Solar Photovoltaics (PV) Introduction

Big Picture

- Solar PV cells convert sunlight to electricity via the photoelectric effect

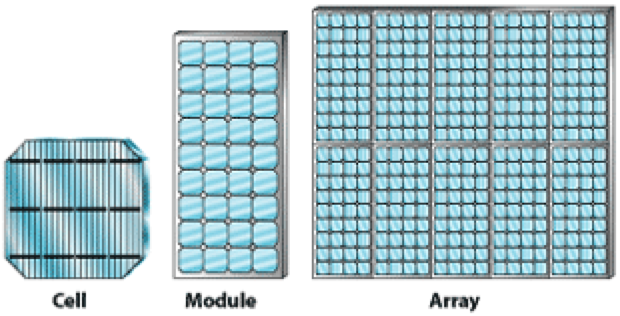
Solar Cell

PV Modules

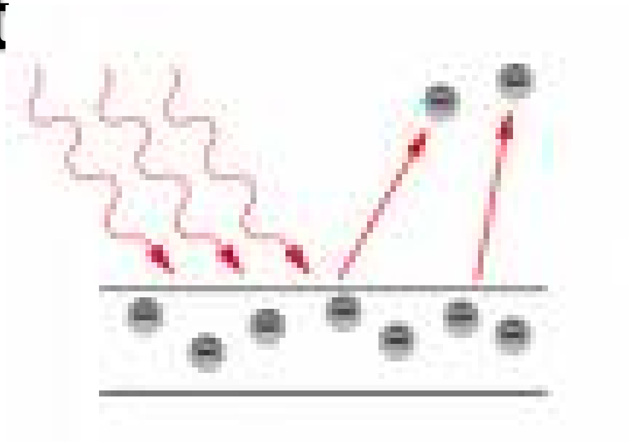
PV Arrays

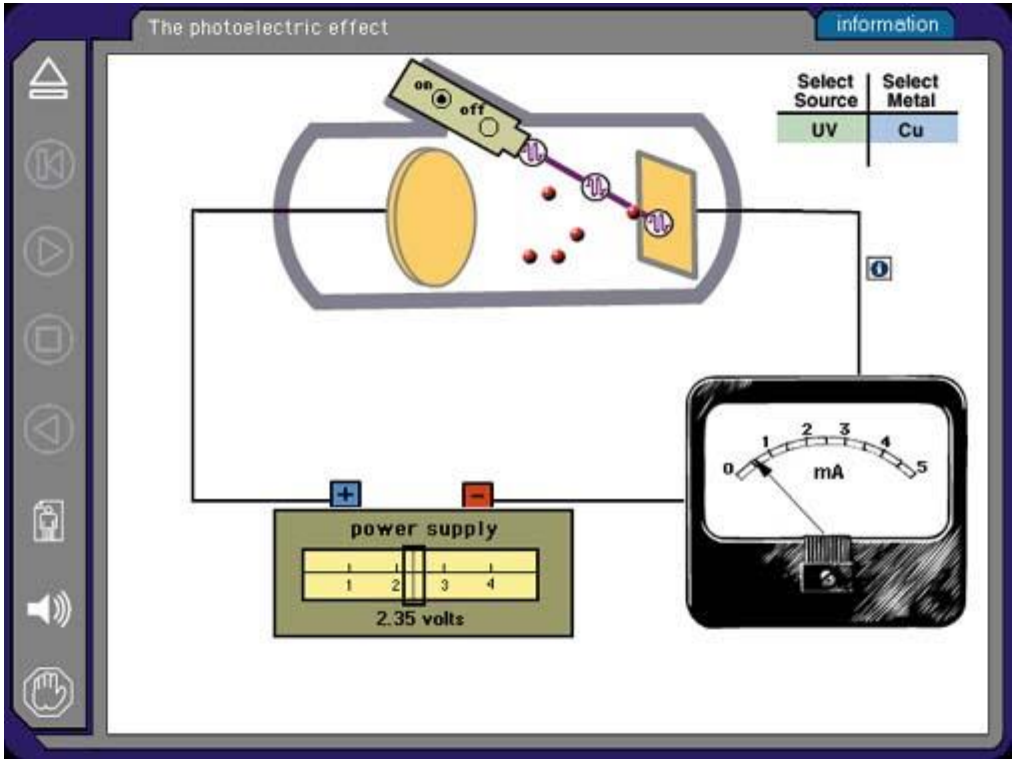
PV System
-includes:
electrical connections, mounting hardware
power conditioning equipment, storage medium

Various Sizes and Power Outputs

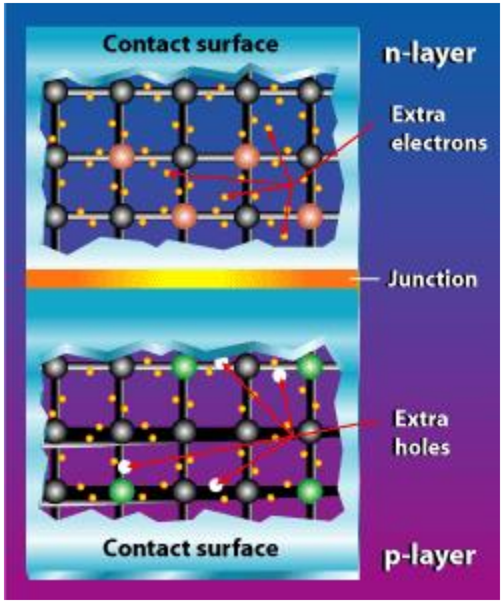


Photoelectric Effect





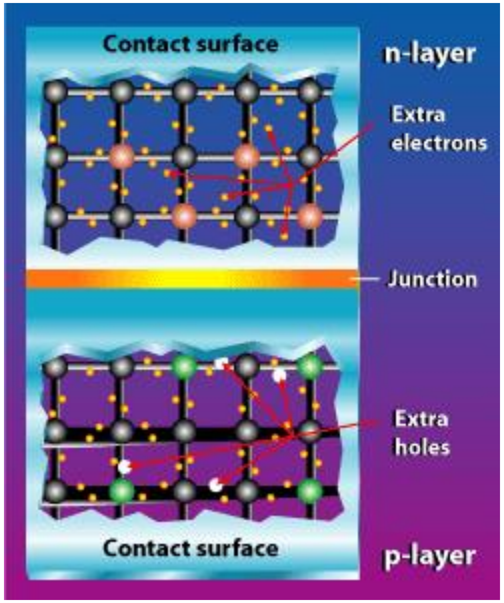
The Crystalline Silicon Solar Cell



- Silicon (4 valence electrons) is "doped" with Phosphorous (5 valence electrons) to make n-type semiconductor
  - These "extra" electrons are free electrons (not bonded)
- Boron (3 valence electrons) is used as dopant to make p-type semiconductor
  - absence of electrons creates "holes."

Note: Each doped silicon crystal lattice is electrically neutral before it is connected to it's counterpart

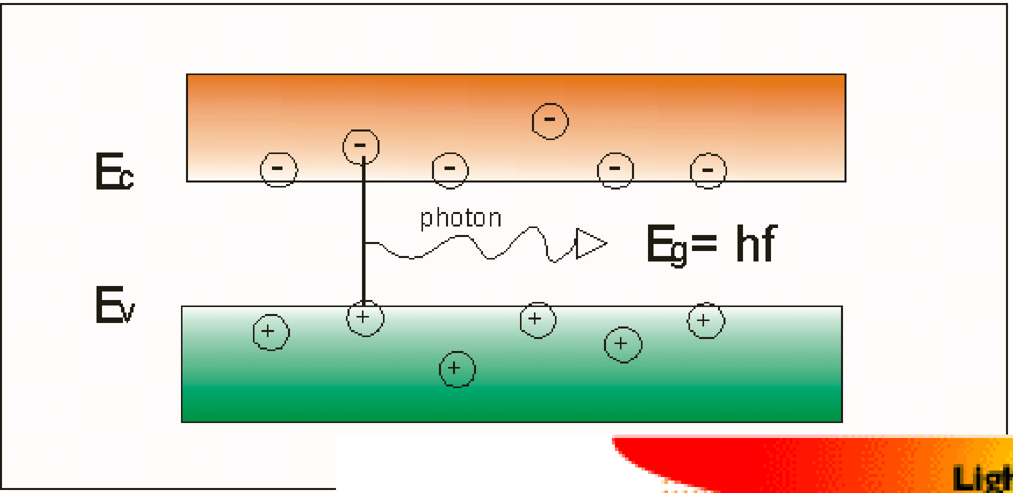
PV Cell has a "built-in electric field"

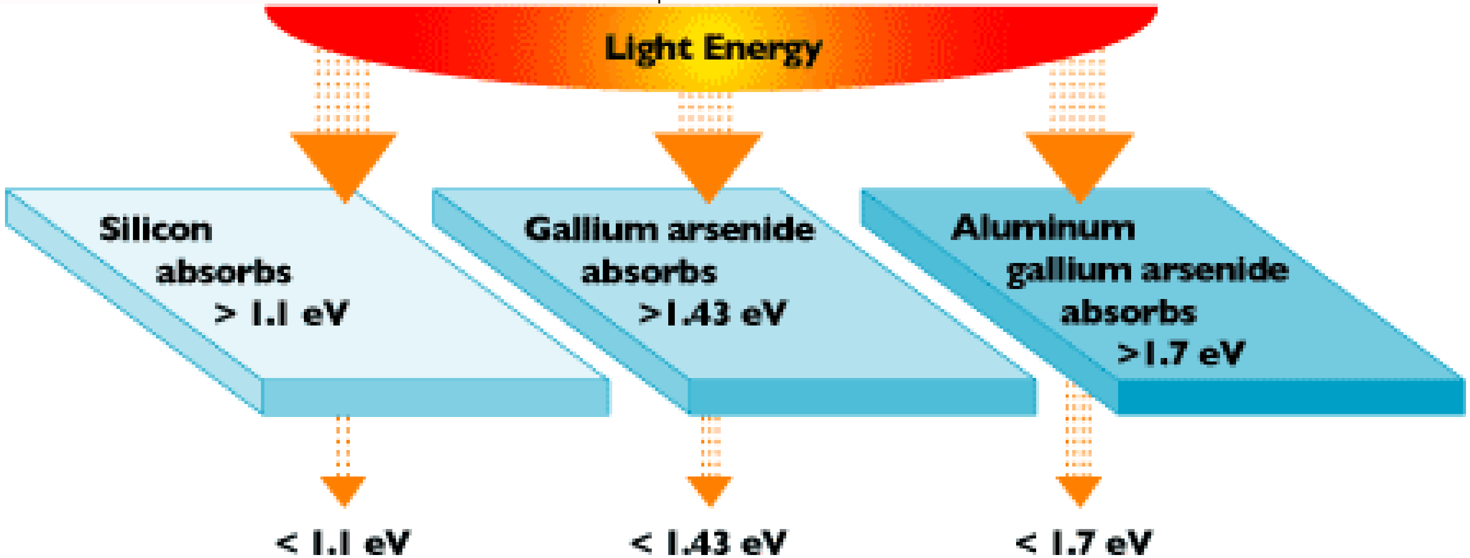


- Incident light is either reflected, absorbed, or transmitted
  - Absorbed light may be converted into electricity via the photoelectric effect
- Two differing semiconductor materials are placed together to form a P/N junction
  - The P/N junction has a built in E-field that provides the potential (voltage) to drive the current through an external load

Semiconductor bandgap energies

- **Bandgap Energy**
  - Amount of energy required to dislodge a valence electron from the semiconductor to the conduction band to allow the electron to become part of electric circuit





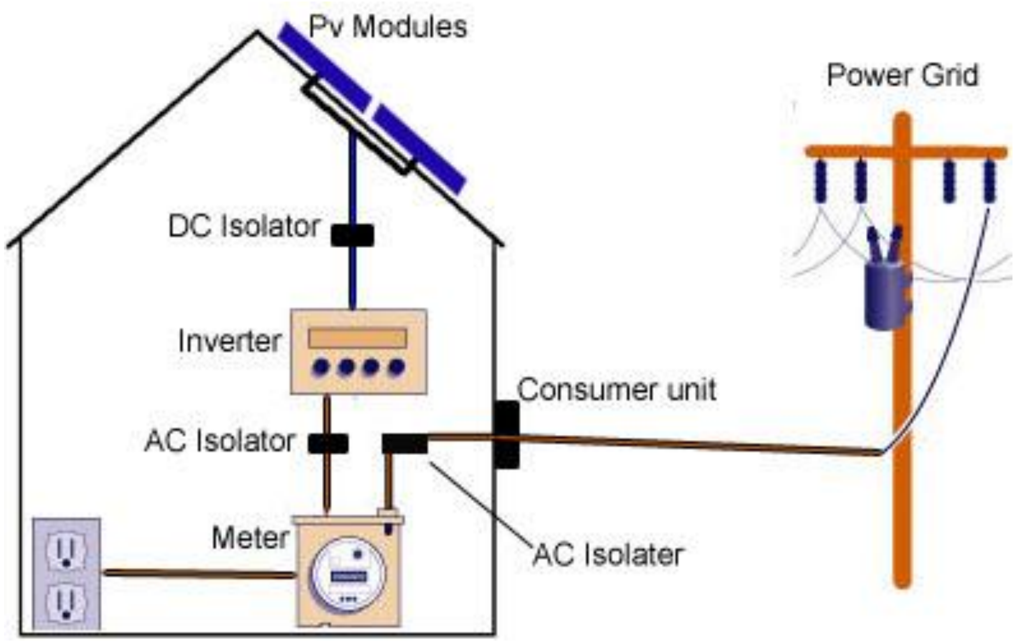
What does solar PV have going for it?

- No carbon emissions from PV electricity generation!
- Cost of traditional electricity production will continue to increase
  - Federal carbon regulation is on the horizon
- Cost of PV modules will continue to decrease
  - Economies of scale
  - New technologies
  - Impact of Chinese production facilities
- Worldwide solar PV industry projected to quadruple by 2020

Important Performance Parameters for Solar PV systems

- Conversion efficiency→what percentage of incident power is converted to electrical power
  - 15 percent is typical
- Peak watt rating for a module
  - this is a lab measurement at a low cell temperature
- Nominal Operating Cell Temperature (NOTC) watt rating for a module
- Expected energy output for a given time period
  - e.g. kWh/yr→ depends on specific installation (geographic location, shading, etc.)

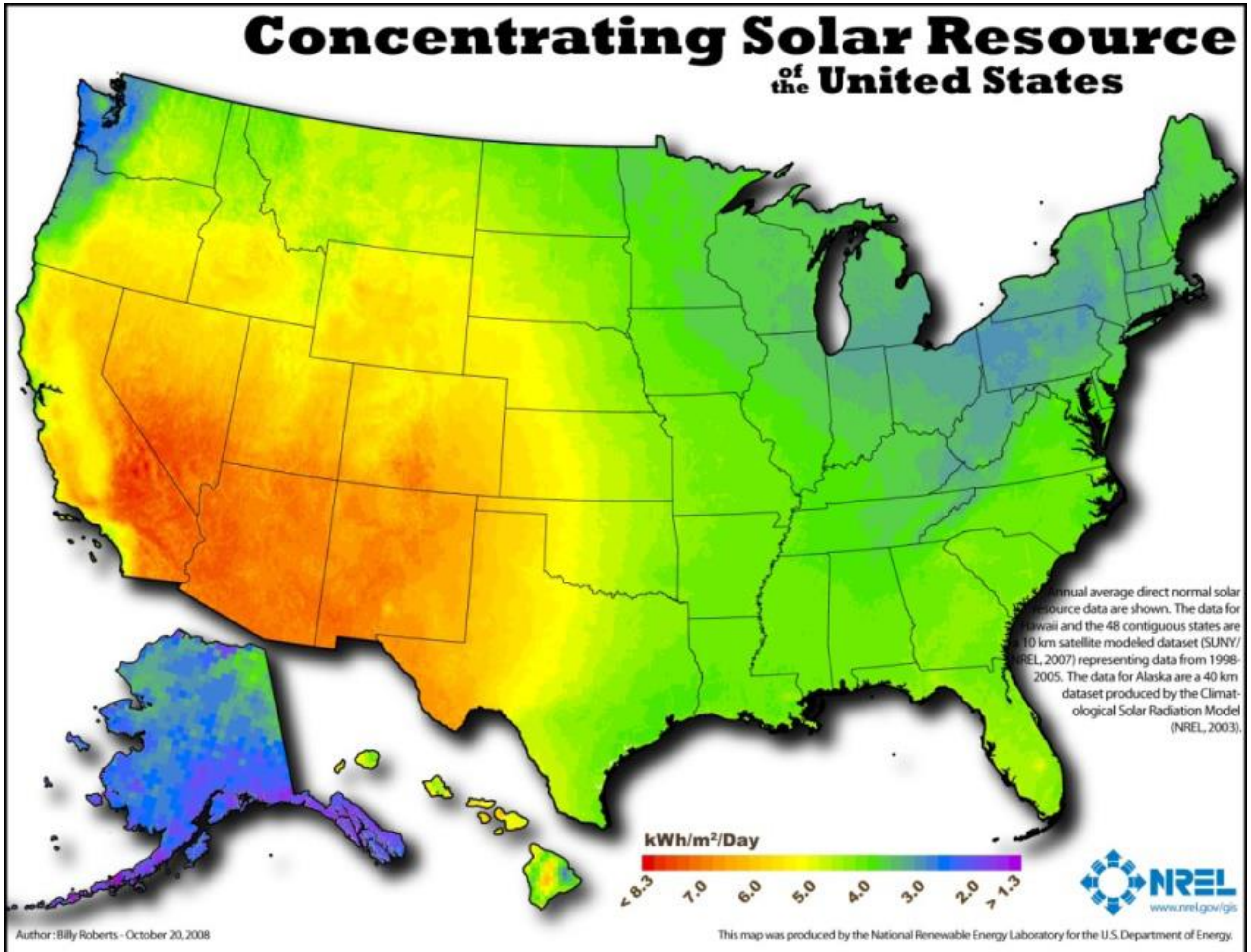
PV system components



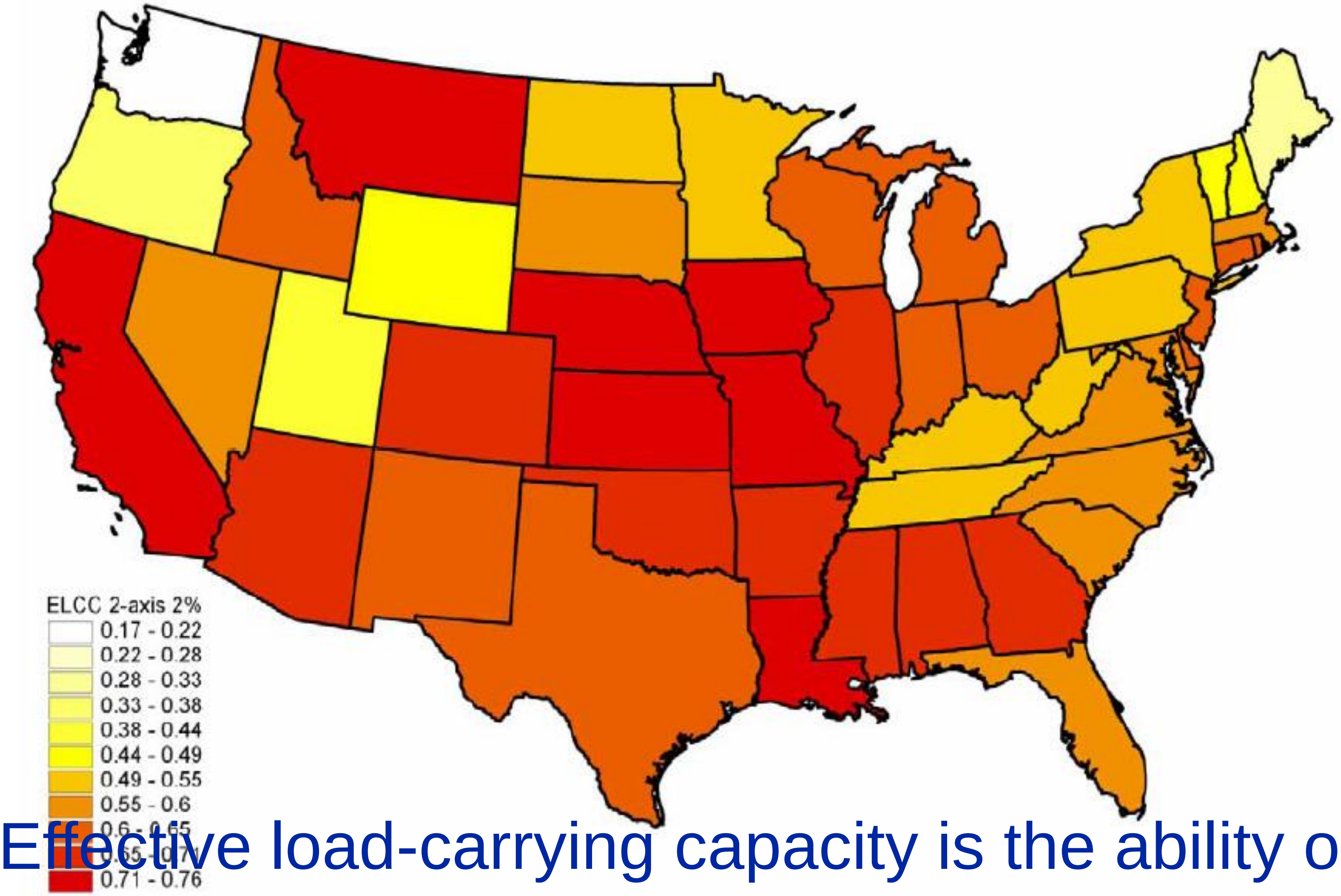
Incident solar radiation (insolation)

- **In Milwaukee Annual Ave on flat or tilted surface**

  ~ 4 kWh/m²/day



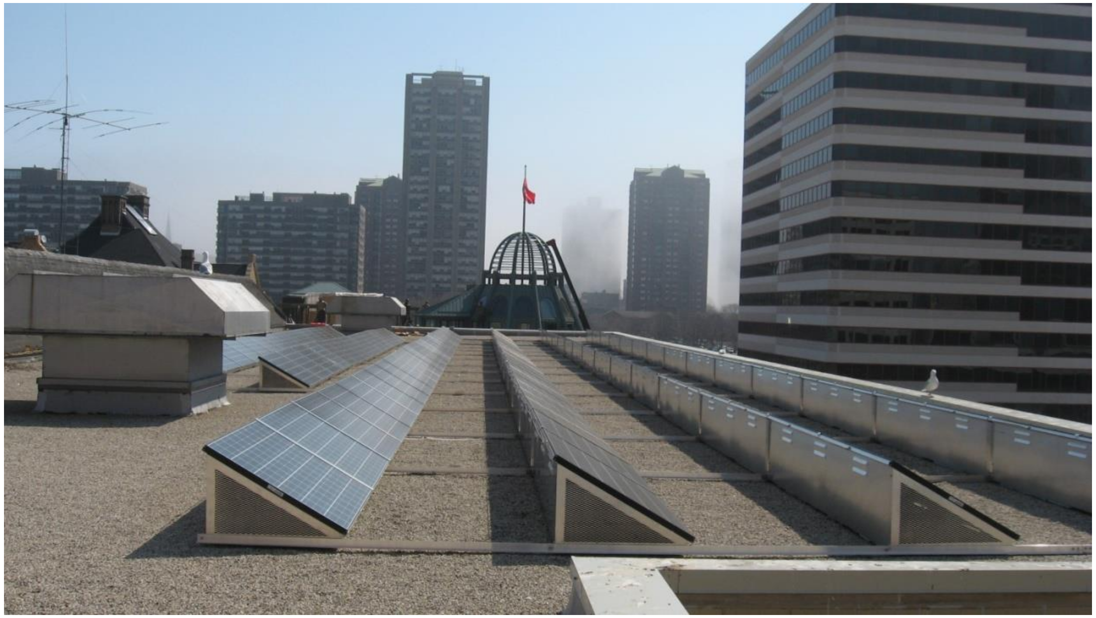
PV resource potential (NREL)



■ Effective load-carrying capacity is the ability of a power generator to effectively contribute to a utility's capacity, or system output, to meet its peak load.

MSOE’s Solar PV system

- Installed in August 2008
- 30 kW system (peak DC rated output)
- 230 m^2 of collection area (~2500 ft^2)
- Output is about 31,000 kWh/year
- System cost: $231,000



MSOE system funding

- $35,000 from Wisconsin Focus on Energy
- $98,000 from We Energies
- $98,000 cost for MSOE

$210,000 ($7/Watt) system components and installation

(panels $140k, racking $27k, install $43k)

$21,000 extra monitoring and outreach

Simple payback time

- **w/o incentives**

  Simple payback time

  \$210,000/(\$6500/yr) ~ 32 years

  at 2017 prices it would be about 10 years (about 7 yrs for a for-profit company w/ federal tax credit)

- **w/ incentives**

  ~\$7000/year in revenue selling renewable energy to the grid for the first 10 years and about \$6500/year thereafter (peak shaving→includes avoided demand charges)

  Simple payback time~14 years

Racking is important

MSOE system performance

- Website→ http://solar.msoe.edu/
- Can view system power output and historical performance