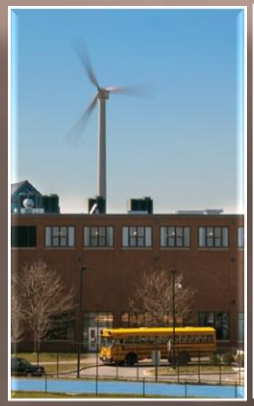
INTEGRATING RENEWABLE ENERGY SYSTEMS IN BUILDINGS

Sheila J. Hayter, PE, FASHRAE

National Renewable Energy Laboratory

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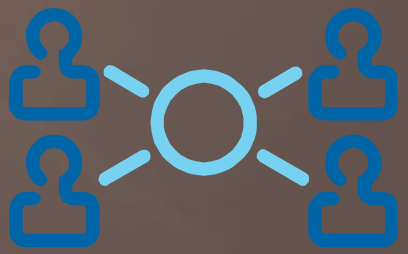

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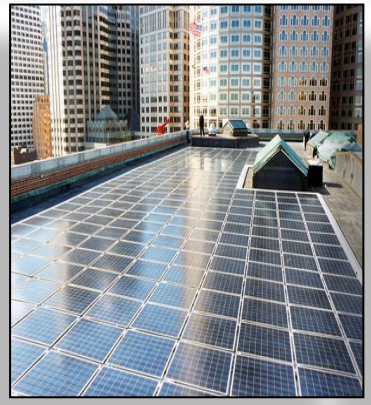
PRESENTATION OVERVIEW




Why Use Renewable Energy in Buildings?

Invest in Energy Efficiency First

What Renewable Energy Resources and Technologies Are Available?

Connecting to the Electrical Grid

Where to Start

How to Implement the Project

Solar Project Overview

Q and A

WHY INTEGRATE RE SYSTEMS IN BUILDINGS?

- Buildings account for 40% of worldwide annual energy consumption
  - in U.S., ~18% commercial and ~21% residential
- Most of world energy consumption is from fossil fuels
- 75% to 80% of the buildings that will exist in 2030 already exist today
- National and local energy policy moving towards requiring clean energy solutions

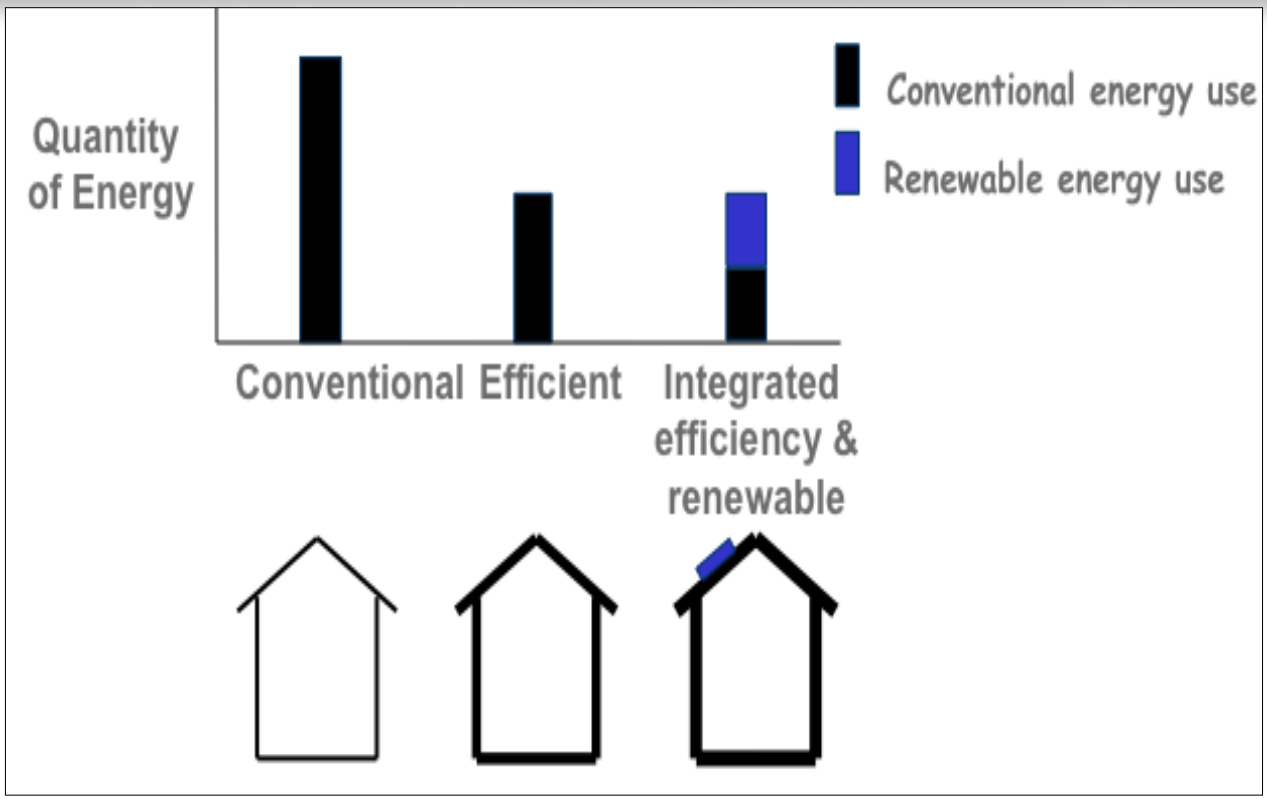
Total global energy consumption in 2007 was 495 quadrillion British thermal units (Btu),

Buildings account for approximately 40% of the worldwide annual energy consumption (WBCSD 2009). meaning the buildings sector consumed about 198 quadrillion Btu.

According to the Energy Information Agency, worldwide energy consumption is expected to increase 1.4% per year through 2035, implying that buildings will consume 296 quadrillion Btu by the year 2035 (EIA 2010).

INVEST IN ENERGY EFFICIENCY FIRST

Efficiency costs about half of the renewable energy generating capacity installed cost for equivalent offset.



INVEST IN ENERGY EFFICIENCY FIRST

Reduce energy loads through:

- Efficient building envelope
- Building orientation
- Renewable energy (architectural):
  - Daylighting
  - Passive solar heating
  - Cooling load avoidance

Meet remaining loads with:

- Efficient HVAC & lighting equipment
- Efficient systems control strategies
- Renewable energy (building equipment):
  - Solar thermal: water heating, transpired collectors
  - Solar electric: photovoltaics, wind
  - Geothermal heat pumps

- Energy savings = $$$ savings
- Applicable to many operations
- Often short payback
- Non-energy benefits include:
  - Water savings
  - Reduced O & M costs
- $1 invested in energy efficiency saves at least $2 in renewable energy

INTEGRATING RENEWABLE ENERGY SYSTEMS IN HISTORIC BUILDINGS

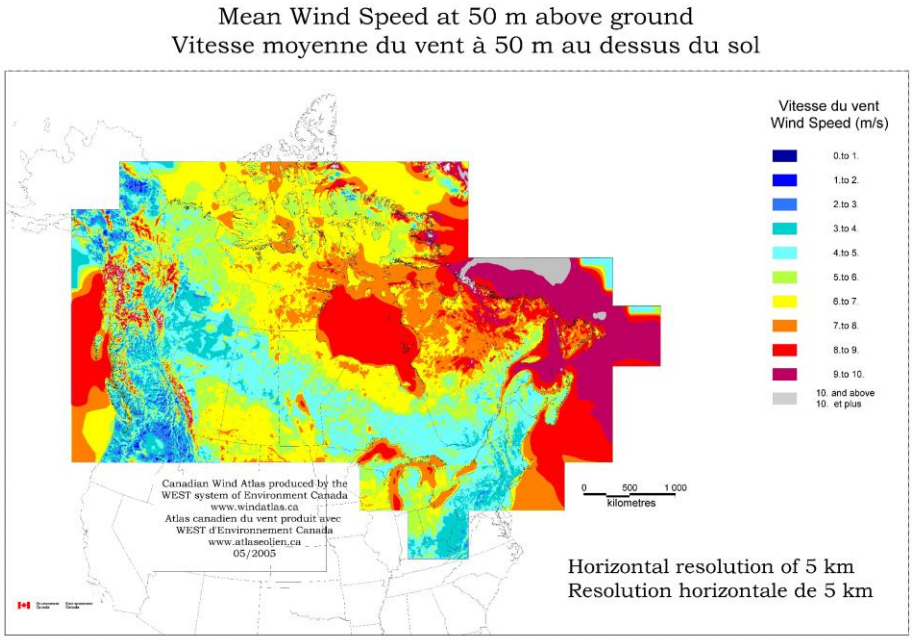
- Proper planning helps avoid compromising architectural and structural integrity of installing renewable energy systems on or near historic buildings.
- Understand applicable regulations of historic preservation entities having jurisdiction over the building project.
- Rehabilitate existing energy efficiency measures first.
- Incorporate renewable energy installation carefully.

WHAT RENEWABLE ENERGY TECHNOLOGIES ARE AVAILABLE FOR BUILDINGS APPLICATIONS?

- Solar
- Wind
- Geothermal
- Biomass
- And others (including)
  - Hydroelectricity
  - Ocean Power

RENEWABLE ENERGY RESOURCE ASSESSMENTS

Determine appropriate resource availability for solar, wind, biomass, and geothermal technologies.



Canadian Wind Energy Atlas (Environment Canada)

PHOTOVOLTAIC (SOLAR ELECTRIC) SYSTEMS

- Converts sunlight to electricity
- Different cell types meets various design challenges
- Locate unshaded location for installing PV array
  - Building roof (flush or tilt-mounted)
  - Ground (pole-mounted)
  - Integrated into building materials
- Orientate PV array due south preferred
- Tilt array to maximize energy production
- Analyze building electrical load profile
- Address grid-connection issues

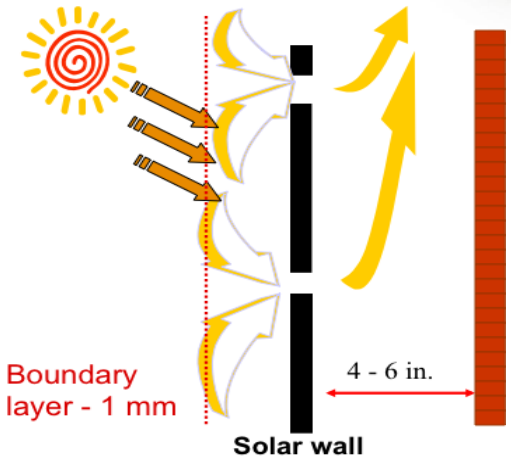
UTILITY-CONNECTED, BUILDING-INTRGRATED PHOTOVOLTAICS – example

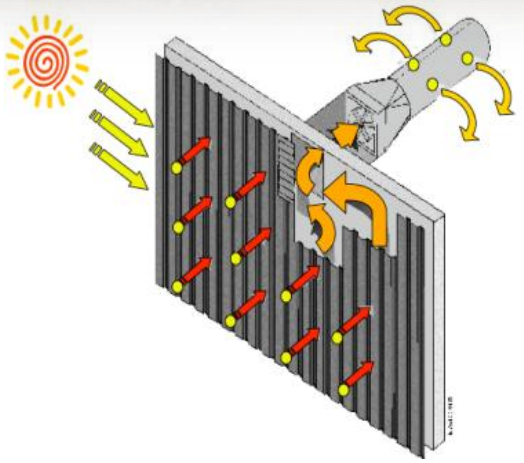
Presidio Thoreau Center

- Building-Integrated Photovoltaics
- 1.25 kW PV Array
- Spacing between cells admits daylight into entry atrium below.

SOLAR VENTILATION PREHEATING SYSTEMS

- Low-cost, low maintenance, high efficiency (up to 80%)
- Best suited for applications having
  - High volumes of ventilation air required
  - Relatively high utility rates for heating
  - Relatively long heating seasons
  - Large south-facing wall surface area
- Can be added to existing building or part of new construction





SOLAR THERMAL SYSTEMS – SOLAR HOT WATER



- Reliable and low maintenance
- Components are: collectors, heat transfer systems (including heat exchanger), pumps, storage, controls
- Solar thermal collector types typically used for buildings
  - Low-temperature (unglazed collectors)
  - Mid-temperature (flat-plate collectors)
  - High-temperature (evacuated tube collectors)
- Guideline for PV apply to solar thermal systems

Photovoltaic Ground-Mounted Systems

Dangling Rope Marina, Glen Canyon National Recreation Area, UT

Arizona Public Service, Prescott, AZ

Alamosa PV System, Alamosa, CO

5 – 10 acres per MW for PV systems

Land can be left as is or graded

CONCENTRATING SOLAR PV SYSTEMS

Reflective

Refractive

Reflective + optical rod

- Concentrators can only use direct radiation from the sun
- Drop CSP from consideration if the site is not in the southwest

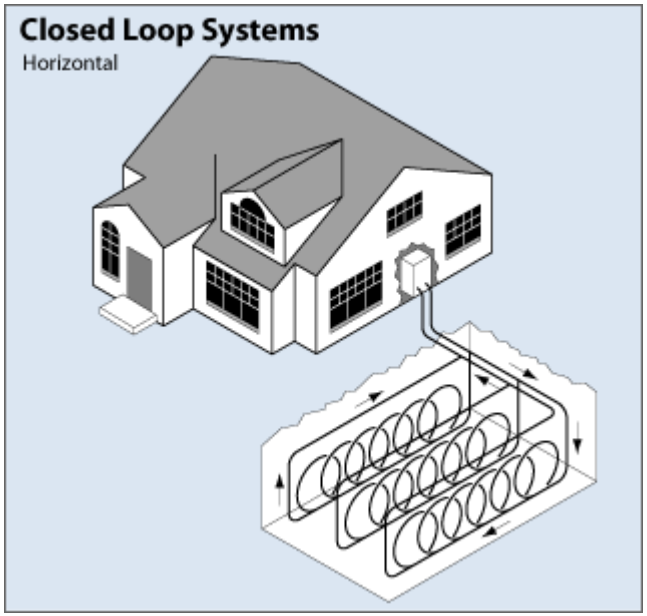
WIND

- **Needs specific resource**
  - Site much have an appropriate wind resource and few obstructions
- Site near facility to provide power directly to building
  - Land area required to install turbines
  - Best if can be sited 150-200m (500-650ft) from any occupied facility
- 20-year operating life for most turbines, little maintenance required
- For roof-mounted turbines, carefully consider issues such as noise, structural integrity and added cost

GEOTHERMAL

Geothermal Heat Pumps

- Most common geothermal applications for buildings
  - Shallow ground (upper 3m of earth's surface) maintains nearly constant temperature of 10°-16°C.
- Affective in mixed climates – can heat/cool buildings and supply buildings with hot water
- System components – heat pump, air delivery system, heat exchanger (buried pipes)
- Four types – horizontal, vertical, pond/lake, and open loop
- Challenges
  - For retrofit projects, tying the system to existing building HVAC system



Geothermal Direct Heat

- Needs specific resource
- Available resource is less common - typically in the western North America
- Best for buildings with heating loads due to climate or process needs
- Can be a cost-effective and consistent energy source

BIOMASS

- If there is a permanent, steady stream of biomass resource within a 80-km radius, consider this resource further.
- Consult a local expert if resource maps reveal limited or no biomass resources for the site
- Especially good for Combined Heat and Power needs

BIOENERGY

- Types of biomass
  - Organic matter (plants, residues from agriculture, forestry)
  - Organic components of municipal and industrial wastes
- Biomass technology breaks down organic matter to release stored energy
  - Process used to break down biomass depends on type of biomass and the intended end use
- Biomass can heat buildings and produce electricity.

CONNECTING TO THE ELECTRICAL GRID

- Grid-tied, distributed generation (DG) systems – building-sited renewable energy systems generating electricity and connected to the electrical utility grid
- Net metering – allows for the flow of electricity from grid-connected DG systems to/from customer through a single, bi-directional meter
- Interconnection standards specify technical and procedural process for connecting a DG system to the grid
- Electrical utility acceptance of DG systems varies widely

WHERE TO START

- Define your goals and objectives for energy efficiency and renewable energy use
  - Reduce peak demand, save money, make money, provide a good example, etc.
- Do an energy audit
  - Understand how the building uses energy and how to reduce total energy consumption
- Enlist help
  - Within your organization, private firms, utility, etc.
- Begin to assess potential for renewable technologies

PROJECT ENERGY TARGETS ARE ESSENTIAL

- Energy targets need to be included and given priority within the program, for example:
  - Energy use should be at least 40% below the baseline of energy use for a building at applicable codes
  - Renewable energy usage must account for at least 50% of building energy use
- Better to specify targets for energy use rather than specifying certain technologies
  - Gives design team more flexibility
  - Possible to reach same goals at less cost
- Prioritize energy goals
  - Prioritization now helps ensure renewable energy is not dropped during value engineering

PLAN FOR A RENEWABLE ENERGY PROJECT

What? Narrow options to technologies best suited to your project

When? START EARLY

Why? Decide which options are worth investigating

Who? Can be completed at the organization/building owner level with simple training, often design team conducts screening.

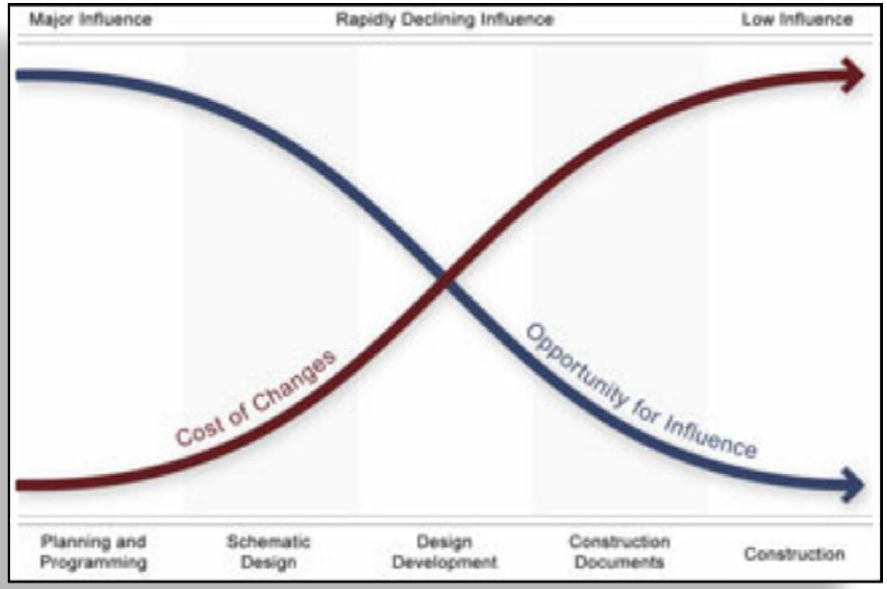
UPFRONT PLANNING

Upfront planning will cost a bit extra, but can lead to long-term savings

- Meet requirements with cheaper, more effective energy solutions

Now is the time to think about renewable energy!

- Considering energy now keeps options open and costs down.
- Selecting sites with renewable energy in mind paves the way.
- Understanding energy use in master planning can open up options.



RE IN BUILDINGS PROJECT CONSIDERATIONS

- Renewable energy resources at or near the building site
  - Canadian solar resource maps - https://glfc.cfsnet.nfis.org/mapserver/pv/index_e.php
  - Canadian Wind Energy Atlas - www.windatlas.ca/en/maps.php
  - Area for siting the renewable energy system
  - Building roofs, parking shade structures, open land
- Characteristics of building's energy profile
  - Simulate building energy consumption and RE system contributions
- Ability to connect to the electrical grid
  - Provincial and local interconnection policies
- Incentives to offset renewable energy system cost
  - Provincial and local RE incentive information
- Cost of purchased electrical and thermal energy
  - Utility bill information
- Local regulations affecting renewable energy systems
- Desire to preserve/not alter existing building architecture

HOW TO IMPLEMENT THE PROJECT

IMPLEMENTATION: POTENTIAL STAKEHOLDERS

- Adjacent property owners
- Technical assistance providers such as equipment vendors
- Public recipients of grants or funding
- Planners
- Contractors
- Engineers
- Property owners
- Federal agencies
- Non-profit preservation and environmental groups
- Local government

IMPLEMENTATION: STAKEHOLDERS, REVIEWS, AND EVALUATIONS

- Engage the right stakeholders at the right times
- Renewable energy installation review process will vary
  - Project size, type, complexity affect review needs
  - Historic sites are subject to applicable regulations
  - Locally applicable environmental protection processes affect renewable energy installation review requirements
- Project design and construction begins after stakeholders are fully engaged
- Evaluating renewable energy project can help increase the rate of success of future projects
  - Review should occur during process and after installation to analyze success of stakeholder coordination
  - Review should consider impacts on policies, neighbors, etc.

SOLAR PROJECT OVERVIEW

Where to install?

How much will it cost?

What guidance is available?

Project examples

WHERE TO INSTALL SOLAR?

- "Built Environment" where unshaded – size to capacity (pipes & wires) and load (kWh & thermal)
- Existing roofs with life expectancy of 15+ years and able to hold added load. (Reduces solar load on building. NEPA categorical exclusion.)
- ALL new buildings. See Solar Ready Buildings Planning Guide: http://www.nrel.gov/docs/fy10osti/46078.pdf
- Over parking areas, pedestrian paths, etc.
- Compromised lands such as landfills & brownfields.
  - Saves green fields for nature.
  - IF installed on green fields, minimize site disturbance and plant native low height vegetation as needed.

SOLAR INSTALLATION GUIDELINES

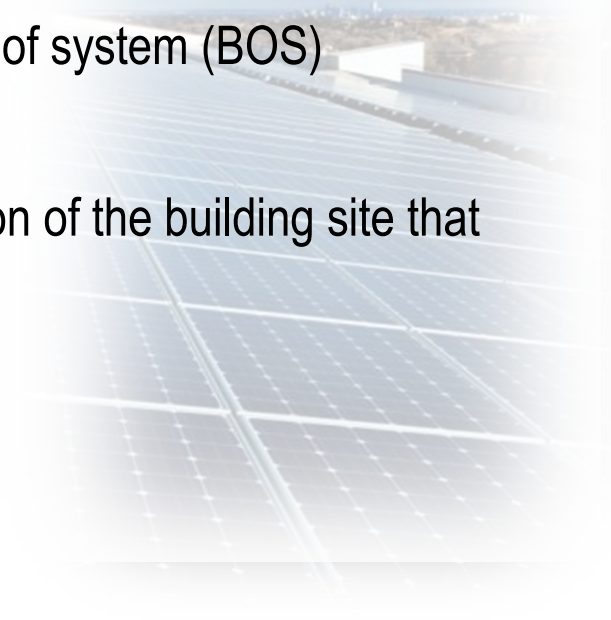
- Avoid shading from trees, buildings, etc. (especially during peak sunlight hours)
- Check the zoning laws for the proposed site to ensure that future, neighboring construction will not cast shade on the array.
- Determine where a future solar array might be placed.
- If the roof is sloped, the south-facing section will optimize the system performance; keep the south-facing section obstruction-free if possible.
- Minimize rooftop equipment to maximize available open area for solar collector placement.

GUIDELINES FOR PV AND SOLAR THERMAL SYSTEMS

- The type of roof installed can greatly affect the cost of installing solar later.
- The roof must be capable of carrying the load of the solar equipment.
  - PV – between 15 and 30 kg/m^2 (3 and 6 lb/ft^2)
  - Solar Thermal – between 10 and 27.5 kg/m^2 (2 and 5.5 lb/ft^2)
- The wind loads on rooftop solar equipment must be analyzed in order to ensure that the roof structure is sufficient.
- If it is going to be a rack mounted system, consider installing the mounting hardware at the time the roof is installed and use flashings for every penetration.
- If the collectors will be placed on the roof, check if the roof installation carries a warranty.
  - Determine if the roof warranty contract has terms involving solar installation.
- Make sure all equipment is in compliance with the current version of the applicable electrical codes.

ADDITIONAL GUIDELINES FOR PV

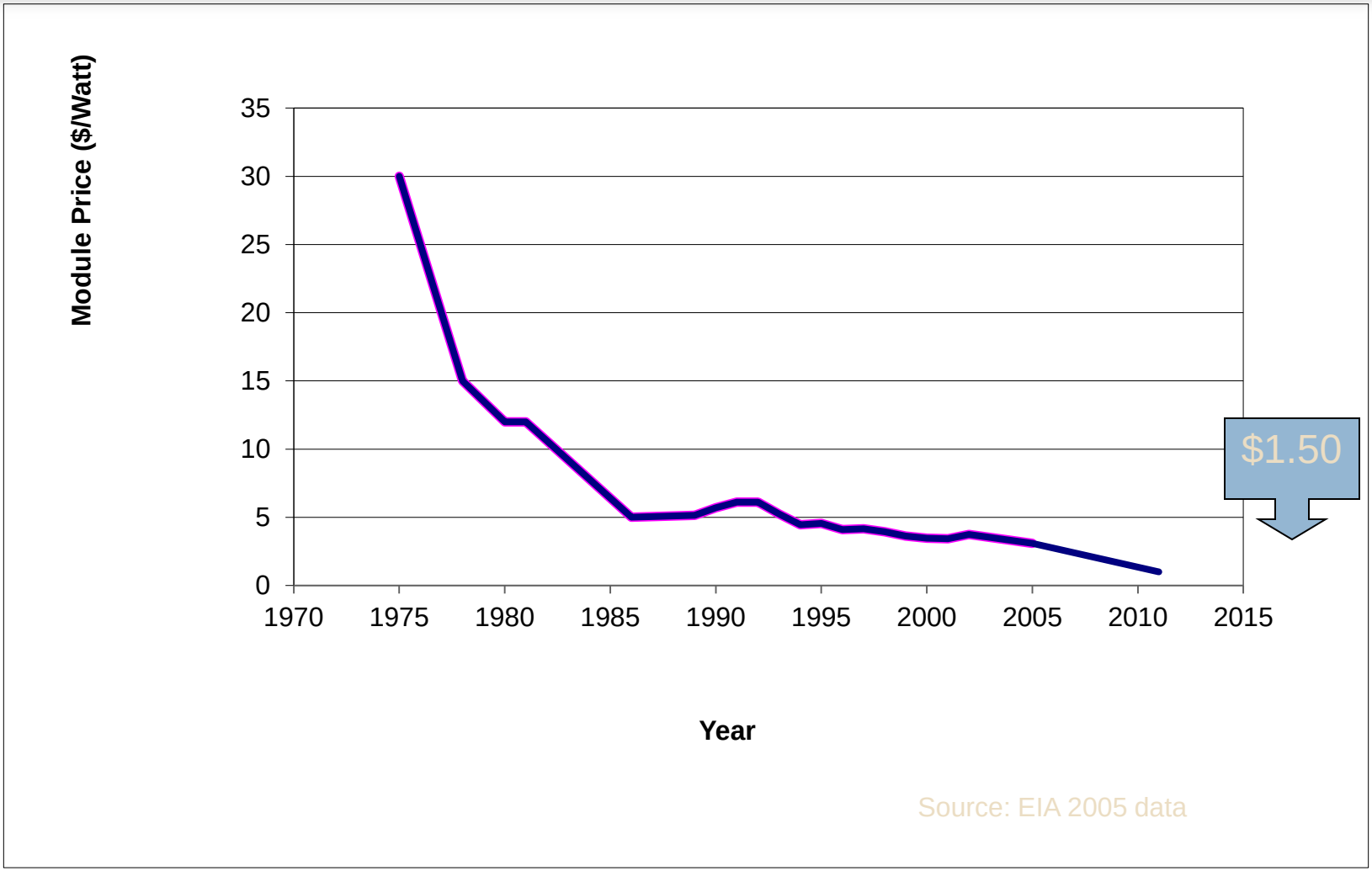
- Identify electrical panel location for PV system inter-connections, and keep space available in the electrical panel for a PV circuit breaker
- Specify panel capacity sufficient to accommodate proposed PV system size power generation plus size of breaker protecting main panel.
    - NEC allows for the sum of these two sources of power to be 20% greater than the panel rating. Consult the local authority having jurisdiction.
- Lay out the locations for the inverter and the balance of system (BOS) components.
- Identify the inter-connection restrictions for the location of the building site that apply to grid-tied PV systems.



COSTS

- Use PERFORMANCE SPECS (kWh/year) not specific manufacturer or kW.
- Provide clear requirements and evaluation criteria
- Costs depend on:
  - Size – bigger is better:
  - Balance of system costs, including structures, inverters, electrical and interconnection.
- Lowest cost is direct roof attachment such as standing seam metal roof – Installed approx. $5/Wdc for 100kW
- Ballasted or racks – add $0.3/W
- Ground mount fixed tilt – add $0.35/W
- Single axis tracking (over 300 kW) – add $0.7/W
- Carports – add $0.6/W
- High efficiency modules (GT 17%) add $0.5 - $1/W

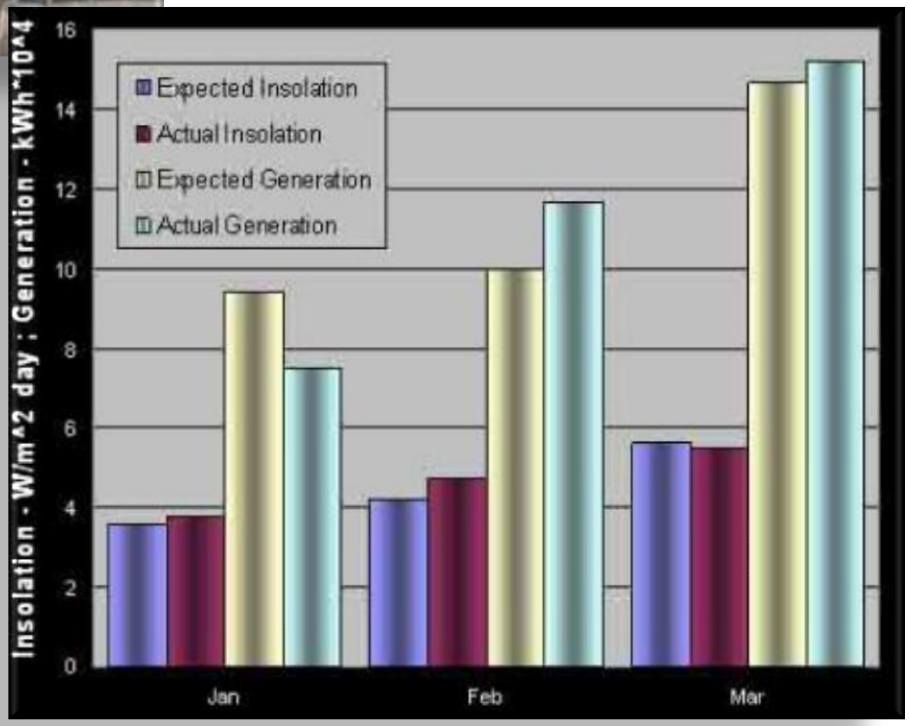
PRICE OF PV MODULES



PV CASE STUDY – GSA DENVER FEDERAL CENTER (DENVER, CO)

1.19 MWdc Fixed-Tilt PV System

- Expected generation: 1,667 MWh/year
- Fixed tilt at 20 degrees
- Requires 6 acres of land
- First cost was $6.9M ($5.8/Watt)
- Incentives: $200K
- REC sales = 1,525 MWh/year,
- $240/MWh for 20 years

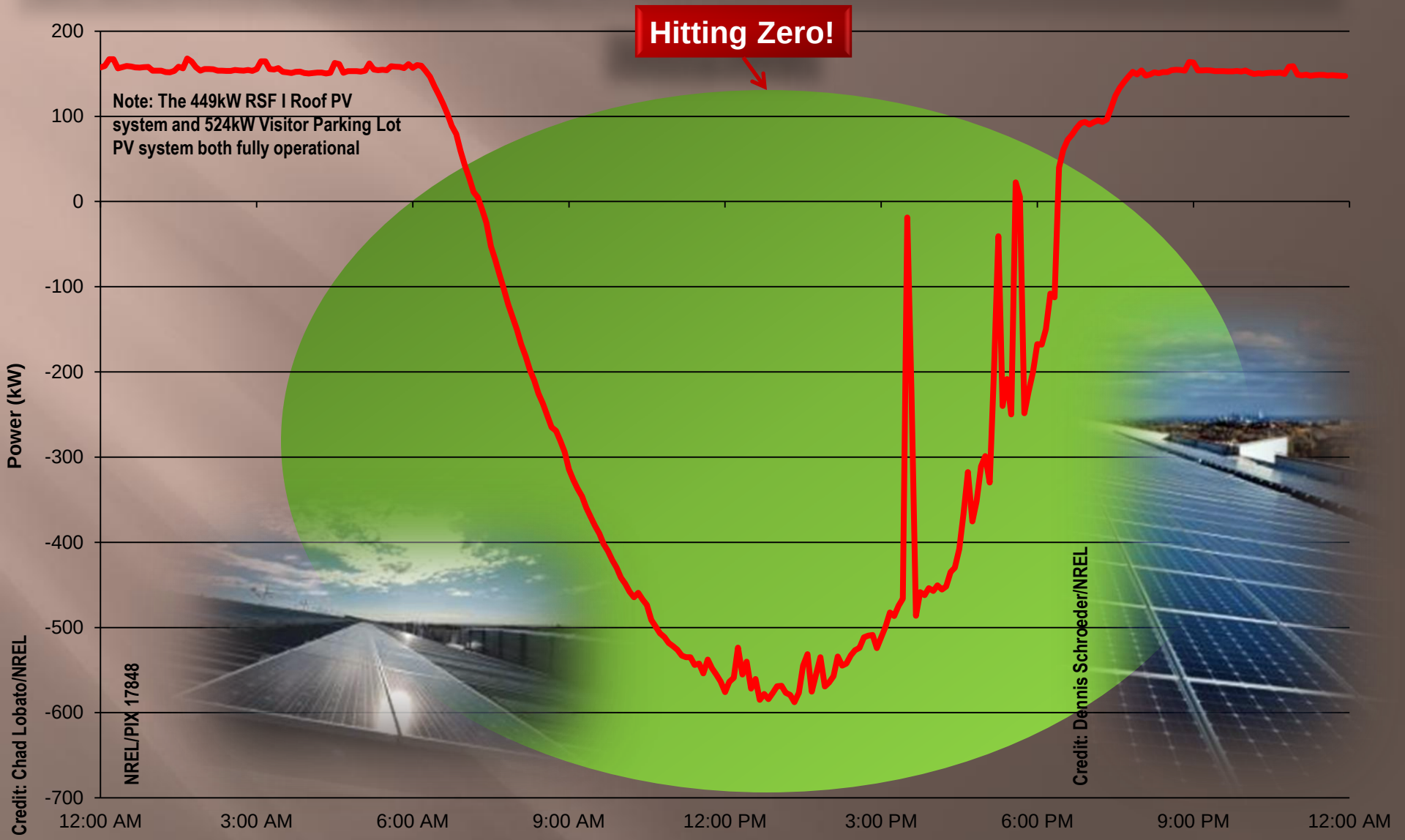


RESEARCH SUPPORT FACILITY (RSF) – A NET ZERO OFFICE BUILDING

PHOTOVOLTAIC SYSTEM

- Power Purchase Agreement (PPA) provides full rooftop array on RSF 1
- Zero energy = building, parking lot and future parking garage arrays (2537 kW)

973-KW ROOF AND SITE MOUNTED PV INSTALLED AND OPERATIONAL JULY 2011



RESOURCES

- General Renewable Energy Topics
  - NREL http://www.nrel.gov/rredc/
  - Whole Building Design Guide www.wbdg.org/resources/
  - Cost estimates for actual RE systems http://www.nrel.gov/analysis/tech_cost_dg.html
  - Building Life-Cycle Cost (BLCC) software http://www1.eere.energy.gov/femp/information/download_blcc.html
- Solar Energy Resources
  - NRC http://atlas.nrcan.gc.ca/site/english/maps/archives/5thedition/environment/climate/mcr4076
  - NREL http://www.nrel.gov/rredc/
  - Firstlook http://firstlook.3tiergroup.com/
- Solar PV Analytical Tools
  - Solar Advisor Model (SAM) https://www.nrel.gov/analysis/sam/
  - HOMER https://analysis.nrel.gov/homer/
  - PVWatts http://www.nrel.gov/rredc/pvwatts/
  - RETScreen http://www.retscreen.net/
  - IMBY http://www.nrel.gov/eis/imby/


Thank You
Sheila.Hayter@nrel.gov
RSF II
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$246/ft2 construction cost