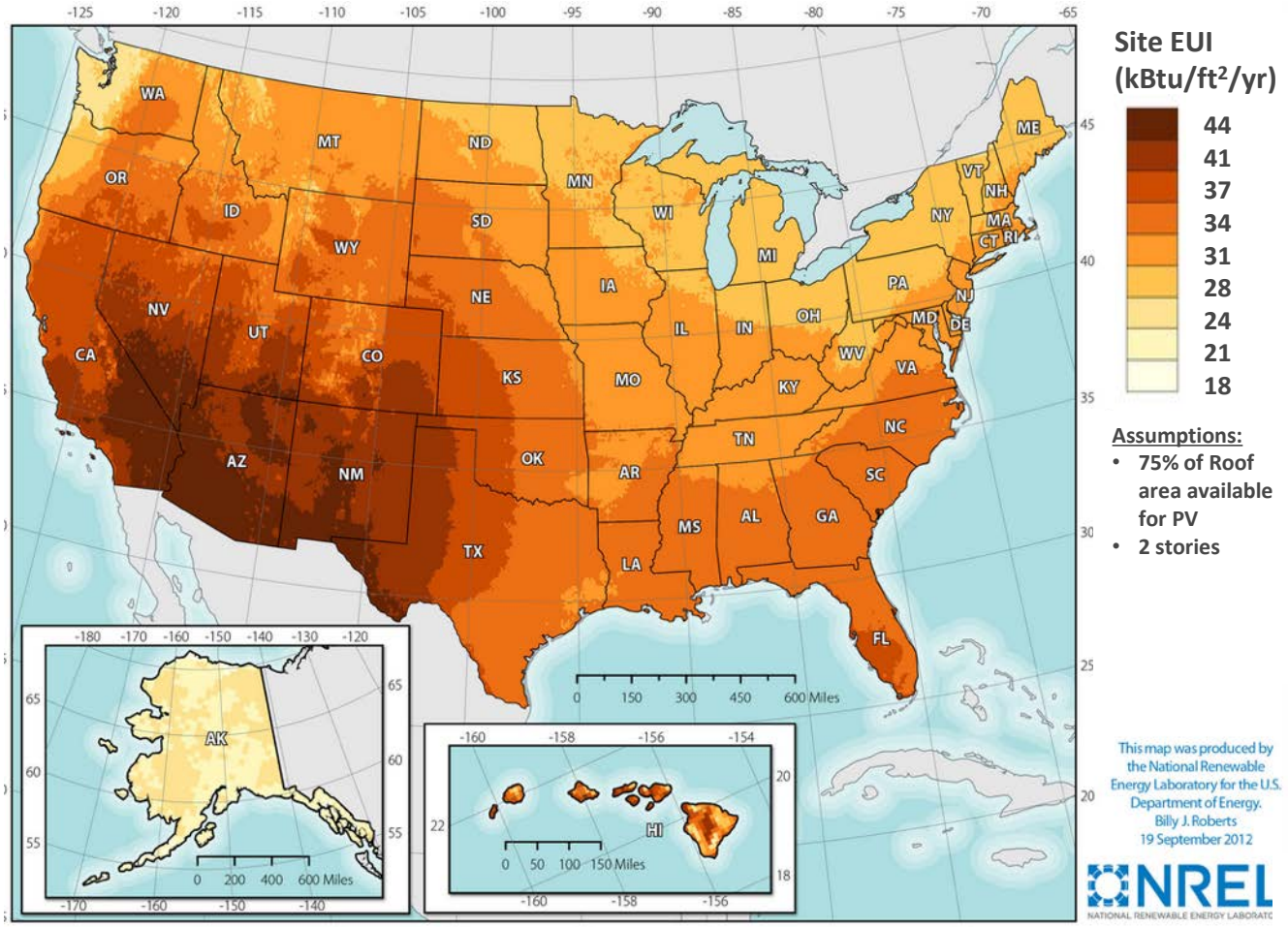
Examples

- Datacenter – Is it in or out?
- Insulation, radiant tubing, and air based systems
  - Worked with subcontractors, vendors, manufacturers
- Domestic hot water
- Creating scale—the façade treatment
- Think about what scaling can be done to overcome barriers

Goals for this effort

- Criteria specified in NYSERDA RFP
  - Ventilation rates
  - Thermal comfort criteria
- Low Cost and Replication
- Zero Energy and Zero Energy Ready
- 20 kBtu/ft^2 annually
  - 11 kBtu/ft^2 for heating and cooling
  - Note: these are consistent with the K-12 and office goals.
  - www.ashrae.org/aedg

Site energy use intensity targets to meet the available rooftop PV annual energy production (75% roof PV, 2 floors)

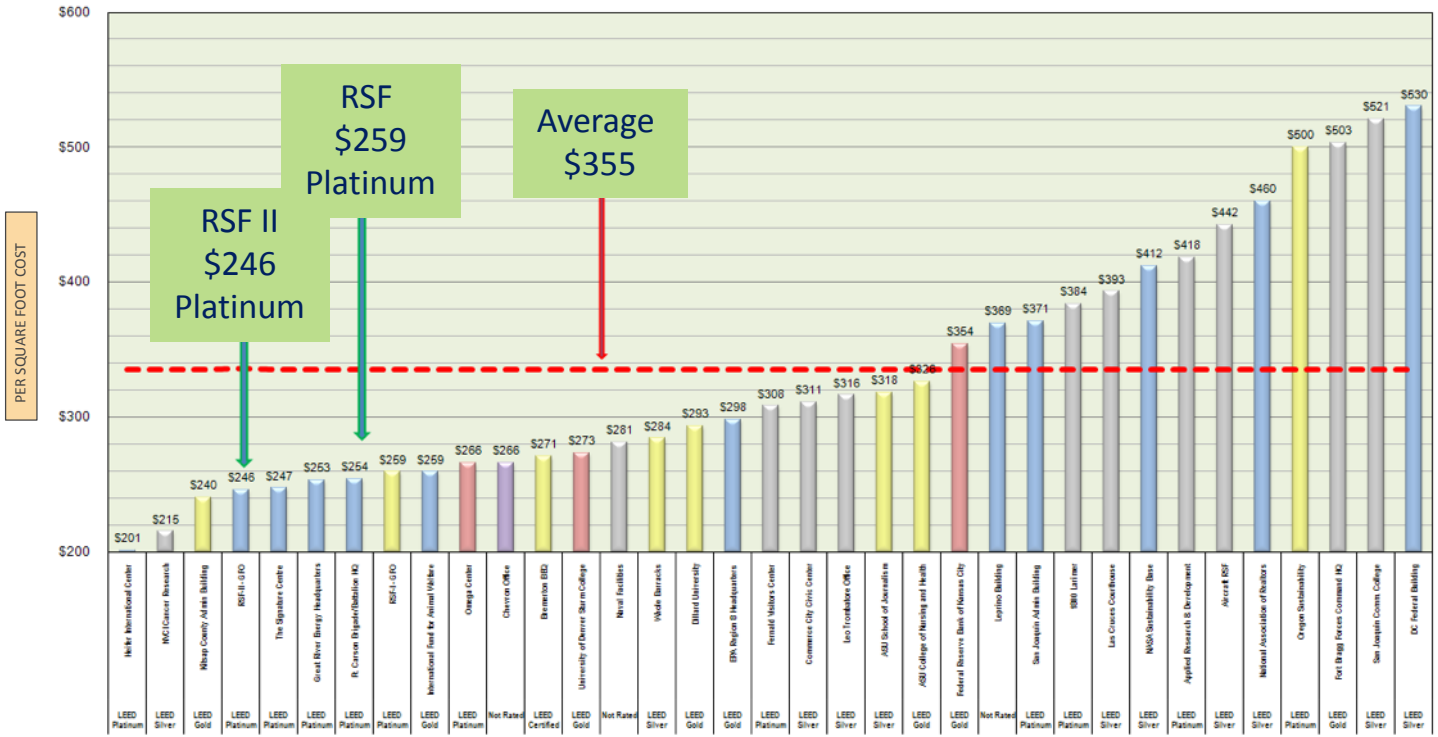


NYC
68 kBtu/ft²/story

Upstate
56 kBtu/ft²/story

4 story
17/14

COMMERCIAL BUILDING CONSTRUCTION COST



LEGEND:

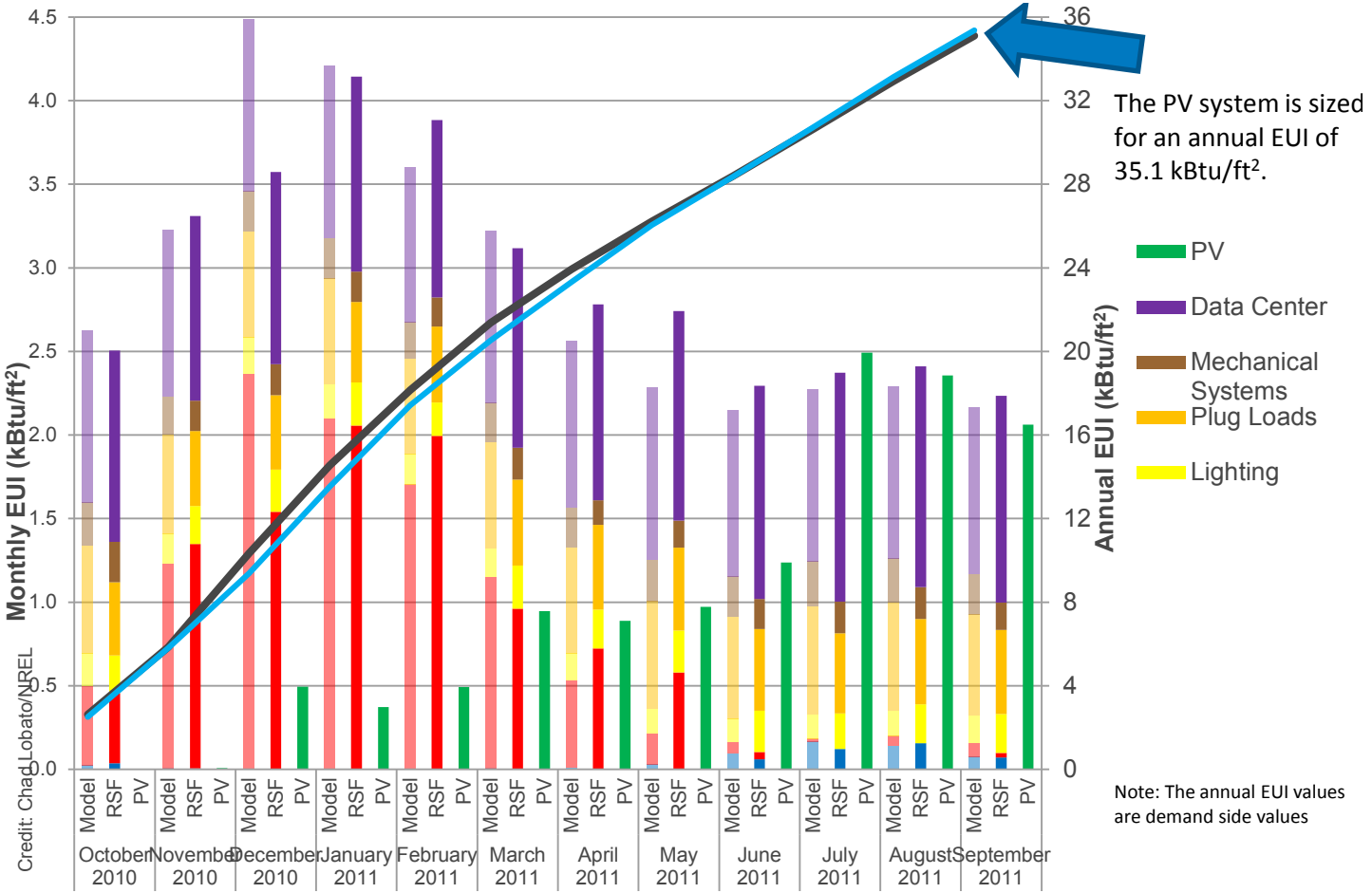
- NOT RATED
- LEED CERTIFIED
- LEED GOLD
- LEED SILVER
- LEED PLATINUM

PROJECTS AND LEED CERTIFICATION

SOURCES:

www.fayobserver.com
www.dbia.com
www.nasa.gov
www.eomega.org
www.oregonsustainabilitycenter.org
www.americas.rlb.com
http://greensource.construction.com
www.1800larimer.com
www.usgbc.org
www.smithgroup.com
www.cronkite.asu.edu

Measured Versus Modeled Monthly and Cumulative EUI

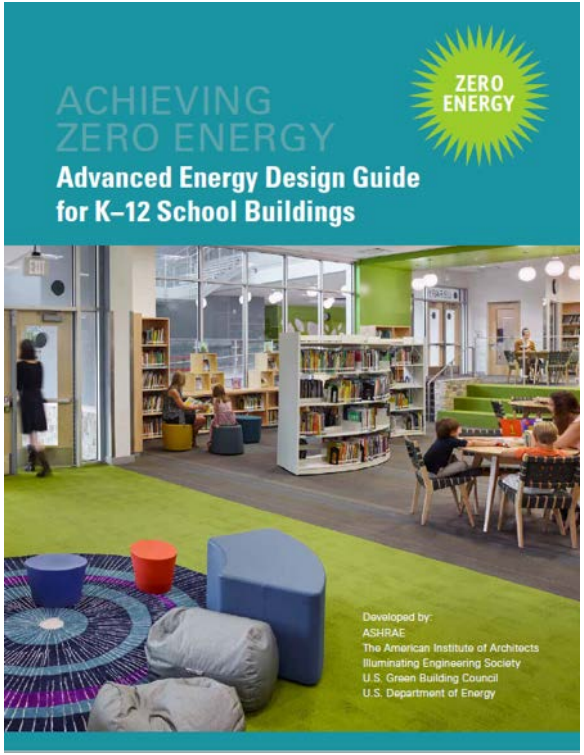


The PV system is sized for an annual EUI of 35.1 kBtu/ft^2.

Note: The annual EUI values are demand side values

Advanced Energy Design Guidance

- K-12 Publication Date: January 2018
- Office Guide
  - 60% draft for peer review September 2018
  - Publication June 2019
- Multi-family underway



Credit: Advanced Energy Design Guide for K-12 School Buildings- Achieving Zero Energy (2018)

Pathway

- ✓ Set energy goal
- ✓ Reduce plug loads
- ✓ Reduce lighting loads
  - Daylighting: massing, orientation, amount of glazing
  - Daylighting only works if you can reduce the electric lighting load
  - Low LPD for lighting + lighting controls
- ✓ Thermal and water envelope
  - Tight and tested 0.10 cfm/ft^2 at 75 Pa
  - View glass is important! (but it is quadrant 2)
  - Frames are the weak point
  - Natural ventilation
- ✓ HVAC system type-selection and sizing

Key Questions

- *What to look for: Where is the cutting edge of the technology?*
- *How do you scale up the technology?*
- *What are the strategies (bulk purchase, etc.) for managing cost?*

Façade and Windows

Photo credit: Karla Butterfield/Steven Winter Associates

What is achievable that is cost effective?

Factory Built, Modular Apartment -in-the-Loop Integration Research Platform

Photo credit: Brice Leconte/iUnit

Shanti Pless, Ron Judkoff NREL Commercial Buildings
Brice Leconte, Developer and www.iUnit.co founder
January 2017

NREL and iUnit: Leading the Design for Net Zero Multifamily Construction

NREL is collaborating with Denver developer iUNIT, using the Energy Systems Integration Facility's apartment-in-the-loop research capabilities and energy modeling tools to lead the design, demonstration, and integration of net zero, grid-friendly, and technology-integrated multifamily construction.

iUnit Brings 380-Square-Foot Modular Apartment to the ESIF to Evaluate Advanced, Multifamily Construction

Roughly 38 million people in the United States live in buildings that contain five or more units, totaling almost 18.5 million households. Increasing energy efficiency in America's multifamily apartment buildings, however,

The report calls for a global effort to modernize and upgrade the construction industry across seven broad areas:

- Reshape regulation and raise transparency
- Rewire the contractual framework
- Rethink design and engineering processes
- Improve procurement and supply-chain management
- Improve on-site execution
- Infuse digital technology, new materials, and advanced automation
- Reskill the workforce

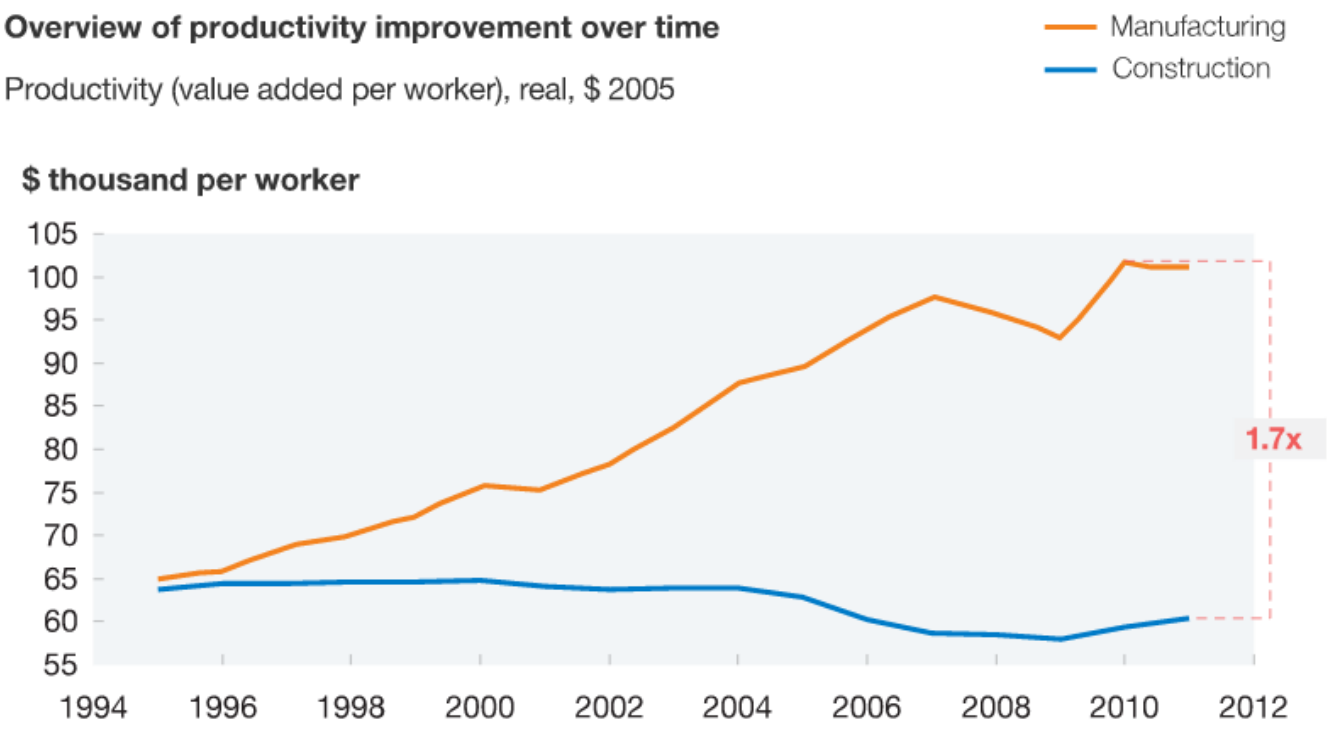
"Parts of the industry could move toward a manufacturing-inspired mass-production system, in which the bulk of a construction project is built from prefabricated standardized components off-site in a factory. Adoption of this approach has been limited thus far, although it's increasing. Examples of firms that are moving in this direction suggest that a productivity boost of five to ten times is possible."

http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution

Productivity in manufacturing has nearly doubled, whereas in construction it has remained flat.

Overview of productivity improvement over time

Productivity (value added per worker), real, $ 2005



Source: Expert interviews; IHS Global Insight (Belgium, France, Germany, Italy, Spain, United Kingdom, United States); World Input-Output Database

McKinsey&Company

TERNER CENTER FOR HOUSING INNOVATION
UC BERKELEY

SEARCH

ABOUT THE CENTER

WHO WE ARE

BUILDING AFFORDABILITY BY BUILDING AFFORDABLY: THE CASE FOR OFF-SITE MULTIFAMILY CONSTRUCTION

POSTED ON MARCH 07, 2017 BY CAROL GALANTE AND SARA DRAPER-ZIVETZ
FILED UNDER: INCREASING THE SUPPLY OF HOUSING,

To remain relevant and successful over time, every industry must modernize and adapt to changing demand
industry is no excep
and revolutions in bu
face rapidly changing
advances, and an ev
timelier than ever.

How will the housing
from McKinsey & Co
better said, overdue,
construction have ha
increasingly costly d
production of housin
produce it demands
cost of construction
certainly a major factor.

"Off-site construction of housing, which leverages the efficiencies of factory production to achieve significant cost savings, represents a much needed solution to this problem. It has the potential to revolutionize the way homes and apartments are built."

"Inefficiencies in traditional construction have hampered productivity and driven costs up for decades, resulting in increasingly costly development. Today, in many regions in the United States, the production of housing - especially infill multifamily housing – has become so costly to produce it demands rents or sale prices that are unaffordable for most people."

http://ternercenter.berkeley.edu/uploads/offsite_construction.pdf

Pre Fab is catching on…

Forbes | Business | #GettingBuzz

The Rise Of The Prefabricated Building

Bisnow, CONTRIBUTOR
Aug 2, 2017 9:52 AM 2,971

POST WRITTEN BY
Julia Bunch

Developers, general contractors and subcontractors swap stories that sound too good to be true about prefabricated construction: a student housing project that cut its delivery time by a third or a hospital that installed hundreds of bathrooms in three days with only five laborers. Though the practice of off-site construction dates back thousands of years, the last real estate cycle has pushed prefabricated construction to prominence.

"No one would question how we build cars today. It would be comical to have all the parts delivered to your driveway with a dozen workers to build it,"

"Yet we build our homes, schools and offices in this inefficient and wasteful manner every day."

https://www.forbes.com/sites/bisnow/2017/08/02/the-rise-of-the-prefabricated-building/amp/

Energy-Efficient Prefabricated Housing

Photo credit: Brice Leconte/iUnit

iUnit Denver Delivery

Eliot Flats, Denver

NREL/48961

Photo credit: Brice Leconte/iUnit

iUnit Interior

NREL iUnit

Photo credit: Brice Leconte/iUnit

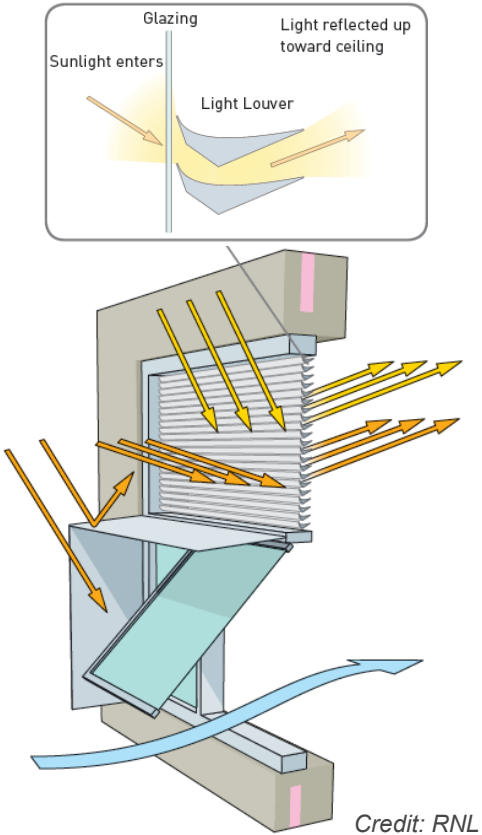
NREL/16763

NREL/17833

Window Design

A light redirecting device reflects sunlight to the ceiling, creating an indirect lighting effect.

Fixed sunshades limit excess light and glare.



Credit: RNL

Windows

- Evaluate the SHGC and the U-factor (tradeoff between solar gains and heat transfer
- Consider the tightness of the window system
  - Casement
  - Double hung
  - Sliders (harder to make tight)
- Installation sealing is critical (lots of great windows, poorly installed)

Windows

- Super windows with U-factors less than 0.1
  - Film layers, trip/quad glazing systems, low-E coatings
    - Low-E rejects certain spectrums (your cat won't like it)
    - Noble gases (do leak out)
    - Operable windows
    - Screens (reduce solar gains, if that is important)
- Ability to create volume and price reductions

Key Questions

- *What to look for: Where is the cutting edge of the technology?*
- *How do you scale up the technology?*
- *What are the strategies (bulk purchase, etc.) for managing cost?*
  - *Trade-offs with other systems*
  - *Economies of scale*
  - *Industrialization & automation*

HVAC and Domestic Hot Water (DHW) Systems

Scalable solutions for all-electric retrofits

Resident Cooling Solutions

NREL/23651

NREL/23650

Better HVAC Technologies

- Heat pumps
  - Ducted or ductless
  - Single-zone or multi-zone

NREL/18327

NREL/18328

- Mini-split/ductless mini-split/multi-split/VRF
  - Very high-efficiency up to 42 SEER and 15 HSPF
  - Don’t forget the EER (95F)
- Ground-source heat pump (GSHP)

Heat Pump Water Heaters (HPWH)

- Extract heat from one place to make hot water
- Ideal if you need cooling and dehumidification (multifunction), but cools in the winter

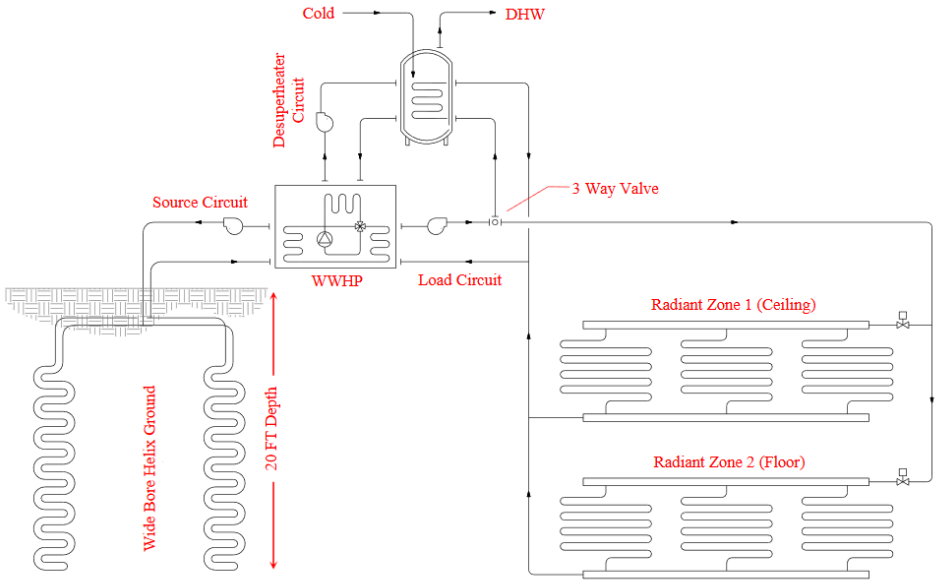
NREL/18671

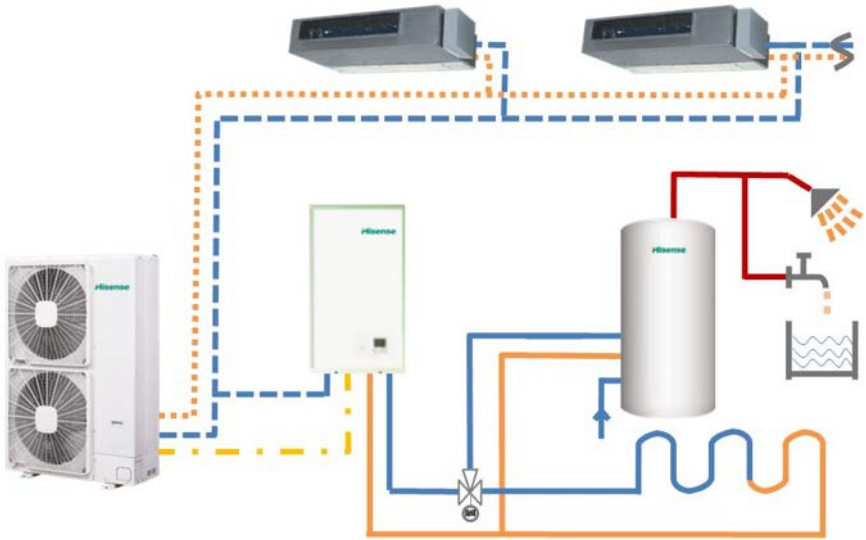
Photo credit: Paul Torcellini/NREL

Small scale multi-function devices

- Heating, cooling, ventilation with heat exchange capabilities
- Small size suitable for an energy efficient dwelling unit
- Example: https://www.minotair.com/minotair-pentacare-v12_us/

Multi-function Heating, Cooling, Water Heating



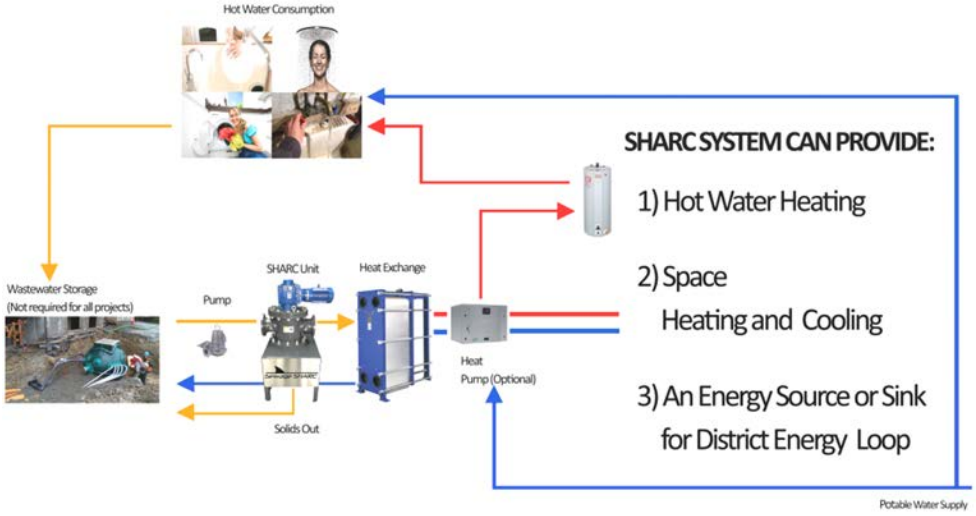


Sewer Energy Recovery

- Heating, air conditioning, water heating
- Applicable for multi-unit residential (400+ units), commercial and district systems
- Energy savings of 30-85%

- Water heating
- Applicable for multi-unit residential (50-200 units), commercial buildings
- 2016 AHR Expo Innovation Award for Green Building Innovation

http://www.sharcenergy.com/what-we-do

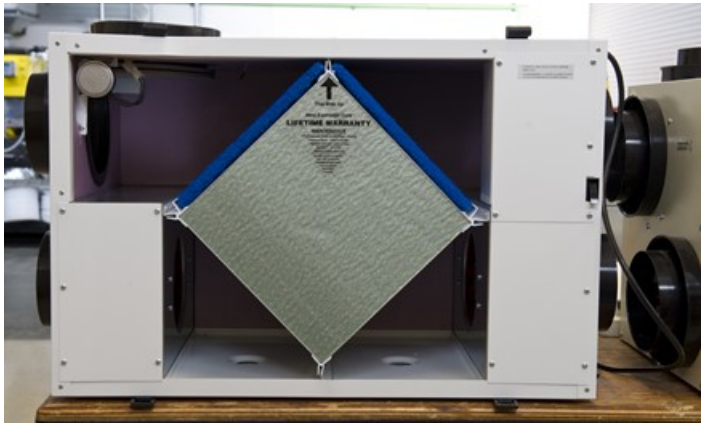


SHARC

PIRANHA

Energy/Heat Recovery Ventilation

- Ducted



NREL/20185

- Ductless

Other Ideas

- Sewer heat recovery
- Equipment with demand response capabilities
- Minimizing ductwork
- All ductwork in thermal envelope
- Insulating and sealing ductwork
- Pipe insulation (first 4 feet on inlet/outlet)
- Variable refrigerant flow and mini-splits
- Ground-source heat pumps
- Thermal zoning (spaces that need minimal conditioning)
- Ability to maintain systems (filters, strainers, equipment swaps, etc.)

Key Questions

- *What to look for: Where is the cutting edge of the technology?*
- *What is the “magic box” that you really want?*
- *How do you scale up the technology?*
- *What are the strategies (bulk purchase, etc.) for managing cost?*

Appliances and Lighting

Low-hanging fruit?

Lighting

- LEDs have come a long way and the technology is rapidly changing
  - Can retrofit into Edison base fixtures
  - Dimming has to be done right
- Efficiency gained with directionality
- Color temperature matters
- Bi-level control
- Fluorescent retrofits

Photo credit: Paul Torcellini/NREL

Photo credit: Paul Torcellini/NREL

Photo credit: Paul Torcellini/NREL

Exterior lighting and common areas

- LED is very directional (which is part of the reason for the efficiency)
- Design the lighting for the space
- Put the Lighting Power Density on the plans
  - Target less than 0.5 W/ft^2 for common areas; 0.2 W/ft^2 for hallways
- Vacancy-sensor based controls (vs. motion sensor)

Appliances

EPA most efficient appliance list for 2018

Bulk purchase across RxNY program?

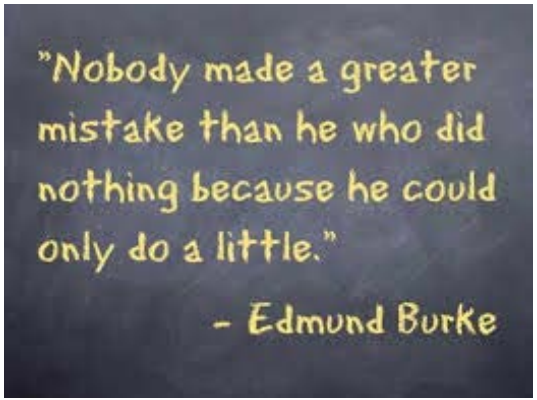
In particular, there's no reason not to replace dated **refrigerators** and **washing machines**.

Also consider:

- Ventless dryers
- Clothes lines
- Smart appliances: Responding to grid signals?

NREL/48439

Miscellaneous Electric Loads / Plug loads



- Reducing the plug, lighting, and appliance loads will reduce the cooling loads
  - Computers should be Energy Star and on energy-efficient settings
  - Home entertainment center (TV and peripherals) should have some type of load management (either via advanced power strips, or built-in smart TV capabilities, etc.)
- Pay attention to Xboxes, gaming computers, aquariums, reptile heaters, etc.
- Metering plug loads—rewarding tenants that meet plug load goals?

Other ideas

- Capitalize on IoT devices
- Regenerative elevators
- Minimize elevator usage (**attractive stairs**, slower elevators)
- Low-light security cameras (and then less night lighting)
- Filtered water systems (rather than bottle water systems)
- Minimize vending machines (and required Energy Star units)
- Thermostatically controlled ceiling fans

Key Questions

- *What to look for: Where is the cutting edge of the technology?*
- *How do you scale up the technology?*
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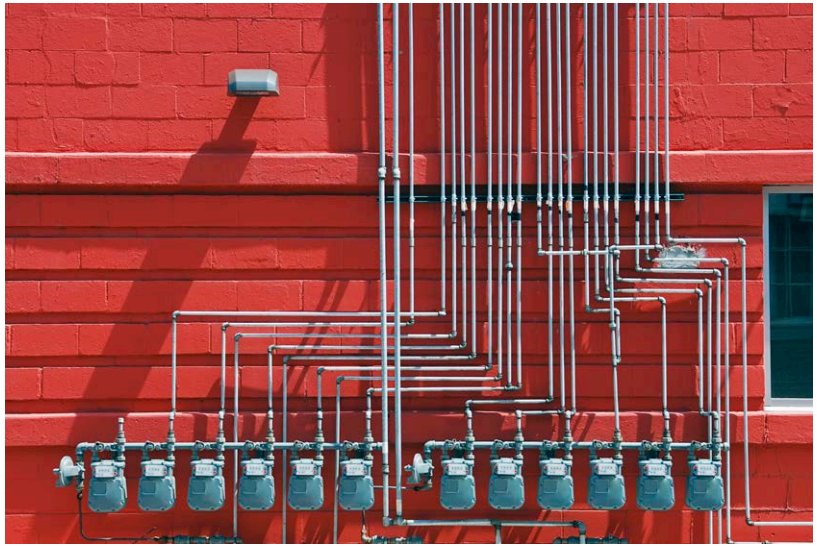
PV and Metering

Important questions for optimization

Current Multifamily Metering Barriers…



iStock/174637491

iStock/470985289

Example: Factory-Built Apartment-in-the-Loop Metering considerations

Individual apartment utility metering

- Residential rate with high fixed meter charge
  - Blended rate up to $0.16/kWh
- Limits large PV systems on Multifamily buildings
  - Need to tie small PV system into each apartment meter
- Expensive hardware and install
  - Up to $1000/apartment
- Split incentive
  - Owner doesn't pay bill
  - Tenant doesn't control building design

Move to Single Building Utility Meter

- Single commercial building rate
  - $0.04/kWh, and $20/ peak kW
  - Software metered at $60/apartment
  - Allows for large PV install
- Software feedback to tenant to overcome split incentive
- Develop "effective" real time rate to apply to each unit in software
  - Provide real time feedback
  - Provide $ energy budget of solar provided energy
  - Pay additional bill if over energy budget, bank if under
- Investigating application of behavior change of "Bill Avoidance" and monthly solar budgets
- Investigate "Tenant in the loop" solutions vs hardware control solutions

Metering

- Establish a metering plan
- Verify the energy goals
- Low-cost metering solutions
- Stand alone servers with multiple channels
- Dashboards for occupants?

What do you plan on accomplishing with metering?

Photovoltaic Systems

- “Best” orientation is latitude facing south based on the maximum power output for a fixed panel—HOWEVER,
- PV is so cheap—
  - Mounting Structure is a major cost. Wind loading, etc.
    - Flat roofs: ballasted system with minimal penetrations (which causes a thermal bridging issue)
    - East/West panels have an advantage on smoothing out the daily load (rather than a high noon peak)

Photo credit: Advanced Energy Design Guide for K-12 School Buildings- Achieving Zero Energy (2018)

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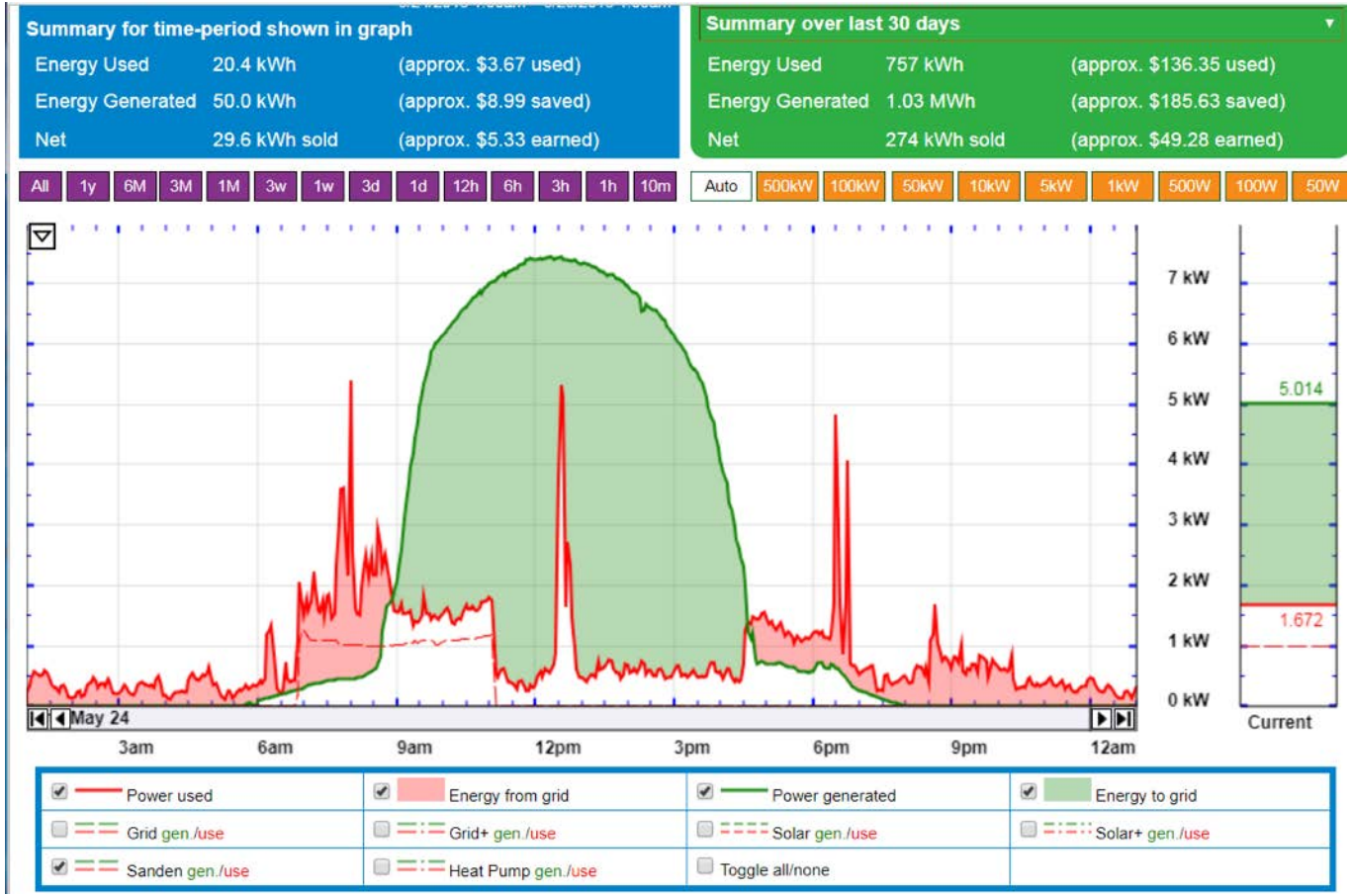


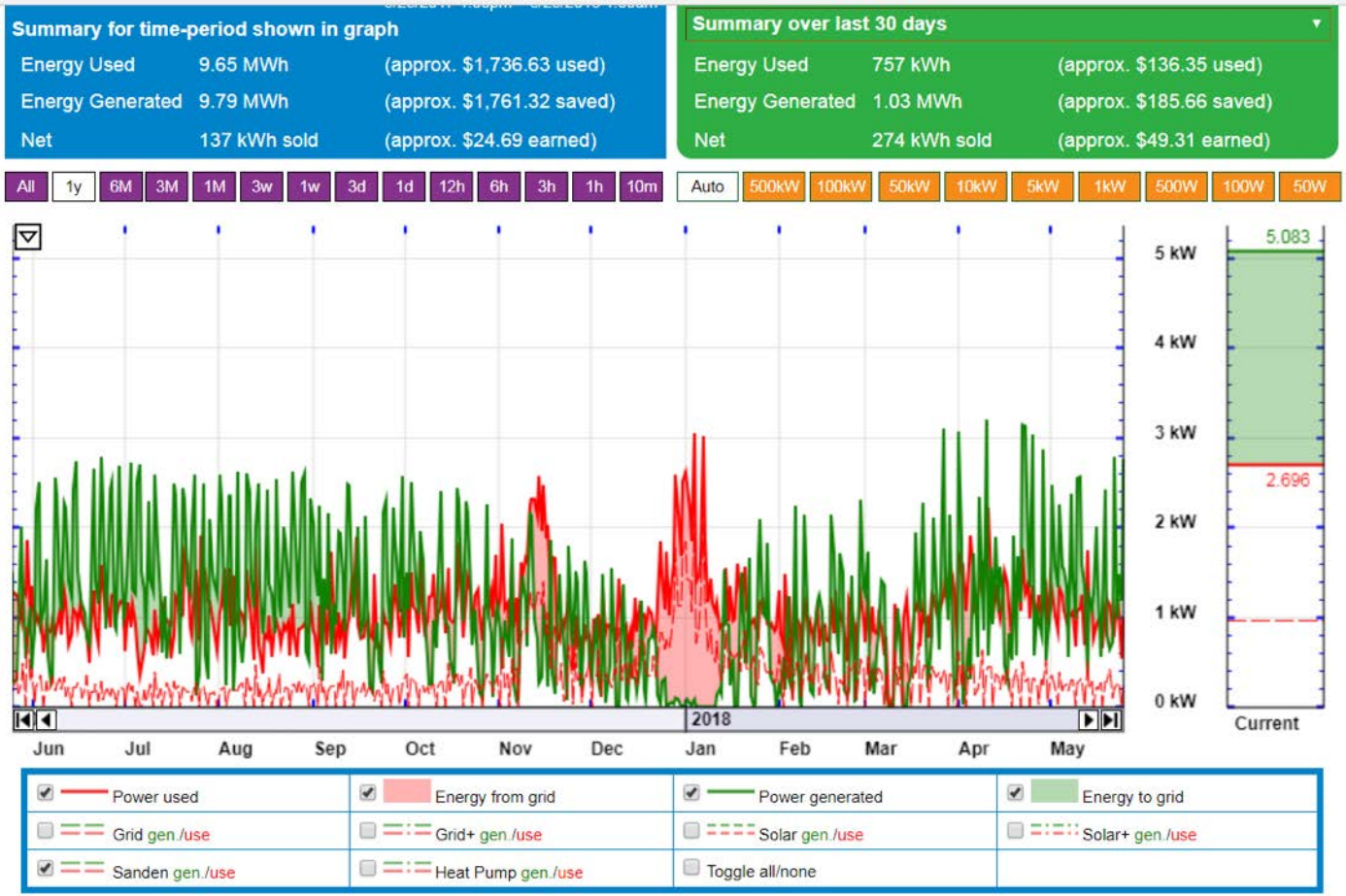
Credit: Paul Torcellinii/NREL

Photovoltaic Systems

- Can add to facades, parking areas, etc.
- In reality, the maximum area that “belongs” to the building is the site footprint.
  - If you cover a façade on a tall building, then that “resource” is taken from another building—or think of it as someone else shading your PV array
- Size estimation: pvwatts.nrel.gov
  - Warning: tends to slightly over-estimate
  - Does not account for snow cover
  - A PV system should generate at least 1.1 kWh/Wdc installed

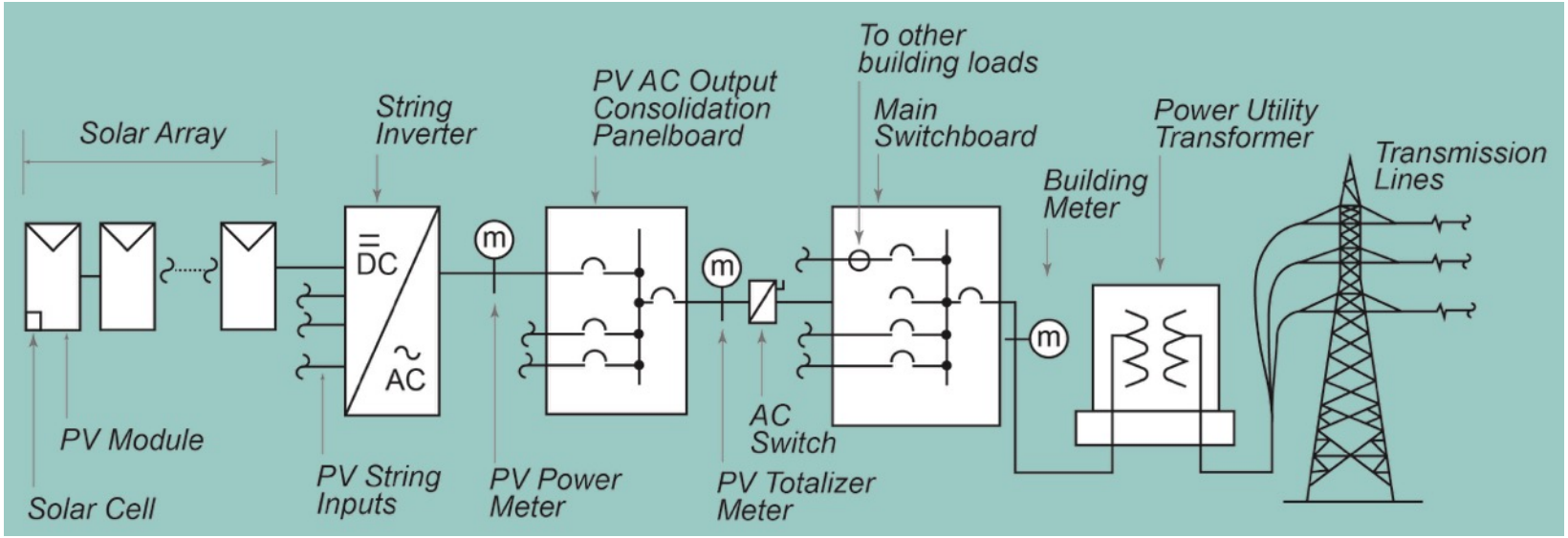
Photovoltaic Systems

- Needs a structural analysis
  - Can the weight support the PV system including the wind loading (if adding a “sail” to the building)?
  - Example:
    - Built up roof could not support structurally a PV system
    - Replace roof at 90% of useful life with EDPM membrane
    - Created enough weight capacity to add PV system and added appropriate amount of insulation



Credit: Paul Torcellinii/NREL

PV Interconnections



Credit: Advanced Energy Design Guide for K-12 School Buildings- Achieving Zero Energy (2018)

Key Questions

- *What to look for: Where is the cutting edge of the technology?*
- *How do you scale up the technology?*
- *What are the strategies (bulk purchase, etc.) for managing cost?*
- *What key information/data are crucial to inform future retrofit projects?*

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Thank you

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