DOE OFFICE OF INDIAN ENERGY

Foundational Courses

Renewable Energy Technologies

SOLAR

Presented by the National Renewable Energy Laboratory



U.S. DEPARTMENT OF ENERGY | Office of Indian Energy

Course Outline

What we will cover…

- About the DOE Office of Indian Energy Education Initiative
- Course Introduction
- Resource Map & Project Scales
- Technology Overview(s):
  - Siting
  - Costs
- Successful Project Example(s)
- Policies Relevant to Project Development
- Additional Information & Resources

Introduction

The U.S. Department of Energy (DOE) Office of Indian Energy Policy & Programs is responsible for assisting Tribes with energy planning and development, infrastructure, energy costs, and electrification of Indian lands and homes.

As part of this commitment and on behalf of DOE, the Office of Indian Energy is leading *education* and *capacity building* efforts in Indian Country.

Training Program Objective & Approach

Foundational courses were created to give tribal leaders and professionals background information in renewable energy development that:

- *Present foundational information on strategic energy planning, grid basics, and renewable energy technologies;*
- *Break down the components of the project development process on the commercial and community scale;*
- *Explain how the various financing structures can be practical for projects on tribal lands.*

NREL's Presenter on Solar is

Otto Van Geet

Otto.vangeet@nrel.gov

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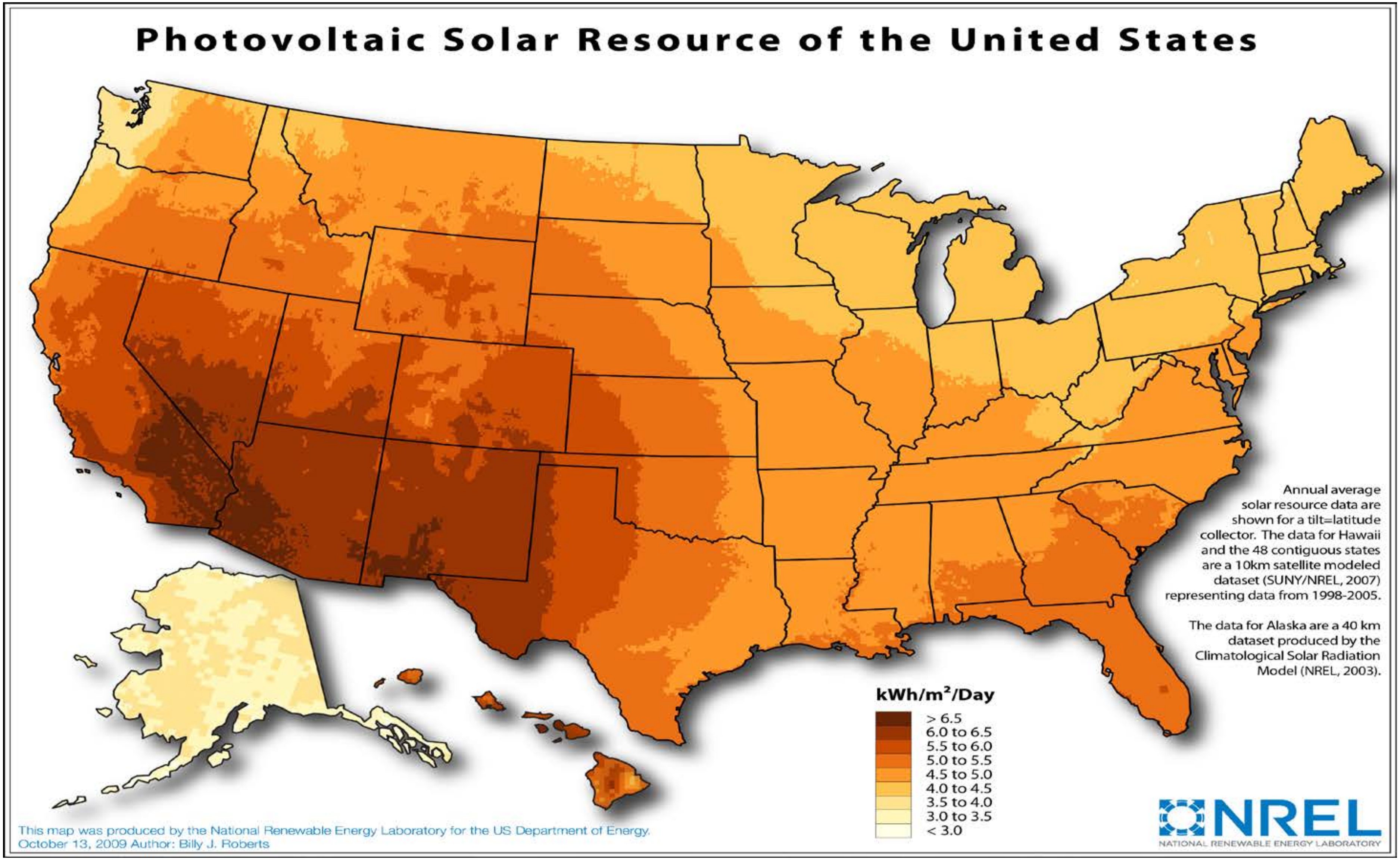
Course Introduction

- **Course Purpose** – define different solar technology, applications, cost, and performance
- **Key Takeaways** – solar technologies work in all parts of the United States, economics of solar are dependent on first cost (including incentives), solar resource, and cost of energy being displaced

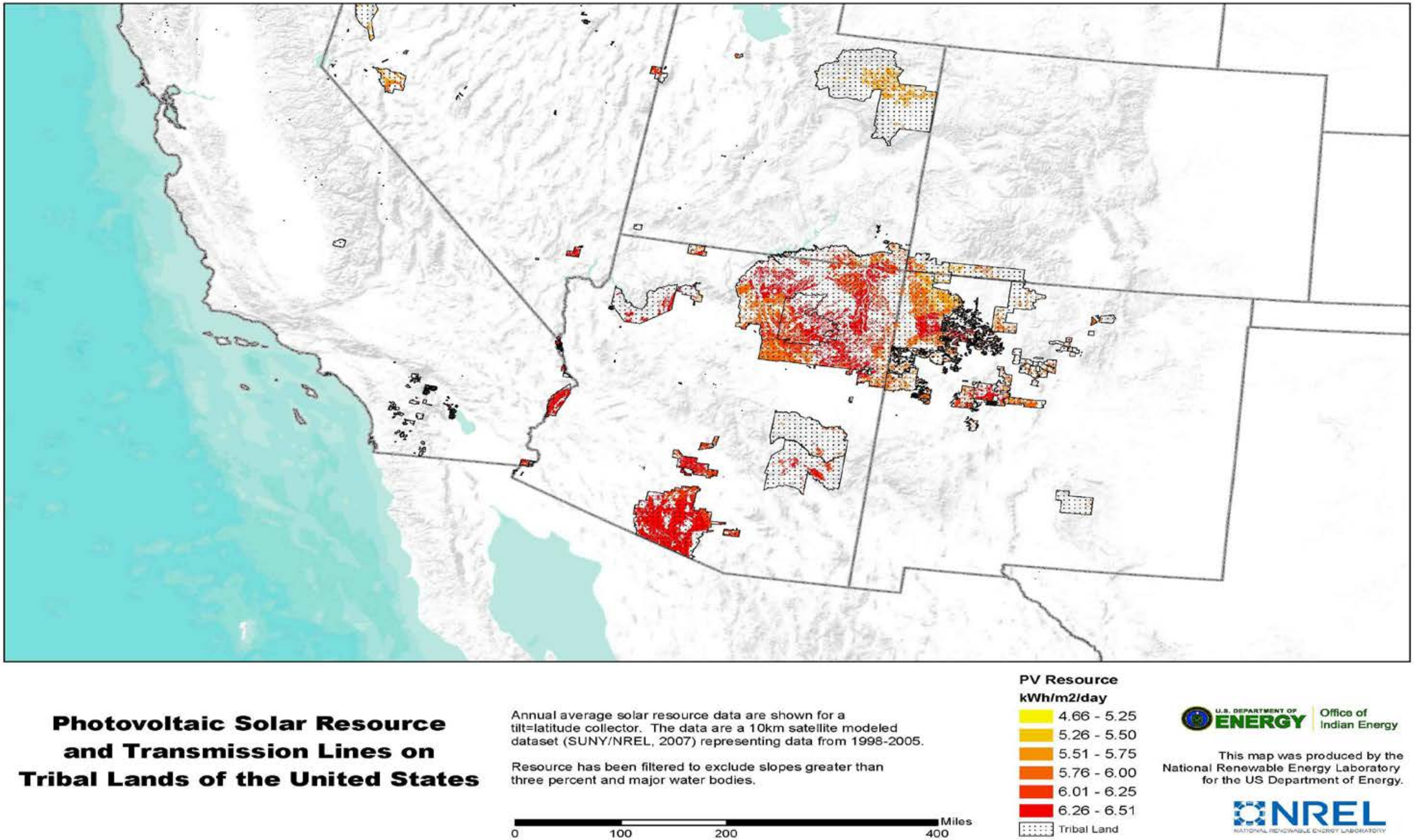
Maps of Resources

- http://www.nrel.gov/gis/maps.html
  - Biomass
  - Geothermal
  - Hydrogen
  - Solar
    - Photovoltaic (PV)
    - Concentrating Solar Power (CSP)
  - Wind
- State and national level maps

PV Solar Resource



PV Solar Resource in Southwest Tribal Lands



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Simple Direct Drive PV System

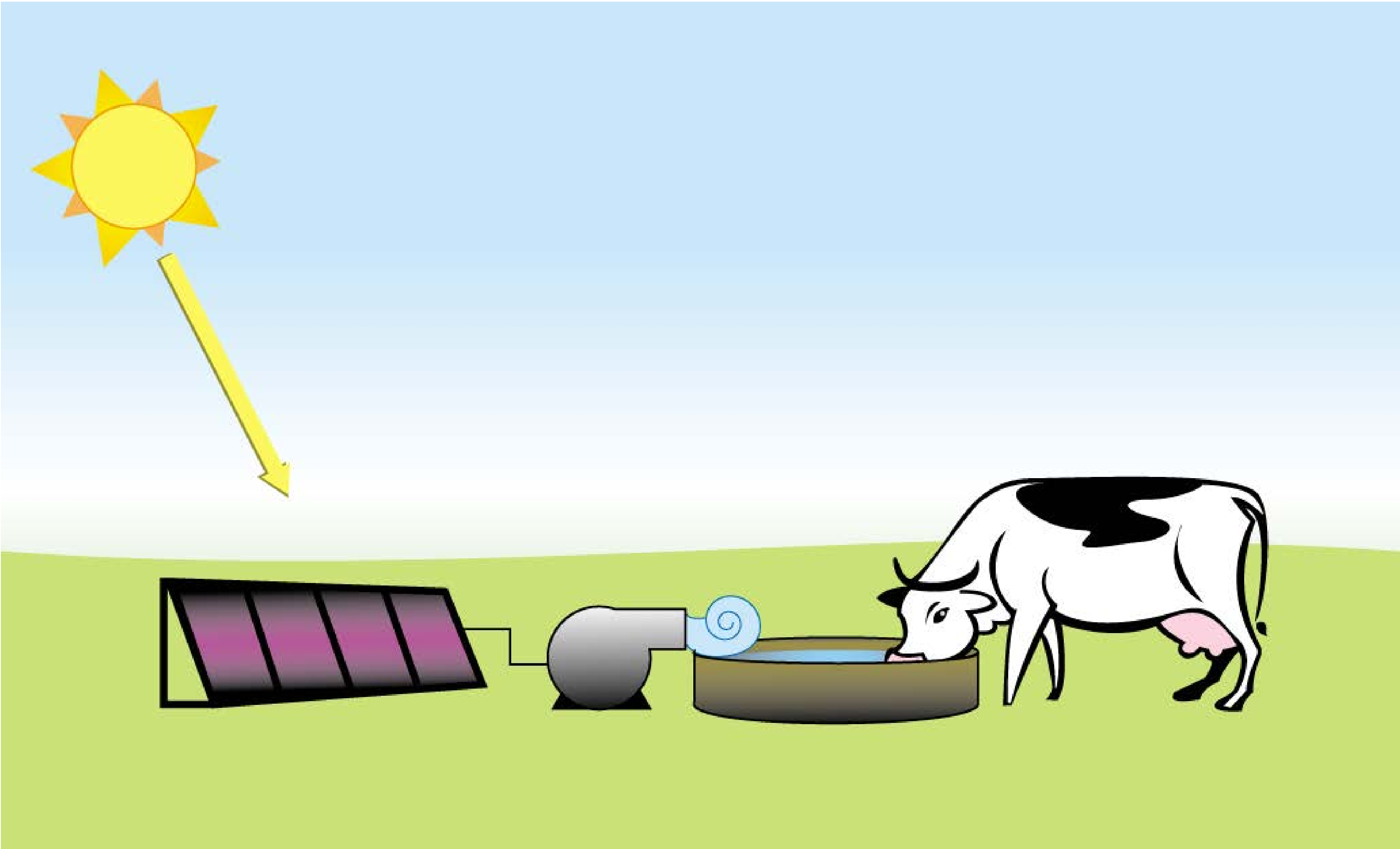


Illustration by Jim Leyshon, NREL

Alternating Current PV System with Inverter

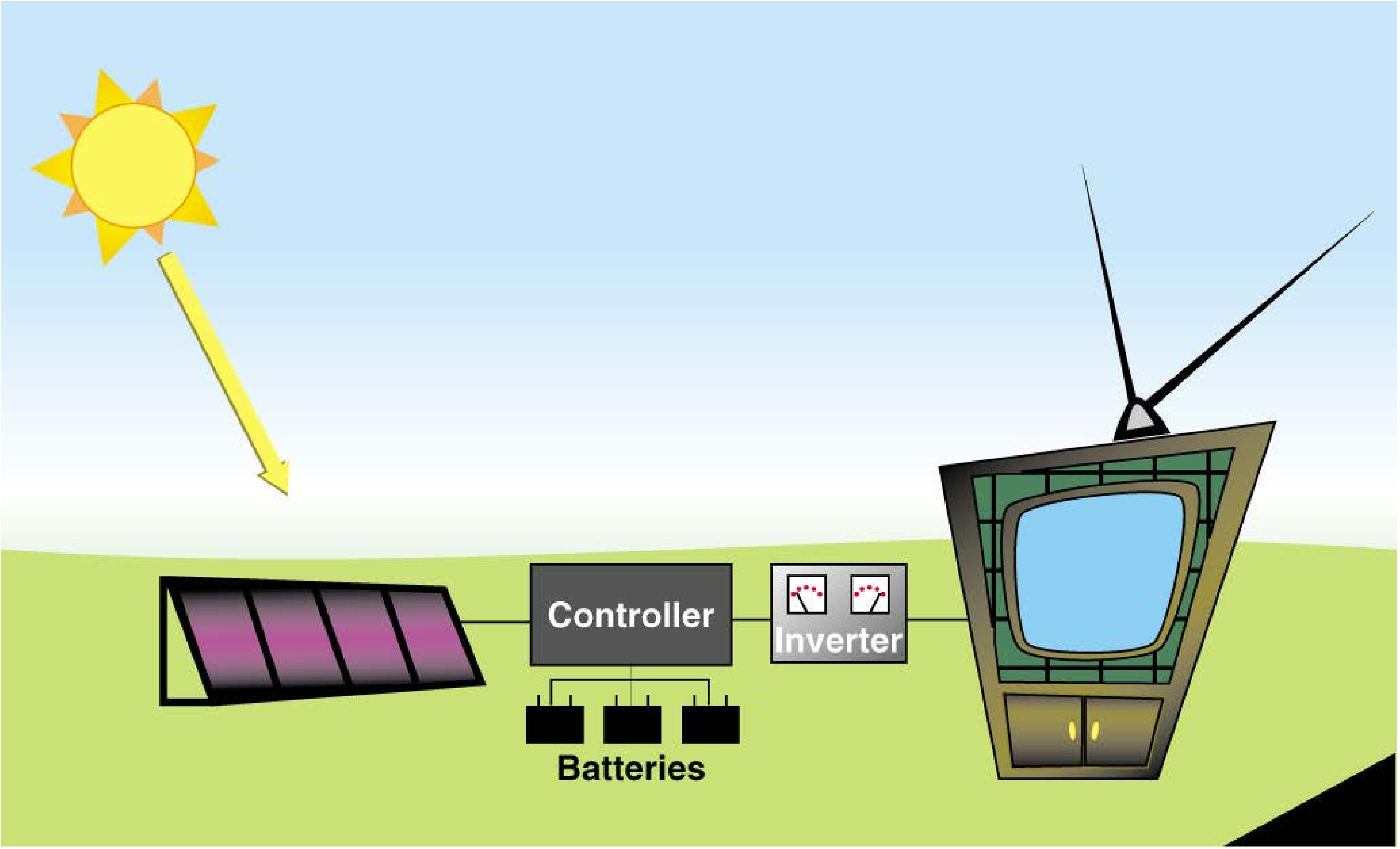
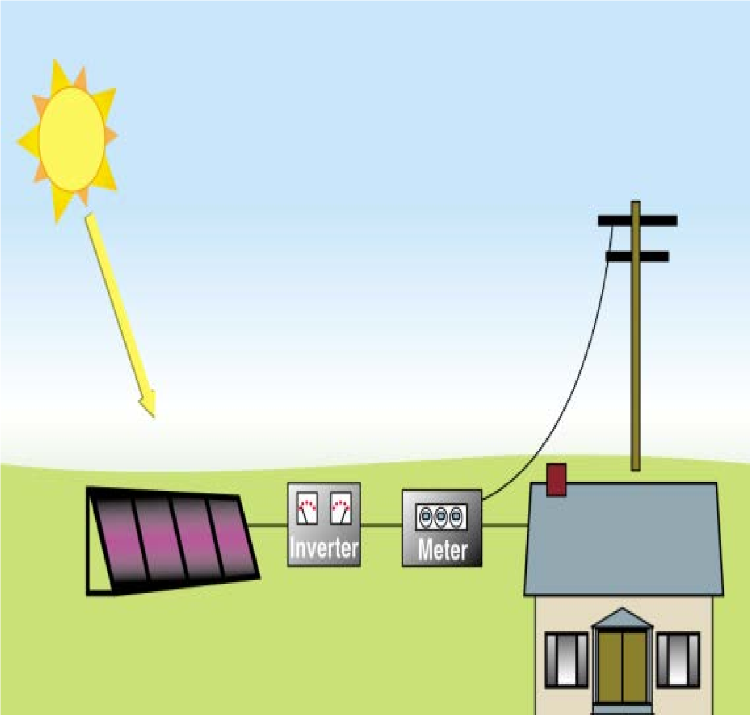


Illustration by Jim Leyshon, NREL

PV Technology

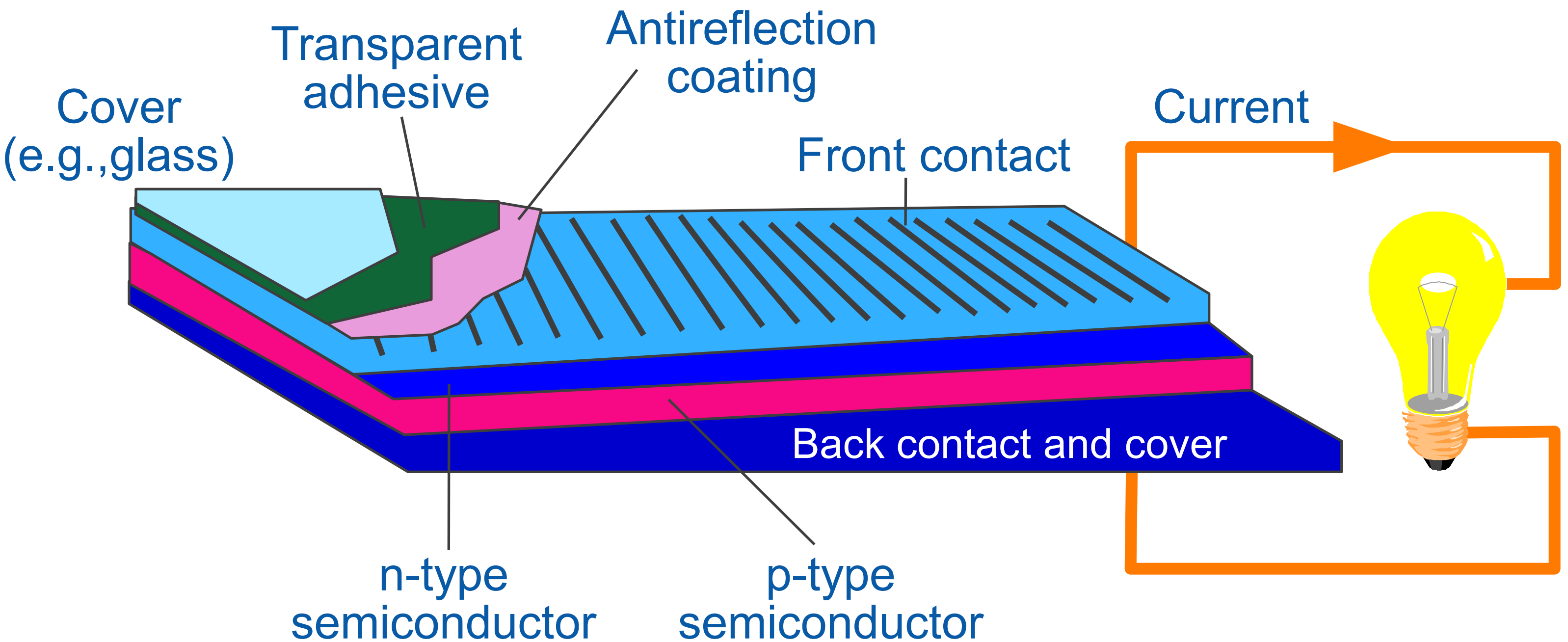
- Direct conversion of sunlight into direct current (DC) electricity
- DC converted to alternating current (AC) by inverter
- Solid-state electronics, no-moving parts



- High reliability, warranties of 20 years or more
- PV modules are wired in series and parallel to meet voltage and current requirements

Illustration by Jim Leyshon, NREL

Photovoltaic Cell Structure

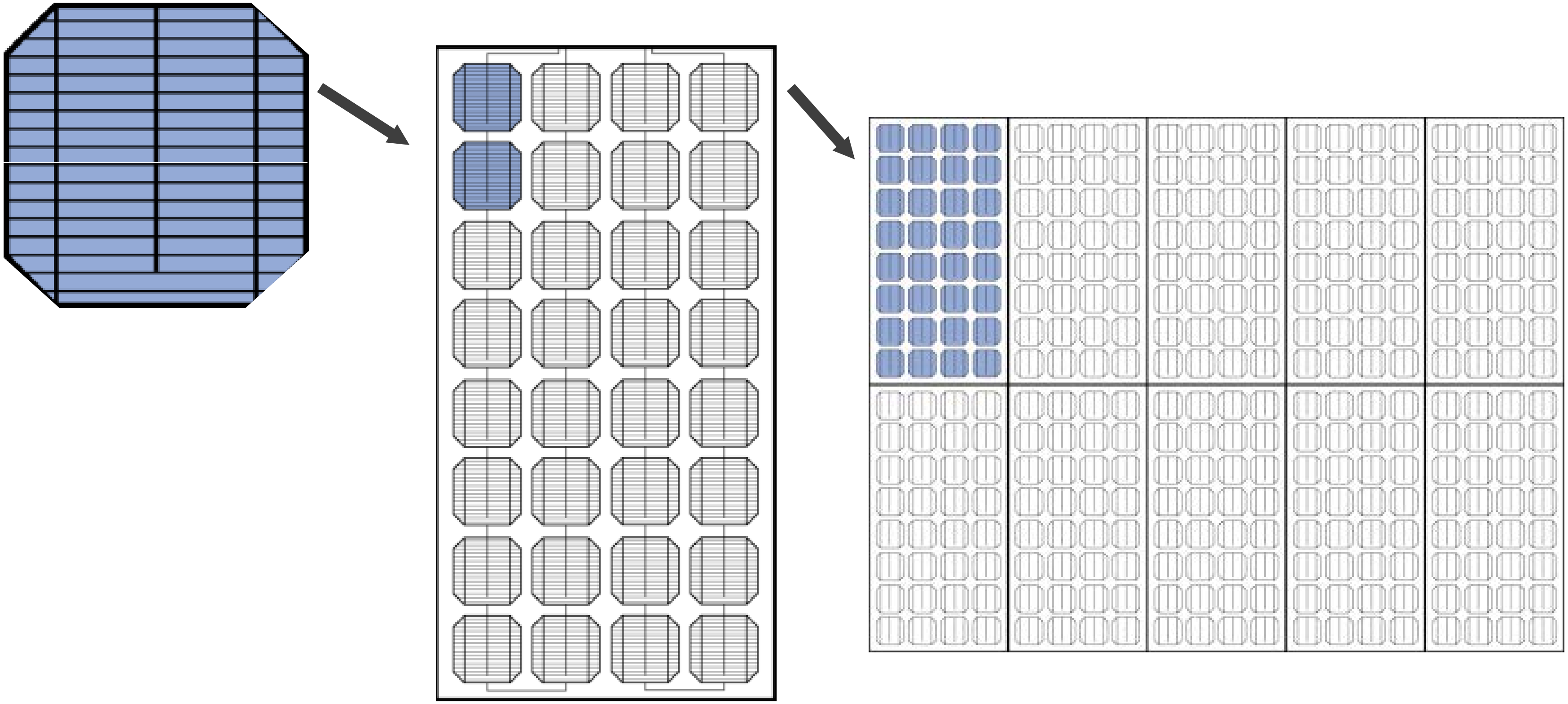


$$\text{Solar cell efficiency (\%)} = \frac{\text{Power out (W) x 100\%}}{\text{Area (m}^2\text{) x 1000 W/m}^2}$$

10% efficiency = 100 W/m^2 or 10 W/ft^2

Illustration by Jim Leyshon, NREL

PV is Modular



Cells are assembled into **modules**... and modules into arrays.

Flat Plate PV Systems

Dangling Rope Marina, Glen Canyon National Recreation Area, Utah
Photo by Warren Gretz, NREL

Arizona Public Service, Prescott, Arizona
Photo from Arizona Public Service

Alamosa PV System, Alamosa, Colorado
Photo by Tom Stoffel, NREL

5–10 acres per megawatt (MW) for PV systems. Land can be left as is or graded

Single Axis Tracking PV

- Increase energy production by 20%
- Large ground mount only
- V is Modular

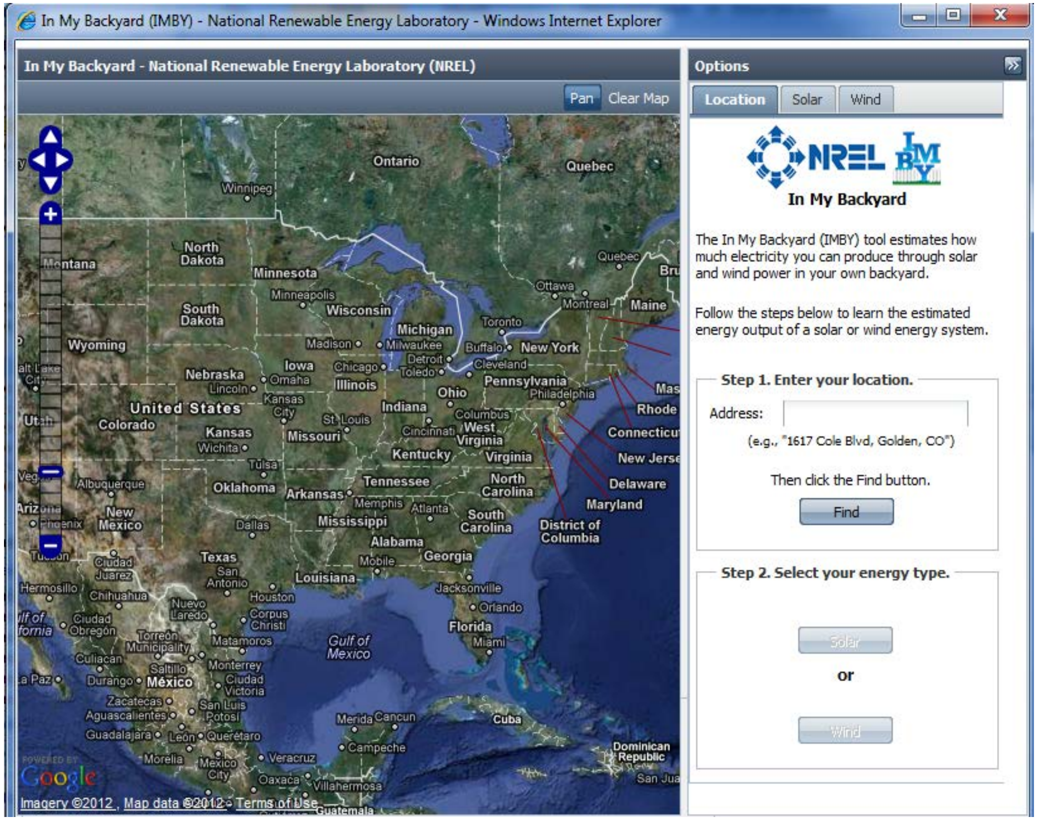
Photo by Warren Gretz, NREL

Total Area Required for PV

- Varies by technology, tilt, and location
- Roof mount - sloped roof, flush-mounted power densities of 11 DC-watt (W)/square foot (ft^2) crystalline
- Flat roof, slope panel = 8 DC-W/ft^2
- Ground mount:

System Type	Fixed Tilt Energy Density (DC-W/ft^2)	Single Axis Tracking Energy Density (DC-W/ft^2)
Crystalline Silicon	4	3.3
Thin Film	3.3	2.7
Hybrid High Efficiency	4.8	3.9

In My Backyard and PVWatts



Benefits of using In My Back Yard (IMBY) and PVWatts:

- Easy to use
- Very quick
- Useful for users of all technical levels
- Widely accepted tool

Link to IMBY: http://mercator.nrel.gov/imby/
Link to PVWatts: http://rredc.nrel.gov/solar/ calculators /PVWATTS/version1/
Link to PVWatts Map serve: http://mapserve3.nrel.gov/PVWatts_Viewer/index.html

Priorities: Where to Install Solar

- On the "built environment" where unshaded
  - On existing building roofs that have an expected life of at least 15 more years and can accept added load - typically 2-4 pounds (lbs)/ft^2. Reduces solar load on building
  - On ALL new buildings – all new buildings should be "solar ready"
    - See http://www.nrel.gov/docs/fy10osti/46078.pdf
  - Over parking areas, pedestrian paths, etc. – energy generation and nice amenity
- On compromised lands such as landfills and brown fields
  - Saves green fields for nature
  - If installed on green fields, minimize site disturbance; plant native low height vegetation as needed

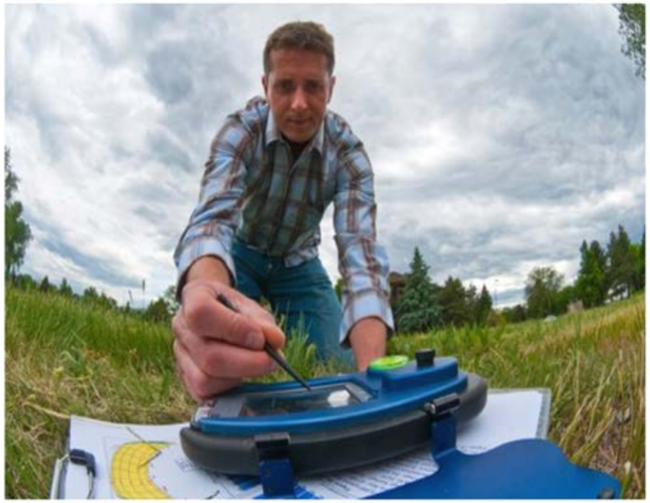
Veterans Administration
Jerry L. Pettis Memorial Medical Center
Loma Linda, California

Project Specifications:

- 309 kilowatt (kW) DC
- 1,584 Sanyo 195-watt PV modules
- SunLink (ballasted) racks minimum roof penetration
- Advanced Energy Solaron 333 kW inverter
- Feasibility study by the National Renewable Energy Laboratory (NREL) estimates: 475 megawatt-hours (MWh)/year delivery

Photo by Warren Gretz, NREL

Solar Assessment – PV is VERY Shade Sensitive



Shade Analyzer

Once preliminary site assessment has been completed, you want to know:

- Estimated system size
- Estimated production (kilowatt-hour [kWh]/yr)
- Estimated cost
- Some economic analysis

Photos top to bottom: NREL/PIX 10314 and 17509

Photovoltaics System (Grid Connected)

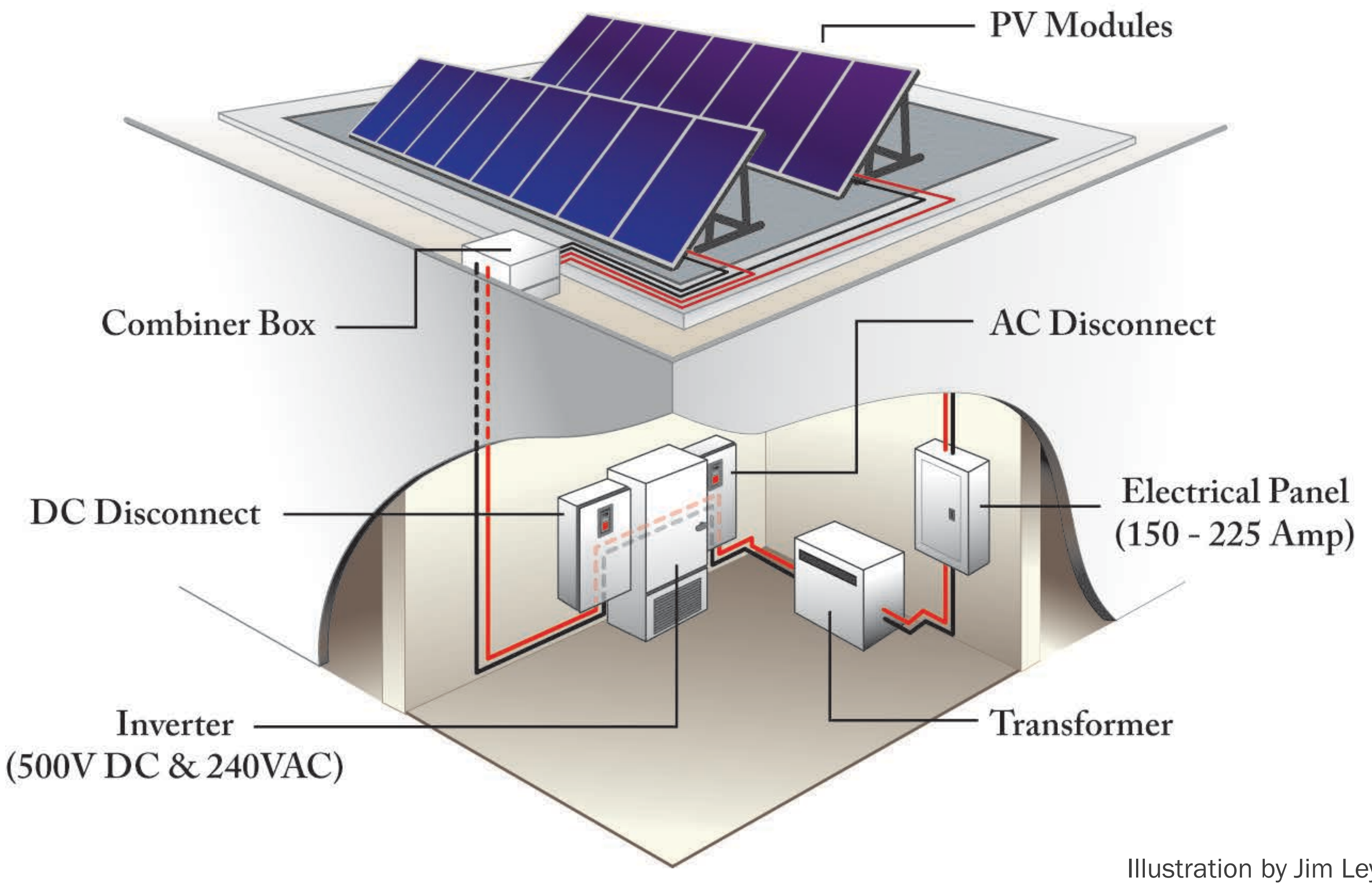
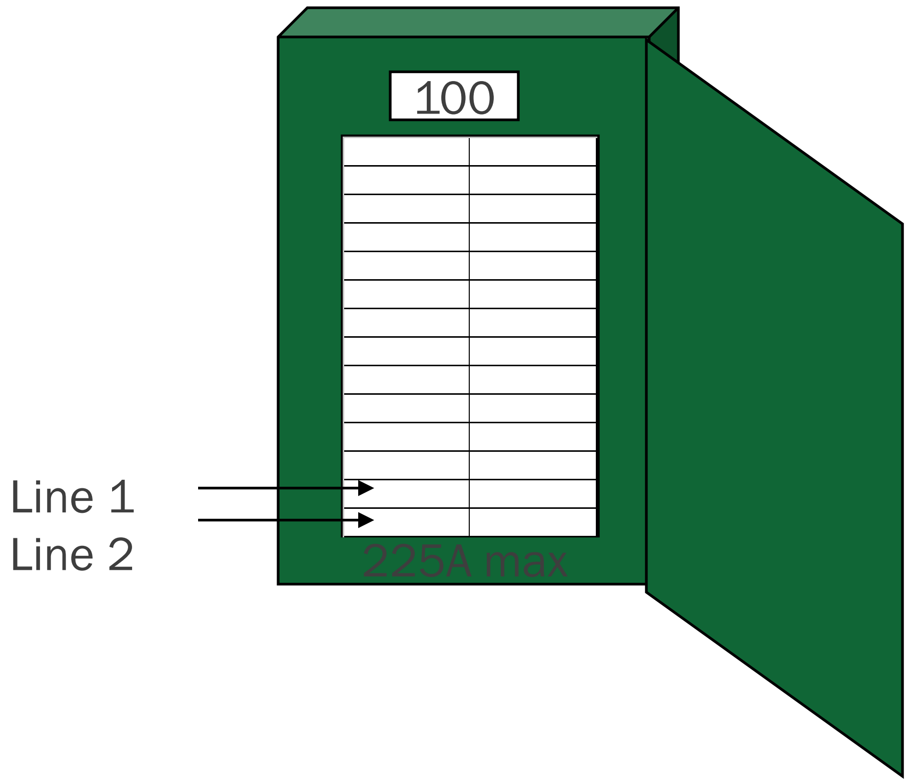


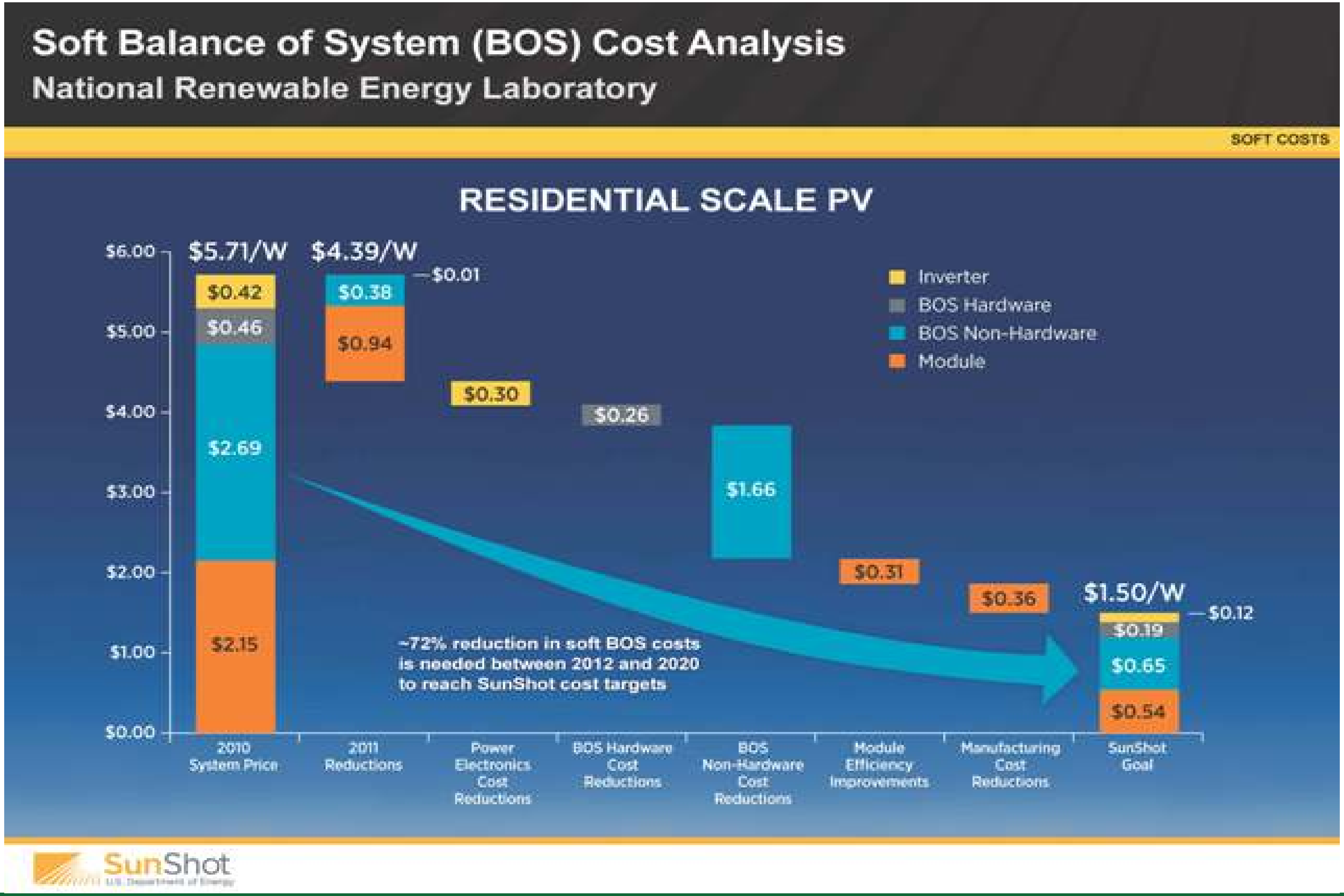
Illustration by Jim Leyshon, NREL

Utility Interconnection - Where to land the power?

- Backfeed breaker in building panel (sum of main breaker and PV breaker not to exceed 120% of panel rating for commercial building, 100% for residential)
- Too big?
  - Survey loads and reduce main breaker rating
  - Upgrade panel (few hundred dollars for home)
  - Line-side-tap
  - Upgrade electrical service



Price of PV Modules



PV Installed Costs

- $5/W in 2012 before financial incentives and tax credits
- Utility scale (1 MW+) $3.5/W

Photo by Dennis Schroeder, NREL

Ground Mounted - NREL PV Project in Colorado

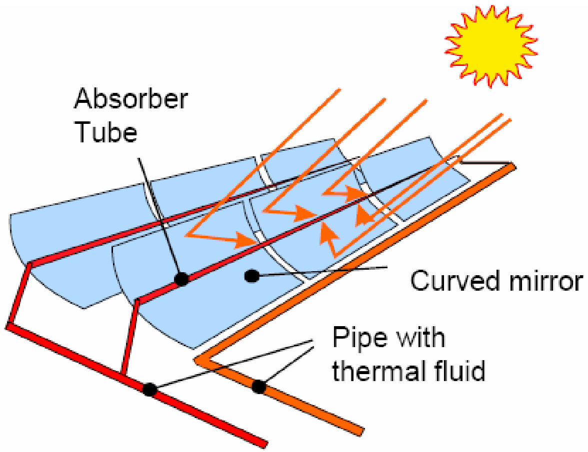
Project Specifications:

- 720 kW (1,200 MWh) single-axis tracking, ~ 5 acres
- 20-year power purchase agreement (PPA) contract (utilizing Western Area Power Administration)
- 20-year easement
- Renewable energy credits (RECs) sold to Xcel Energy for renewables portfolio standard (RPS) solar set-aside (20-year contract)
- PPA price equal to or less than utility electricity prices (based on Energy Information Administration projections)
- Operational December 2008

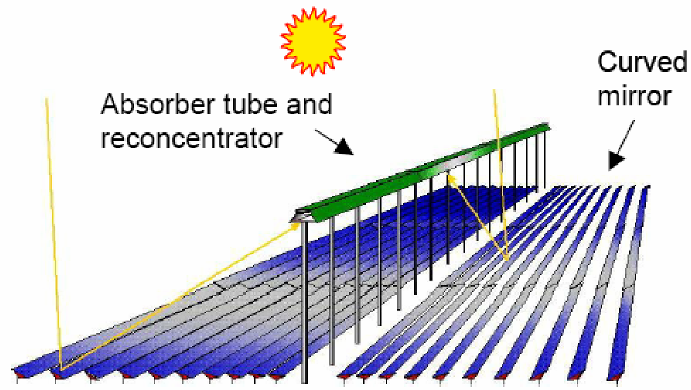
Photo by Pat Corkery, NREL

FEMP Federal Energy Management Program

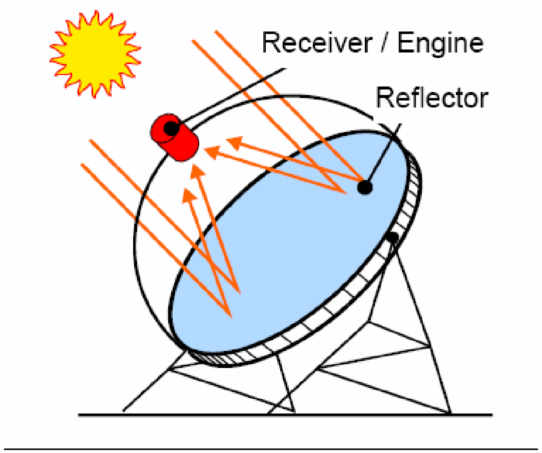
Solar Concentrating Technologies



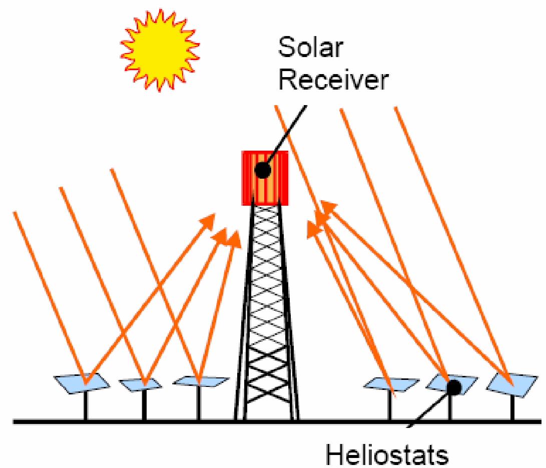
Parabolic Trough



Linear Fresnel



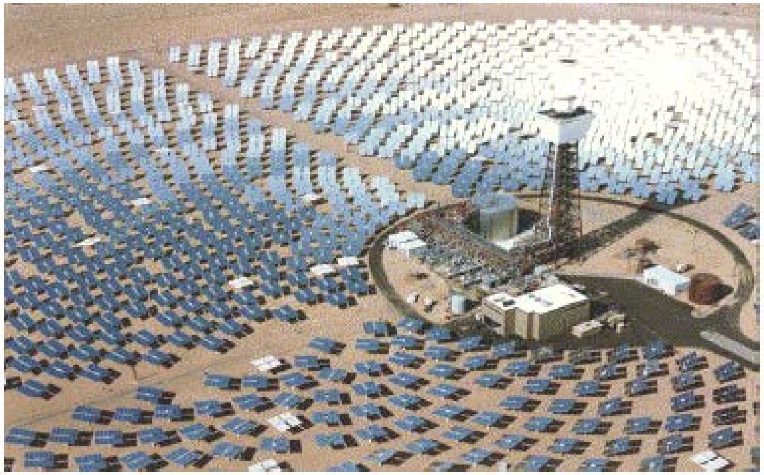
Dish/Engine



Central Receiver

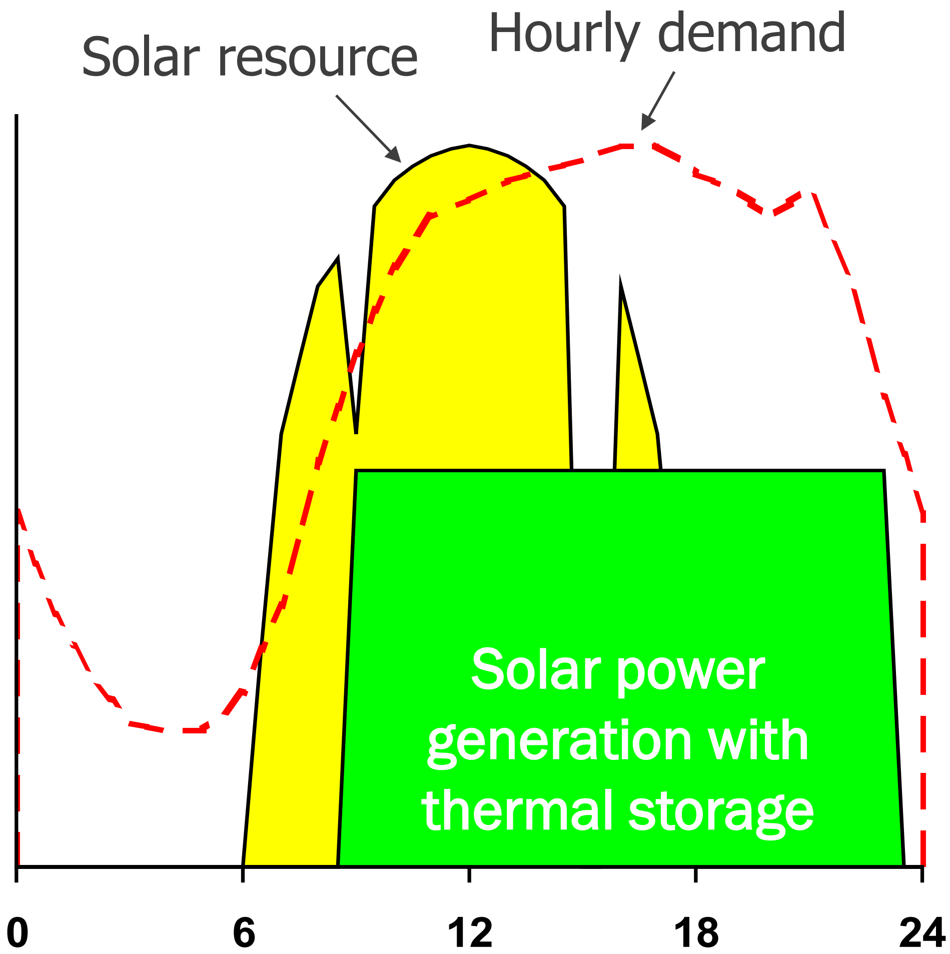
Illustration by Jim Leyshon, NREL

Solar Concentrating Technologies



Photos by (clockwise): Warren Gretz, NREL; AREVA Solar, David Hicks, NREL; Solar One

The Value of Dispatchability



Thermal storage:

- Provides **higher value** as the produced power can adapt to the demand and be dispatched at the request of power grid operators
- Provides **lower cost** as thermal storage introduction into CSP power plants is cheaper than turbine capacity increase
- Is based on the use of **high heat capacity fluids** as heat transfer storage mediums

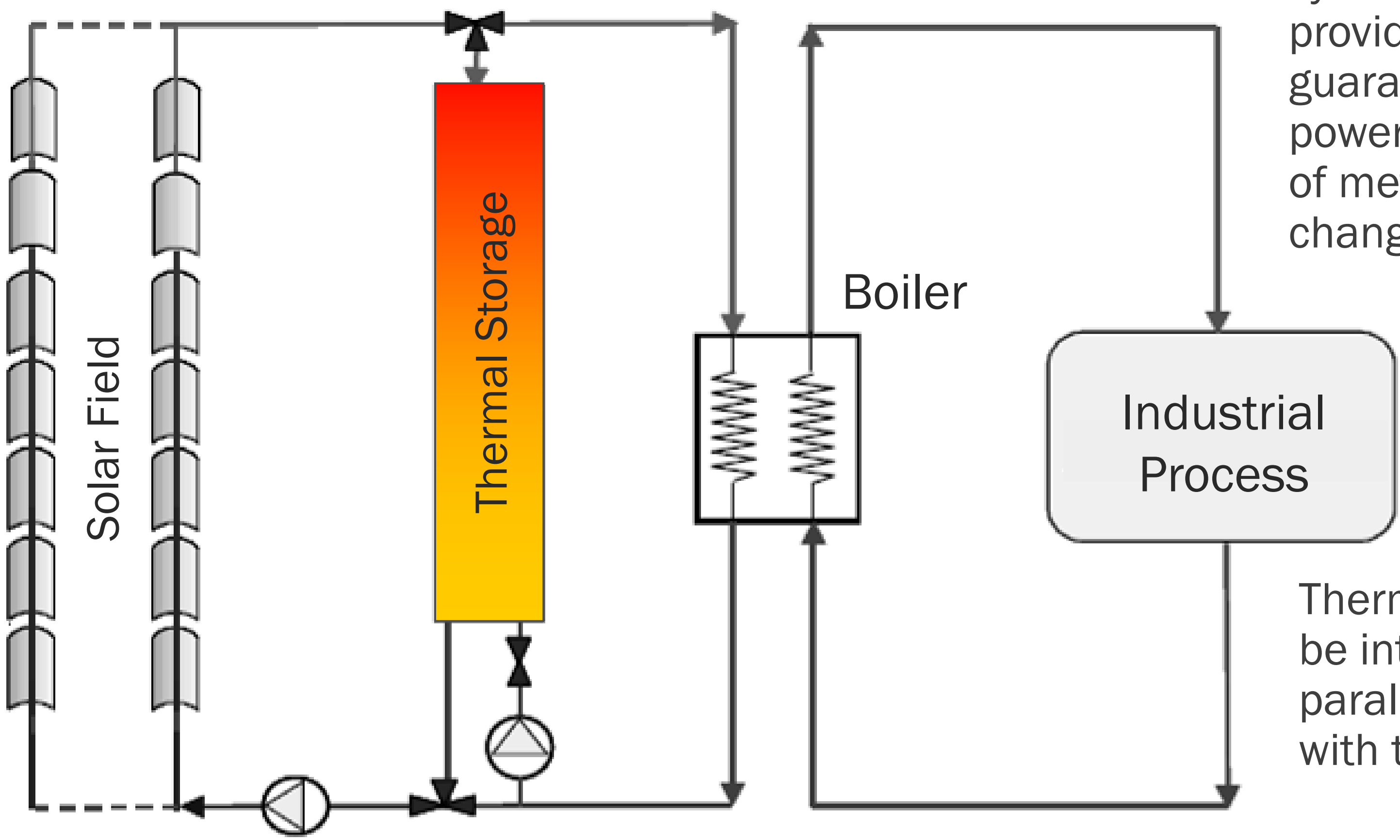
Additional Advantages of CSP

- Can **be easily integrated** into conventional thermal power plants, just connecting the "solar boiler" either in series or in parallel with the "fossil boiler"
- **Not affected by abrupt changes** into the output power (very common in PV plants)
- **Disadvantages:**
  - Viable only for large (50 MW+) plants
  - Only works in the desert Southwest that receives high "direct beam" solar
  - Normally requires water for cooling towers

Photos from Solar One and ACCIONA

Thermal Storage System

Thermal storage system based on one tank



Thermal storage system is needed to provide stability and guarantee the output power, independently of meteorological changes

Thermal storage can be integrated either in parallel or in series with the power block

U.S. Parabolic Trough Power Plant Data

Plant Name	Location	First Year of Operation	Net Output (MW_e)	Solar Field Outlet (°C)	Solar Field Area (m^2)	Solar Turbine Effic. (%)	Power Cycle	Dispatchability Provided By
Nevada Solar One	Boulder City, NV	2007*	64	390	357,200	37.6	100 bar, reheat	None
APS Saguaro	Tucson, AZ	2006	1	300	10,340	20.7	ORC	None
SEGS IX	Harper Lake, CA	1991	80	390	483,960	37.6	100 bar, reheat	HTF heater
SEGS VIII	Harper Lake, CA	1990	80	390	464,340	37.6	100 bar, reheat	HTF heater
SEGS VI	Kramer Junction, CA	1989	30	390	188,000	37.5	100 bar, reheat	Gas boiler
SEGS VII	Kramer Junction, CA	1989	30	390	194,280	37.5	100 bar, reheat	Gas boiler
SEGS V	Kramer Junction, CA	1988	30	349	250,500	30.6	40 bar, steam	Gas boiler
SEGS III	Kramer Junction, CA	1987	30	349	230,300	30.6	40 bar, steam	Gas boiler
SEGS IV	Kramer Junction, CA	1987	30	349	230,300	30.6	40 bar, steam	Gas boiler
SEGS II	Daggett, CA	1986	30	316	190,338	29.4	40 bar, steam	Gas boiler
SEGS I	Daggett, CA	1985	13.8	307	82,960	31.5	40 bar, steam	3-hours TES

http://www.nrel.gov/csp/troughnet/power_plant_data.html

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Considerations: Financial Incentives

Database of State Incentives for Renewables and Efficiency (DSIRE)

- www.dsireusa.org
- Types of incentives: federal, state, local, utility
  - Corporate, personal income, sales, and property tax incentives
  - Grant programs
  - Industry recruitment incentives
  - Leasing/lease purchase programs
  - Loan programs
  - Production incentives
  - Rebate programs
  - RECs sales

DSIRE™

Database of State Incentives for Renewables & Efficiency

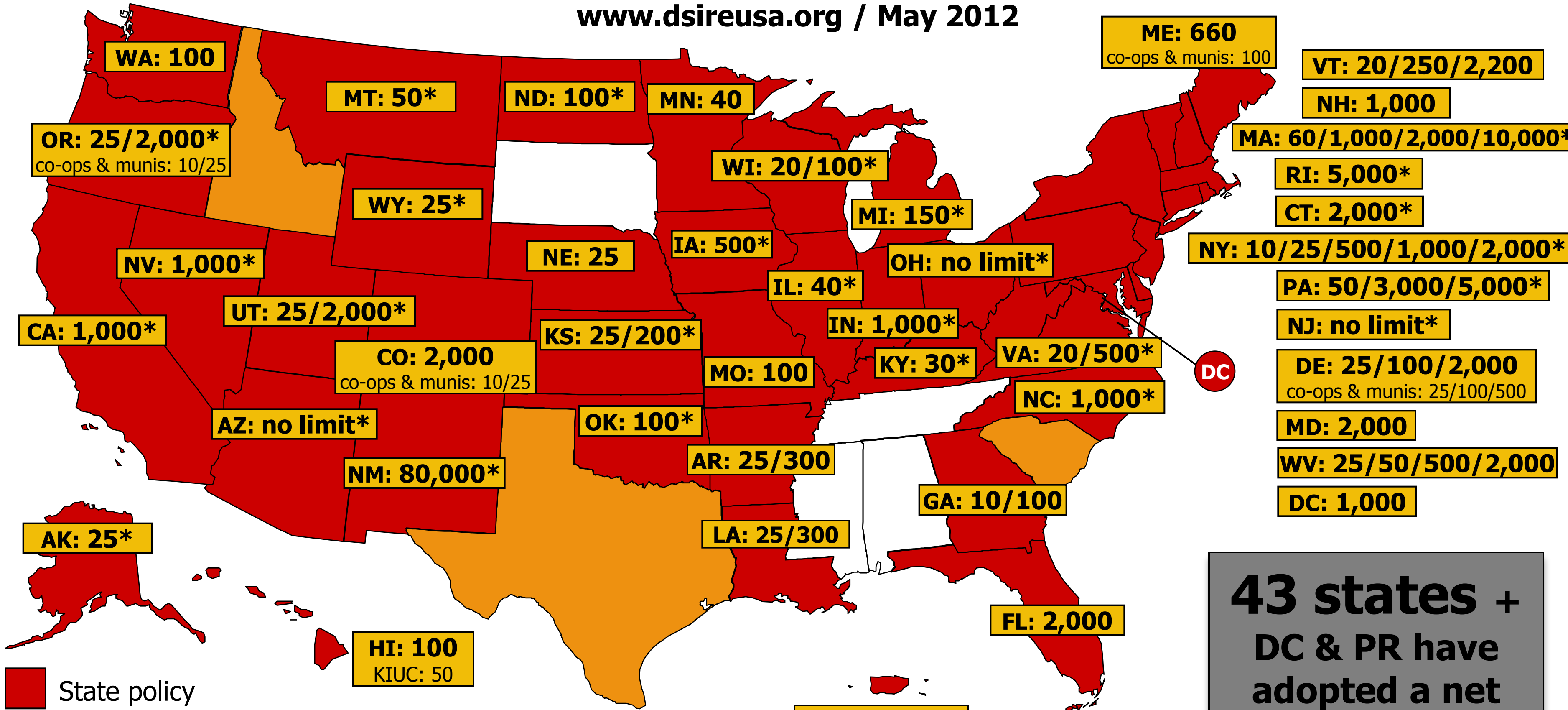
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

IREC INTERSTATE RENEWABLE ENERGY COUNCIL

NORTH CAROLINA SOLAR CENTER

Net Metering

www.dsireusa.org / May 2012



State policy

Voluntary utility program(s) only

* State policy applies to certain utility types only (e.g., investor-owned utilities)

Note: Numbers indicate individual system capacity limit in kW. Some limits vary by customer type, technology and/or application. Other limits might also apply.
This map generally does not address statutory changes until administrative rules have been adopted to implement such changes.

What we covered…

▪	About the Office of DOE Office of Indian Energy Education Iniatiative	√
▪	Course Introduction (Takeaways)	√
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▪	Successful Project Example(s)	√
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▪	Additional Information & Resources	

Useful Resources

SOLAR ENERGY RESOURCES	• NREL: http://www.nrel.gov/rredc/ • Firstlook: http://firstlook.3tiergroup.com/ • TMY or Weather Data: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/
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/
STATE UTILITY POLICIES & INCENTIVES	• DSIRE: http://www.dsireusa.org

Thank You & Contact Information

For Technical Assistance:

IndianEnergy@hq.doe.gov.

DOE Office of Indian Energy Website:

www.energy.gov/indianenergy

NREL Technology Websites:

www.nrel.gov/learning/re_basics.html

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INFORMATION ON THE CURRICULUM PROGRAM & OFFERINGS

Curriculum Structure & Offerings

Foundational Courses

- Overview of foundational information on renewable energy technologies, strategic energy planning, and grid basics

Leadership & Professional Courses

- Covers the components of the project development process and existing project financing structures

Foundational Courses

Energy Basics

- Assessing Energy Needs and Resources
- Electricity Grid Basics
- Strategic Energy Planning

Renewable Energy Technology Options

- Biomass
- Direct Use
- Geothermal
- Hydroelectric
- Solar
- Wind

All courses are presented as 40-minute Webinars online at
www.energy.gov/indianenergy