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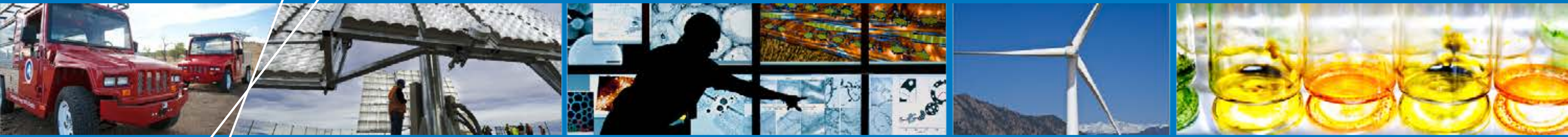
Renewable Energy 101



Andy Walker, PhD PE

Principal Engineer, NREL

Renewable Energy Round Table

March 27, 2012

NREL/PR-7A40-54593

Outline

- **RE Policy**
  - Laws
  - Executive Orders
- **RE Technologies**
  - Operating Principle
  - Cost and Performance
  - Incentives
  - Case Studies
  - Helpful Resources
- **Integration Issues**
  - Net Zero and Beyond
  - RE Project Planning

Photo by Dennis Schroeder, NREL/PIX 19200

Photo by John De La Rosa, NREL/PIX 19978

Photo by Corey Patrick, NREL/PIX 16580

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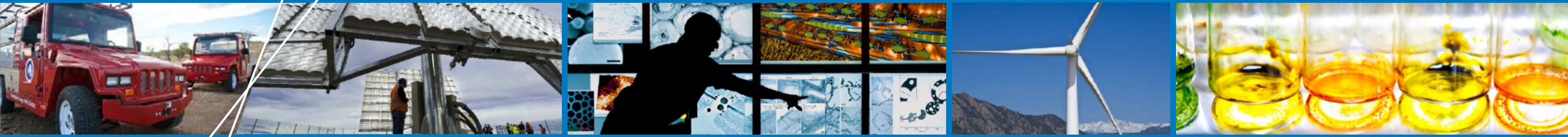


Renewable Energy Policy

What is the Federal Definition of Renewable Energy?

Electric energy generated from:

- **Solar**
- **Wind**
- **Biomass**
- **Landfill gas**
- **Ocean (including tidal, wave, current, and thermal)**
- **Geothermal**
- **Municipal solid waste**
- **New hydroelectric generation capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project**
  - *EPAct 2005*

Renewable Energy Technologies

Photovoltaics

Photo from City of San Jose, NREL/PIX 19487

Solar Vent Air Preheat

Photo by Warren Gretz, NREL/PIX 00595

Daylighting

Photo by Joe Ryan, NREL/PIX 19424

Wind Power

Photo by David Hicks, NREL/PIX 18455

Concentrating Solar Heat/Power

Photo by Geri Kodey NREL/PIX 14380

Ground Source Heat Pump

Photo by Devin Egan, NREL/PIX 17440

Solar Water Heating

Photo by Joe Ryan, NREL/PIX 19691

Biomass Heat/Power

Photo by Kim Yost, NREL/PIX 11915

Landfill Gas

Photo by Warren Gretz, NREL/PIX 03793

Legislation

EPAct 2005

- Not less than 5% of electricity consumed by the Federal government must come from renewable energy in fiscal years 2010-2012
- Not less than 7.5% in fiscal year 2013 and thereafter
- Renewable energy projects provide bonuses if energy is:
  - produced on Federal lands and used at a Federal facility; or
  - produced on Native American land and used at a Federal facility.

Legislation

EISA 2007

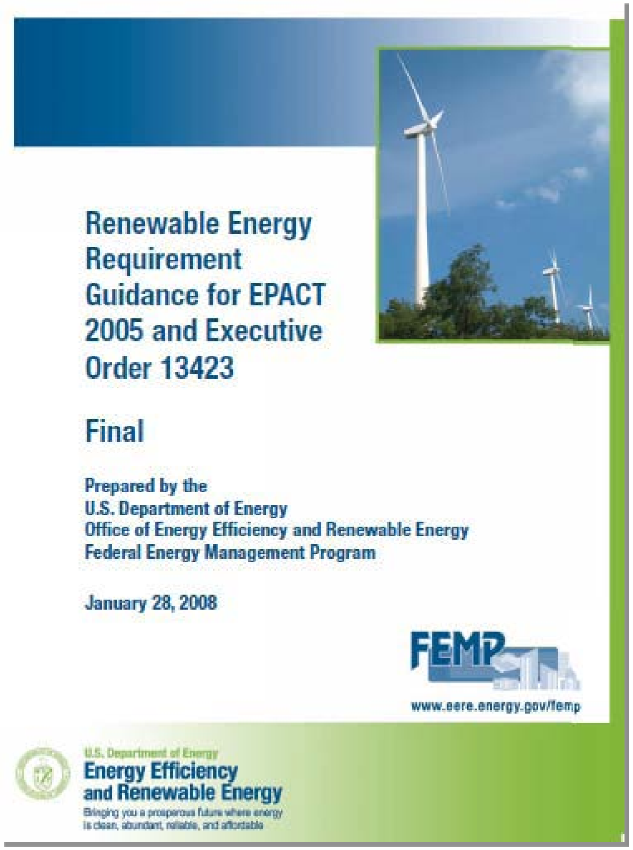
- 30% solar hot water in new buildings
- 0% fossil fuels by 2030 in new buildings
- 40 year analysis period for RE
- Facilitates ESPC for RE

Executive Orders

- **Executive Order. 13423**
  - ½ of RE goal must be "new"
  - Thermal counts in ½ new requirement
- **Executive Order 13514**
- **GHG accounting and sustainability plans**

Guidance Available from FEMP

- For on-site projects, agency must
  retain or replace RECs to show use
- Simply hosting a renewable project without RECs does not help meet Federal goals
- Excludes system mix energy and energy used to meet state RPS requirements
- Rules are stricter for GHG accounting than for EPACT 05 accounting



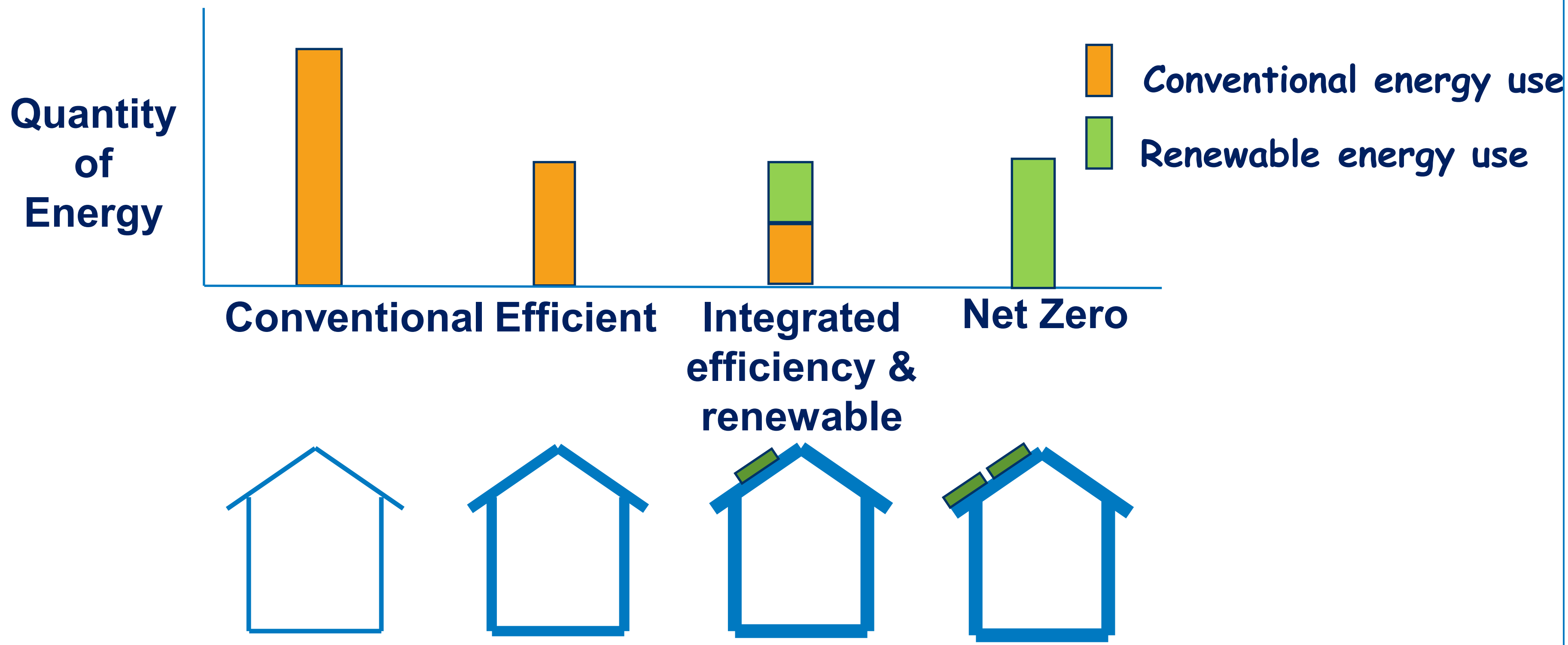
www1.eere.energy.gov/femp/pdfs/epact05_fedrenewenergyguid.pdf

Energy Efficiency

Renewable Energy

Any questions?

EE + RE = 0



Strive for 40-70% energy reduction

$1 spent on EE lighting = $6 of PV (an NPS project)

$1 spent on EE refrigeration = $2 of PV (an NPS project)

$1 spent on EE = $2 spent on RE (EIA Press Release Aug 2011)

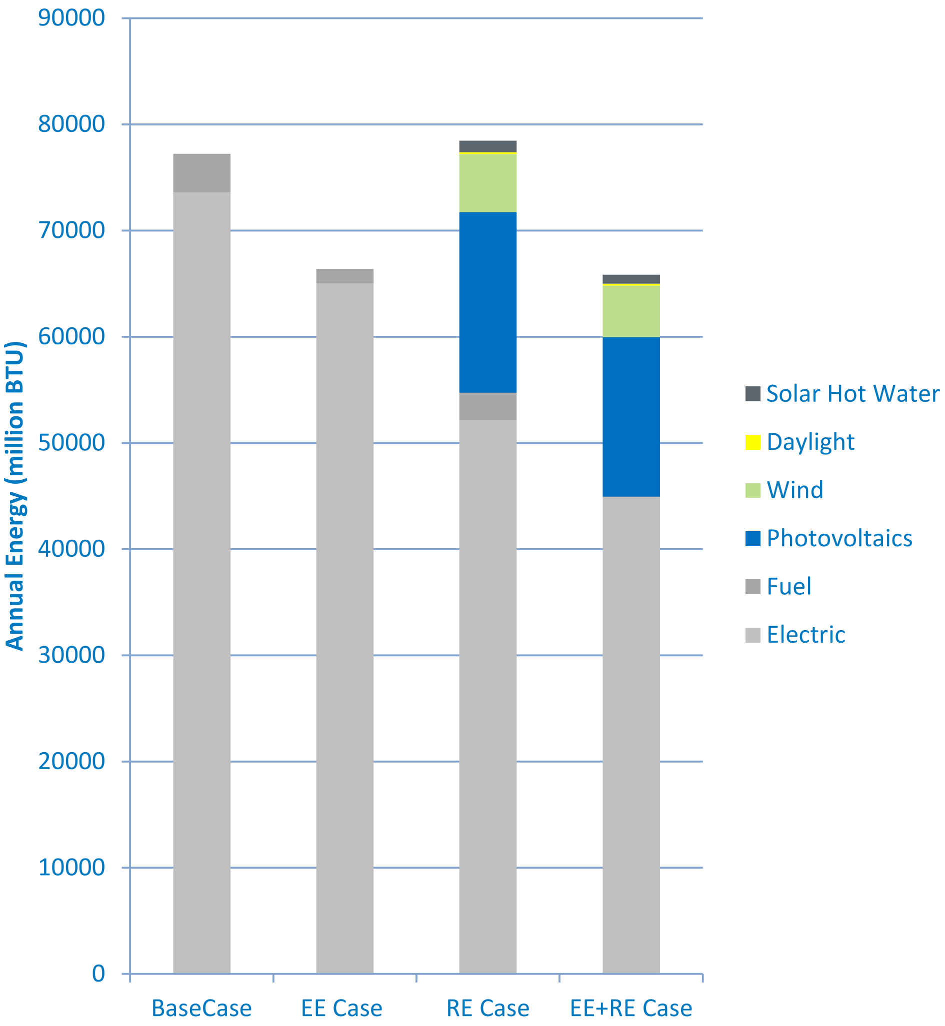
EE+RE Example: Camp Smith, HI

ARRA/FEMP Assessment

PNNL evaluated EE measures

NREL evaluated RE measures

Photo by DOE Federal Energy Management Program (FEMP), *NREL/PIX 17254*



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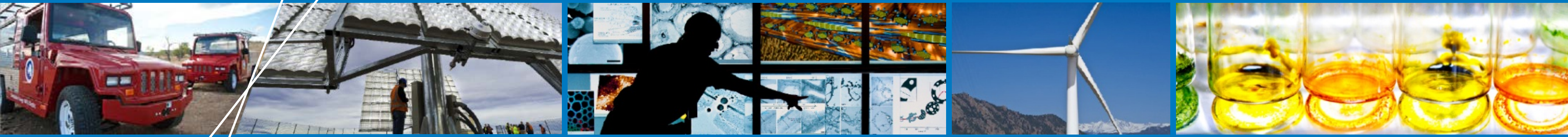


Photovoltaics

Photovoltaics (PV)

- Photovoltaic cells directly transform solar energy to an electrical energy
- DC converted to AC by inverter
- Solid-state electronics, no-moving parts

Photo from MREA, NREL/PIX 18707

Grid Connect PV System

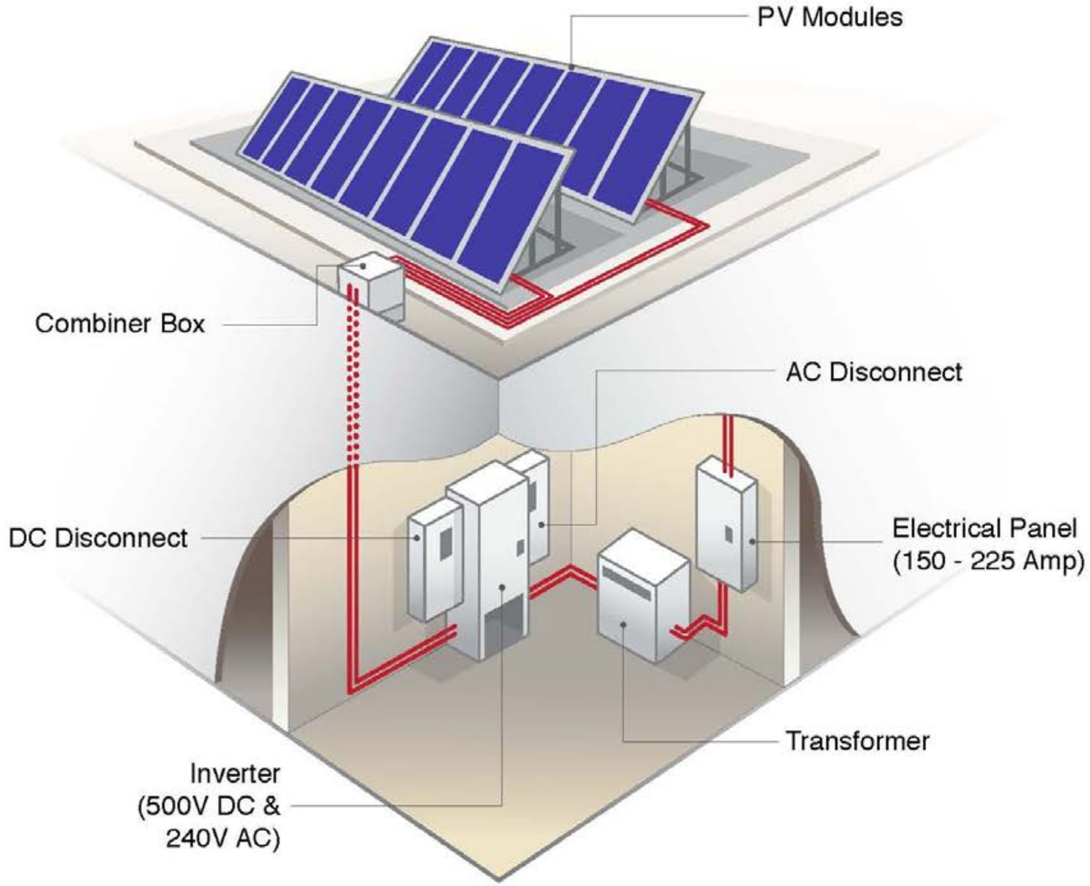


Image by Al Hicks, NREL

Flat Plate PV Systems

Arizona Public Service, Prescott, AZ

Photo from Arizona Public Service, NREL/PIX 13739

Dangling Rope Marina, Glen Canyon National Recreation Area, UT

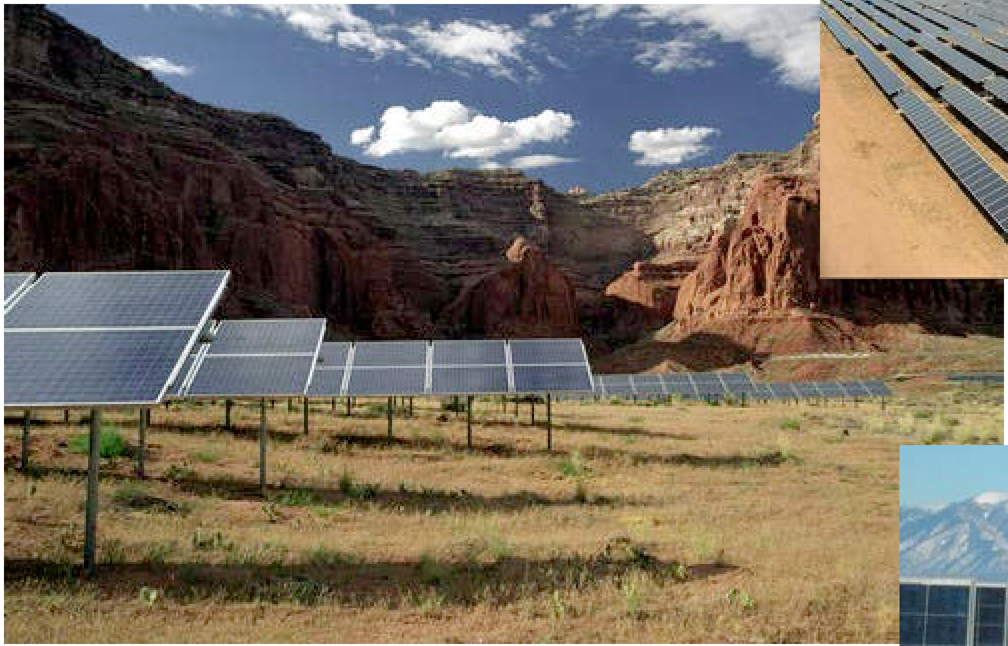
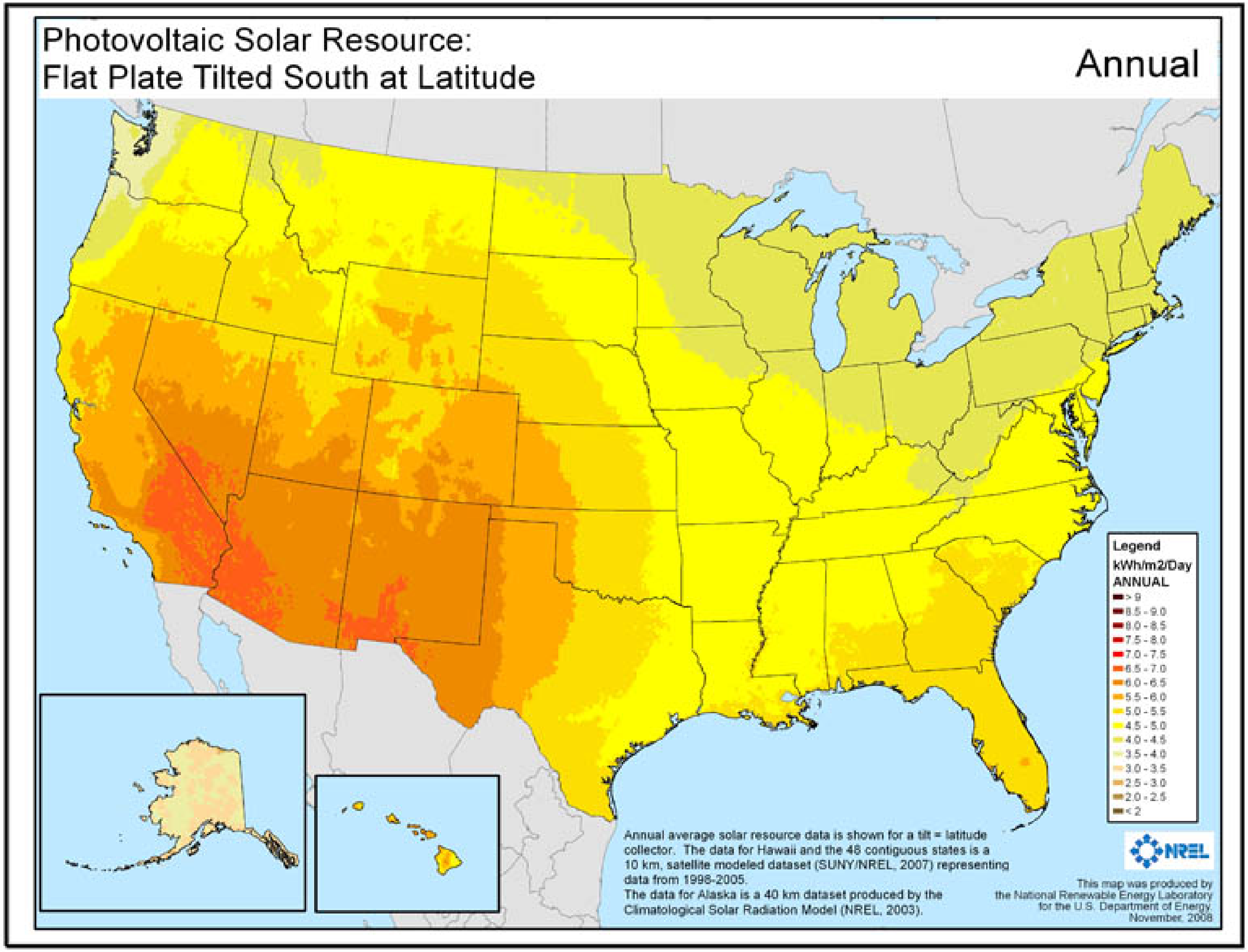


Photo by Warren Gretz, NREL/PIX 07990

Alamosa PV System, Alamosa, CO

Photo by Tom Stoffel, NREL/PIX 15558

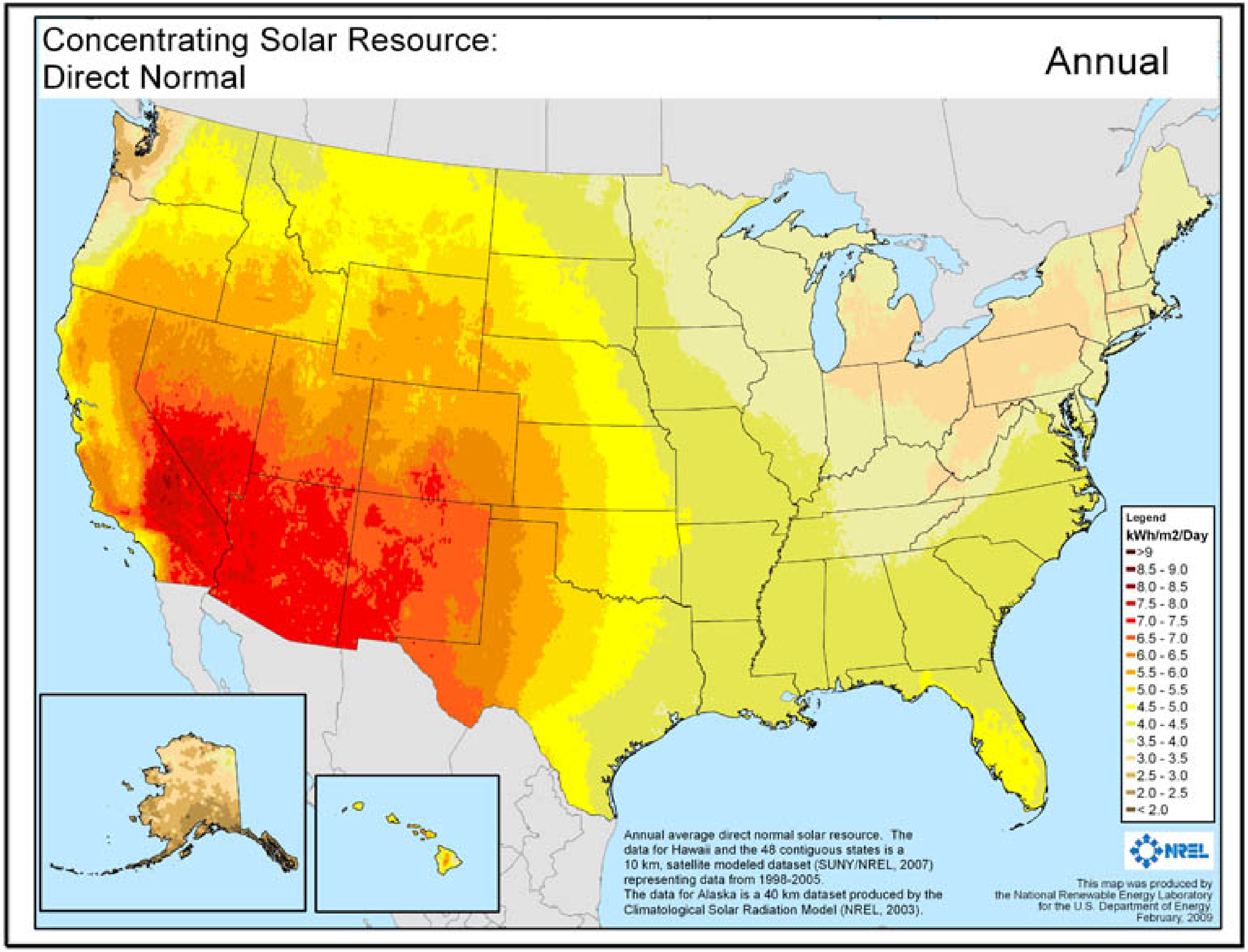
- **5 – 10 acres per MW for PV systems**
- **Land can be left as is or graded**


Photovoltaic Solar Resource:
Flat Plate Tilted South at Latitude
Annual
Legend
kWh/m2/Day
ANNUAL
> 9
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
< 2
Annual average solar resource data is shown for a tilt = latitude collector. The data for Hawaii and the 48 contiguous states is a 10 km, satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.
The data for Alaska is a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. November, 2008

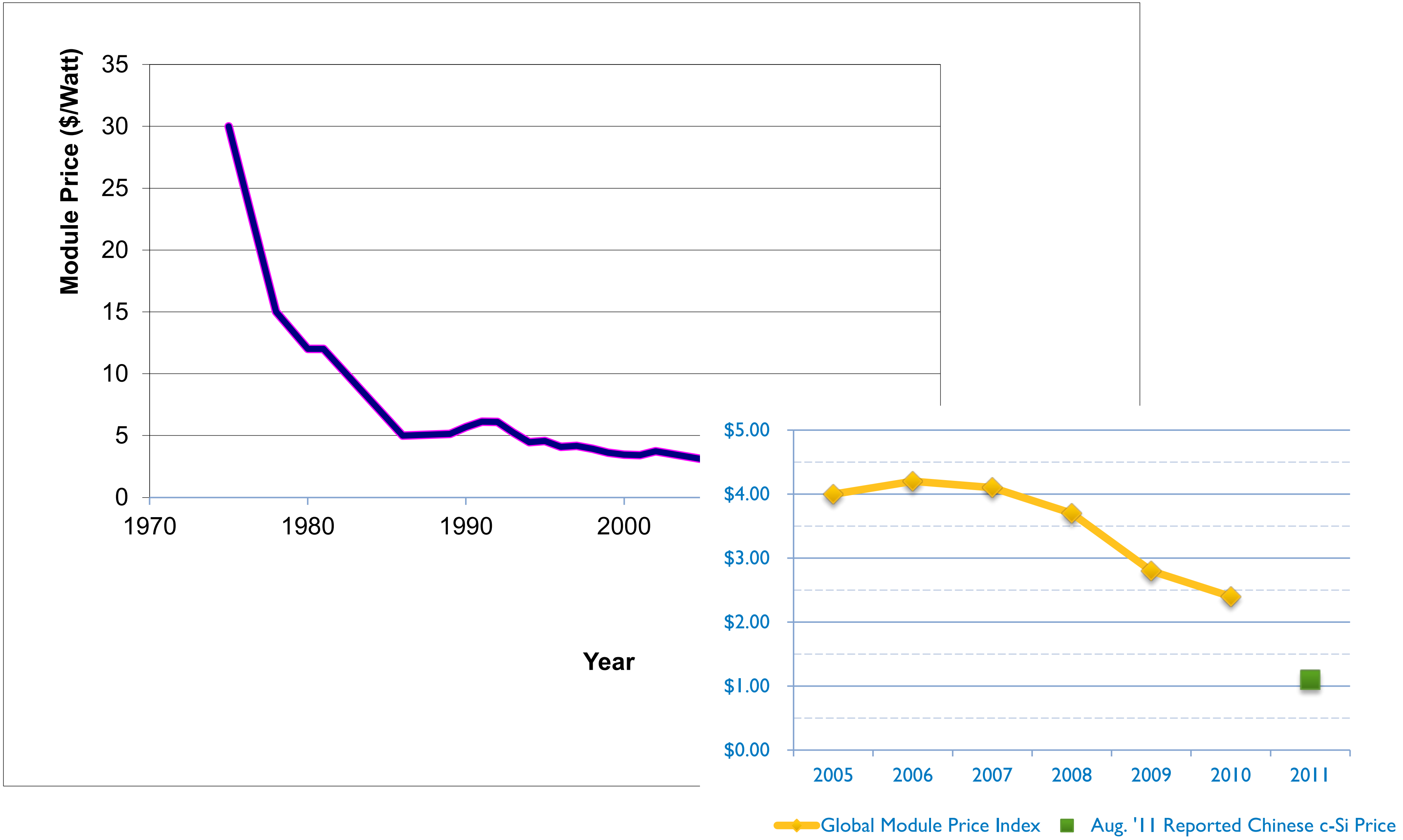
Concentrating PV Systems

Photo from David Parsons, NREL/PIX 06639

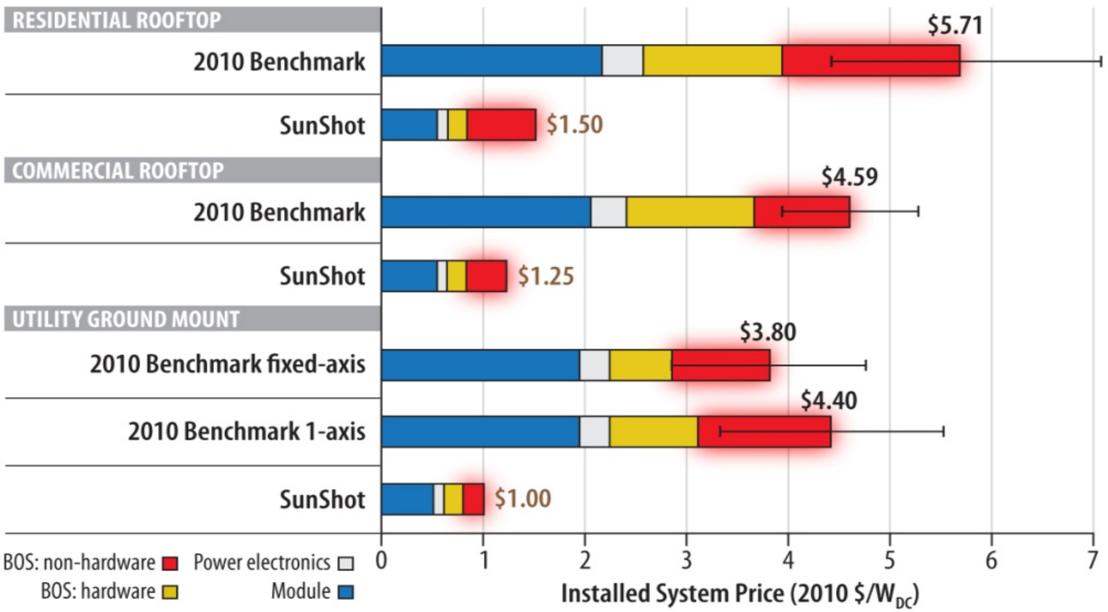
Reflective


Concentrating Solar Resource:
Direct Normal
Annual
Legend
kWh/m2/Day
>9
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
< 2.0
Annual average direct normal solar resource. The data for Hawaii and the 48 contiguous states is a 10 km, satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.
The data for Alaska is a 40 km dataset produced by the Climatological Solar Radiation Model (NREL, 2003).
NREL
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. February, 2009

Price of PV Modules



PV Cost, O&M, and Efficiency



PV System Type	Annual O&M Cost as a Percentage of Installed Cost
Ground Mounted - Fixed	0.17%
Ground Mounted - Tracking	0.35%

Efficiency = Power Out/Power In

Module Efficiencies	Single Crystal	14-19%
	Multi Crystal	13-17%
	Thin Film	6-11%
Balance of System Efficiency		77%

Efficiency vs. Size

- 1 kW of 15% eff. crystalline 71ft^2
- 1 kW of 9.5 % eff. amorphous 99ft^2
- 1 kW of 19.3% eff. hybrid 55ft^2

PV Operation and Maintenance

Table II. Maintenance cost as a percentage of capital investment

Year	Scheduled (%)	Unscheduled (%)	Total (%)
2002	0 08	0 01	0 09
2003	0 07	0 22	0 29
2004	0 06	0 04	0 10
2005	0 06	0 01	0 07
2006	0 04	0 03	0 07

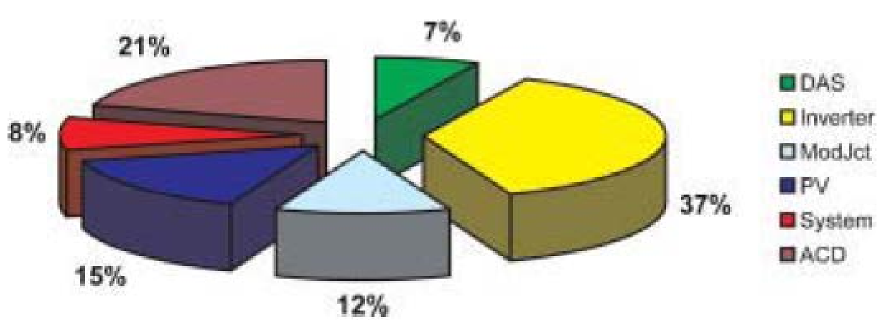


Figure 7. Unscheduled maintenance events by component

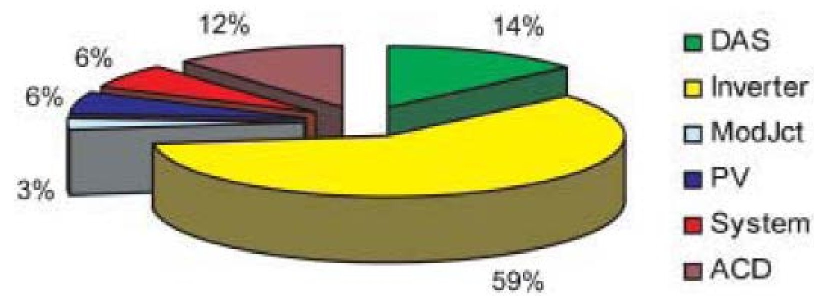


Figure 8. Unscheduled maintenance costs by category

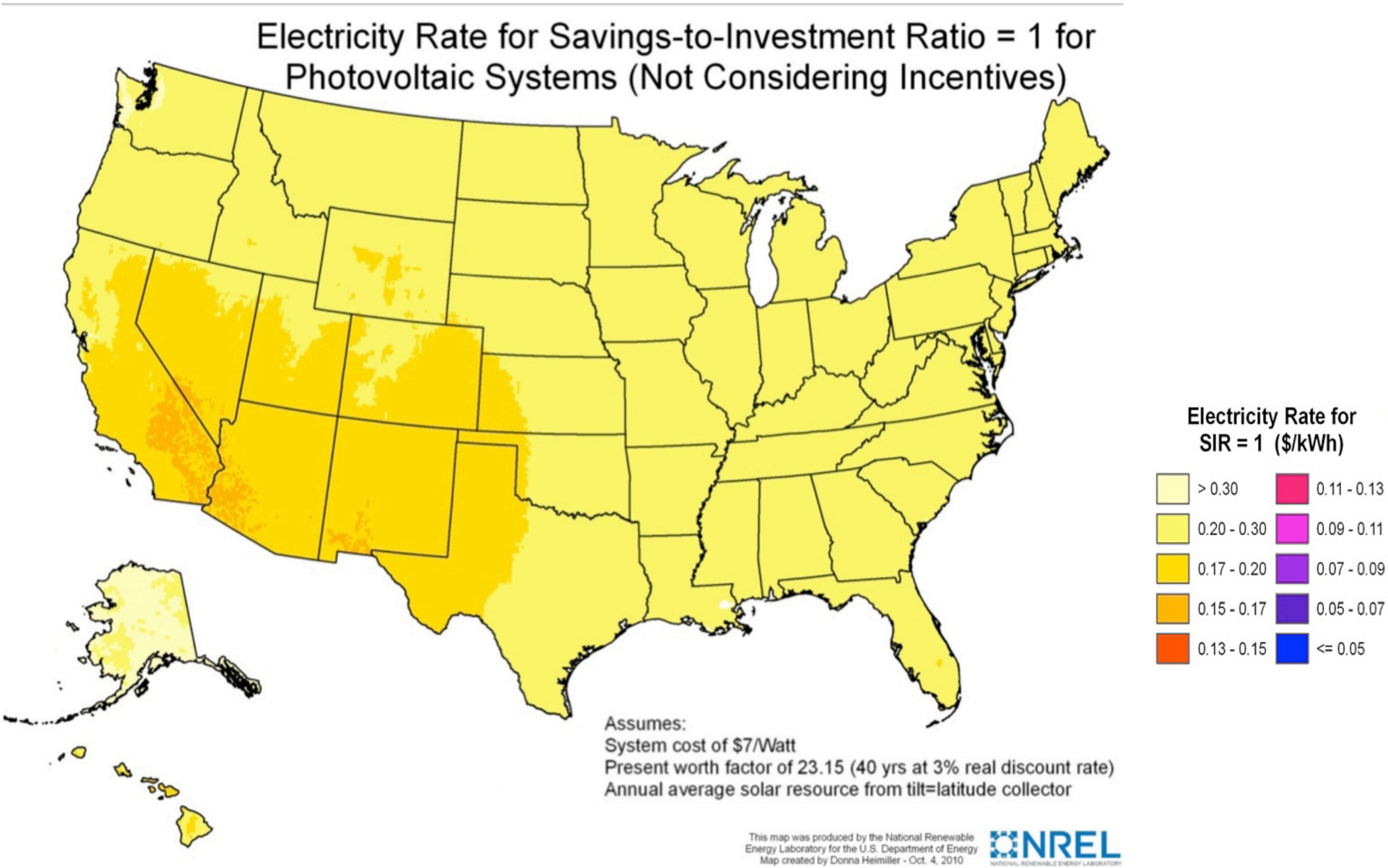
Tuscon Electric Power Data PROGRESS IN PHOTOVOLTAICS: RESEARCH AND APPLICATIONS
Prog. Photovolt: Res. Appl. 2008; 16:249–259
Published online 3 December 2007 in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/pip.800

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

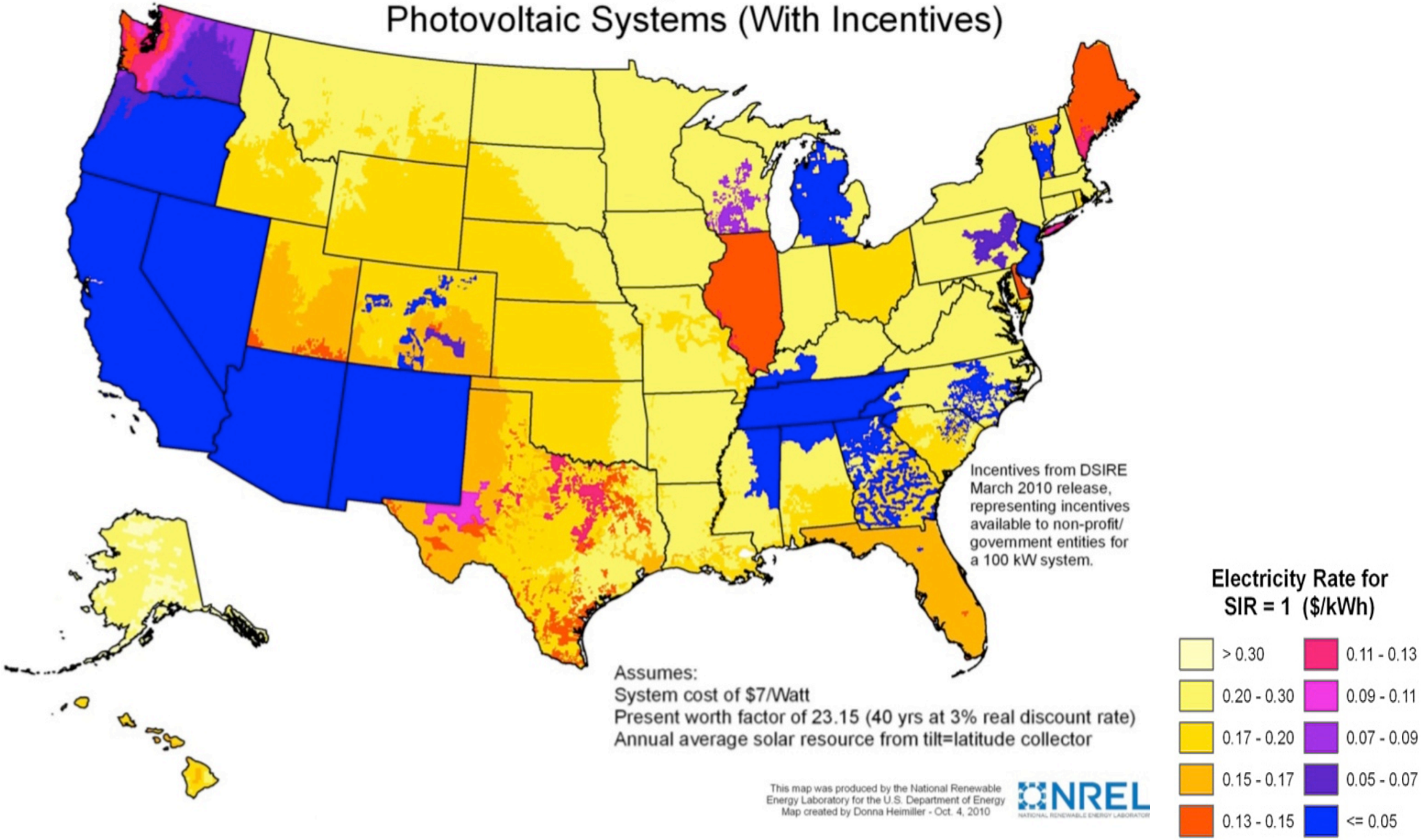
- 309 kWdc
- 1,584 PV modules
- SunLink racks minimum roof penetration
- Advanced Energy Solaron 333kW inverter
- Feasibility Study by NREL estimates:
  475 MWh/year delivery;
  $60k/year savings; $2.9million cost without any incentives
- Procured off GSA Schedule for
  complete PV systems

Results

- **Veterans Administration Loma Linda, CA**


Electricity Rate for Savings-to-Investment Ratio = 1 for Photovoltaic Systems (Not Considering Incentives)
Electricity Rate for SIR = 1 ($/kWh)
> 0.30
0.20 - 0.30
0.17 - 0.20
0.15 - 0.17
0.13 - 0.15
0.11 - 0.13
0.09 - 0.11
0.07 - 0.09
0.05 - 0.07
<= 0.05
Assumes:
System cost of $7/Watt
Present worth factor of 23.15 (40 yrs at 3% real discount rate)
Annual average solar resource from tilt=latitude collector
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 4, 2010
NREL

Electricity Rate for Savings-to-Investment Ratio = 1 for Photovoltaic Systems (With Incentives)



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. Reduces solar load on building. NEPA categorical exclusion.
  - On ALL new buildings – all new building 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 & brownfields.**
  - Saves green fields for nature.
  - IF installed on green fields minimize site disturbance, plant native low height vegetation as needed.

Customs and Border Protection

- **Solar-Powered SBI*net* Towers Secure the U.S. Southwest Border**
  - Solar panels
  - Battery system
  - Propane-fueled backup generator

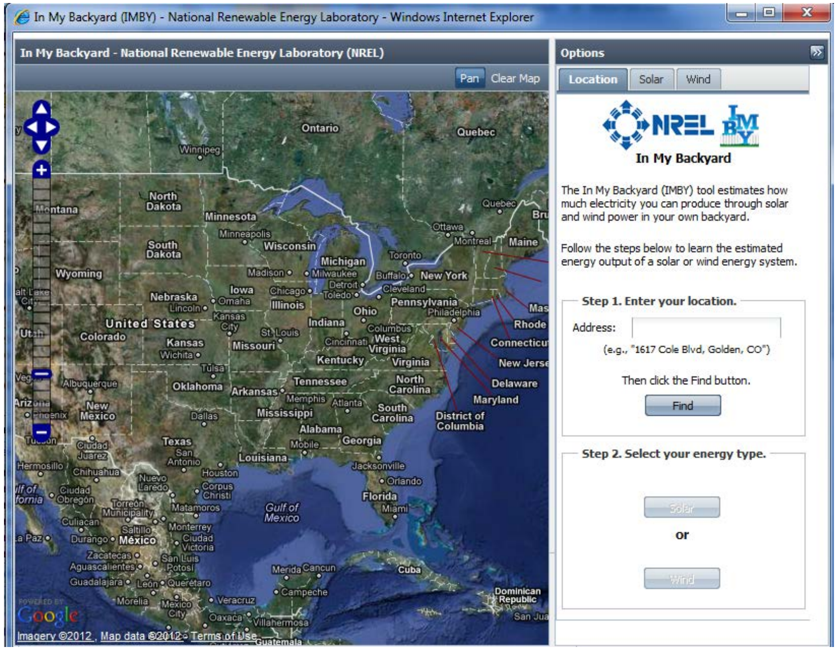
- **Federal funding and appropriations covered the installation costs and continues to cover testing and maintenance costs.**

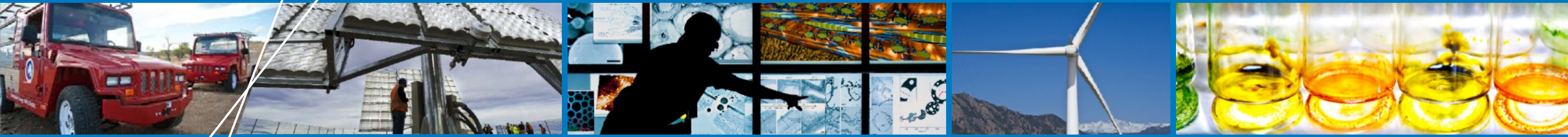
Photovoltaics Resources

- **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/

- **State and Utility Incentives and Utility Policies**
  - http://www.dsireusa.org

- **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/





Solar Water Heating

Solar Water Heating Applications

Photo from Gen-Con, Inc., NREL/PIX 09320

Photo by Amy Glickson, NREL/PIX 14167

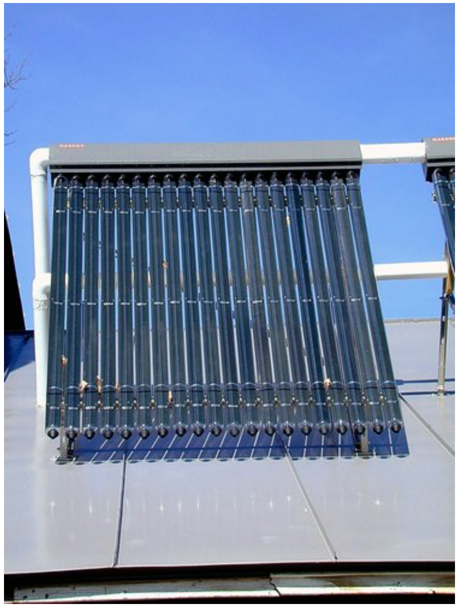
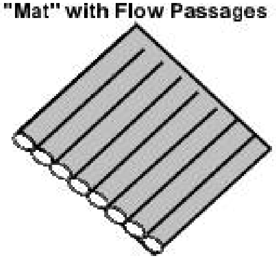


Photo from Alan Ford, NREL/PIX 09501

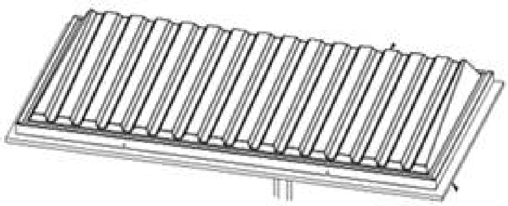
- **Low Temperature**
  - Swimming pool heating
- **Medium Temperature**
  - Domestic water and space heating
  - Commercial cafeterias, laundries, hotels
  - Industrial process heating
- **High Temperature**
  - Industrial process heating
  - Electricity generation

Solar Thermal Collector Types

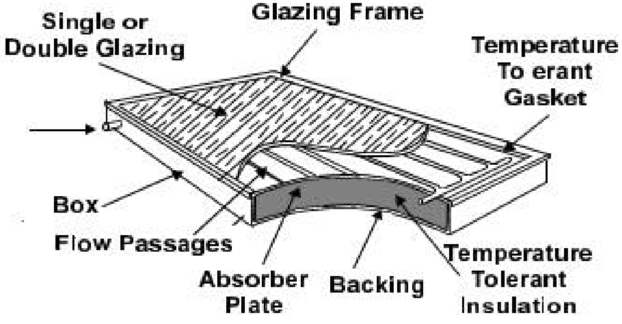
1. Unglazed



2. Low-Cost Plastic Flat Plate

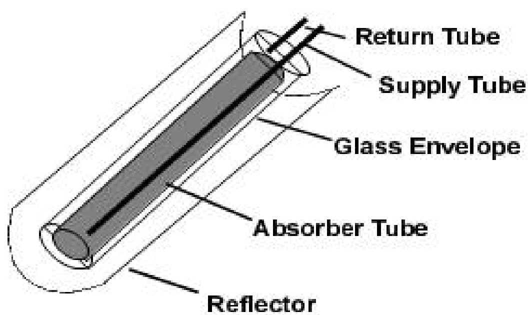


3. Glazed, Insulated Flat Plate

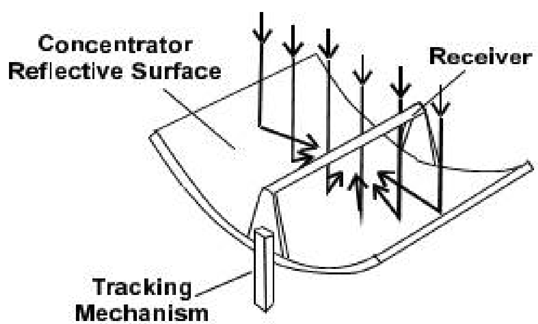


4. Integral Collector Storage (ICS)

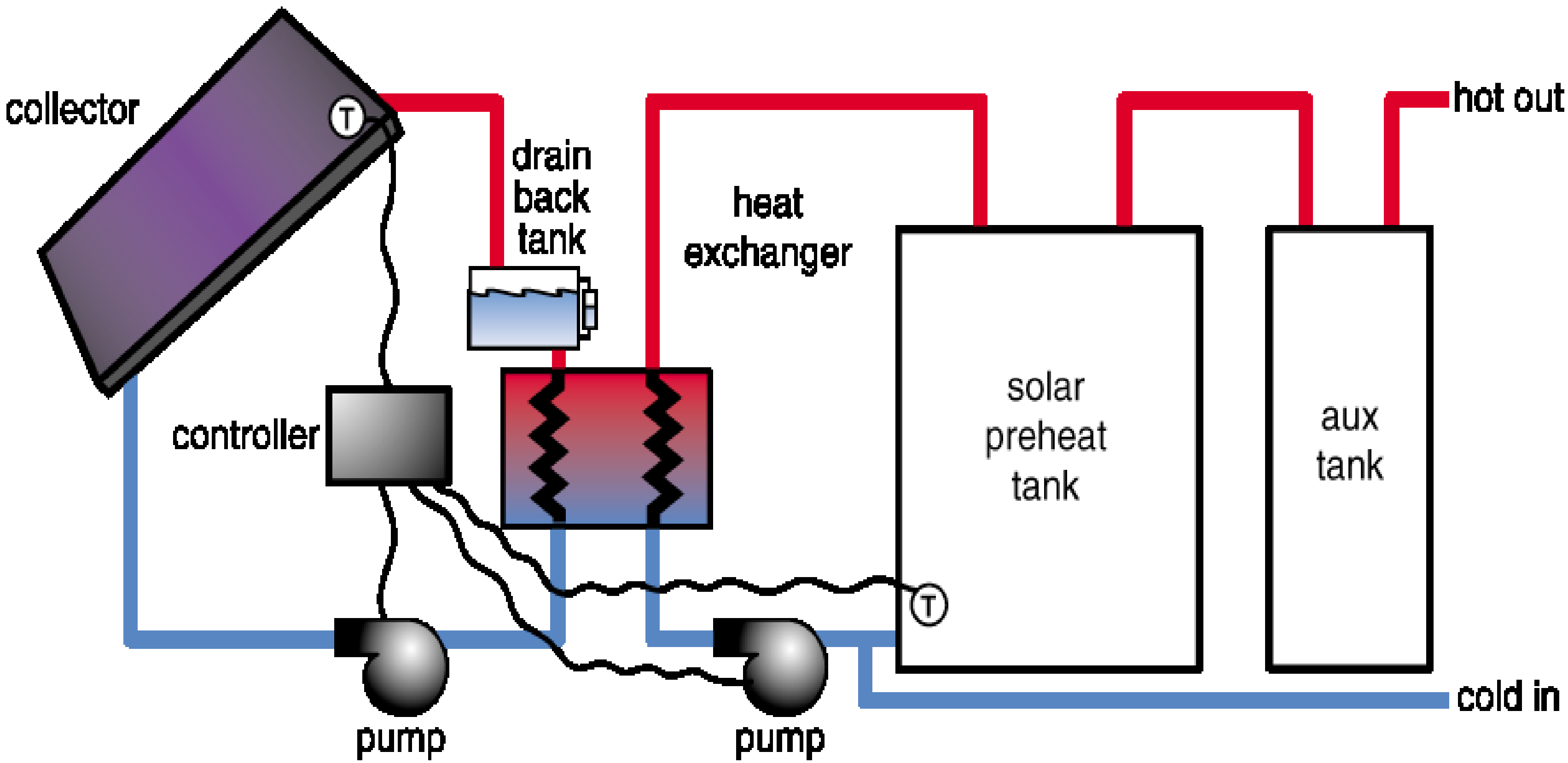
5. Evacuated Tube



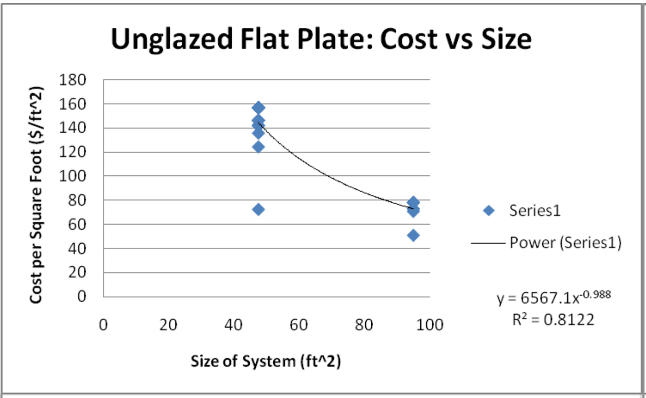
6. Parabolic Trough

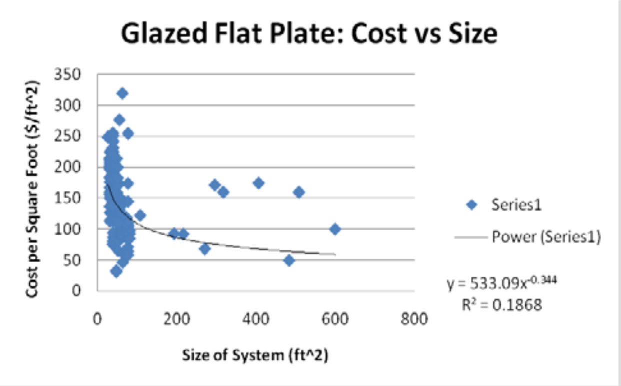


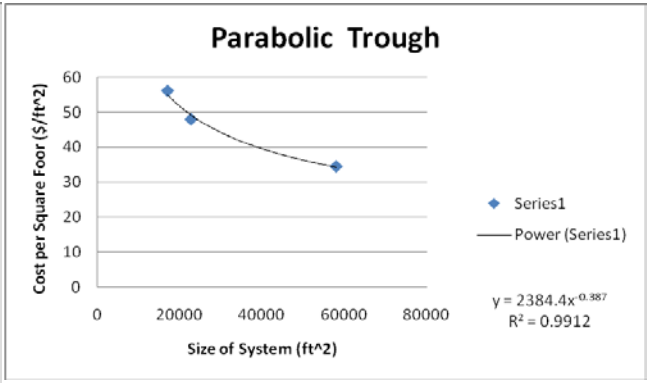
Solar Water Heating System

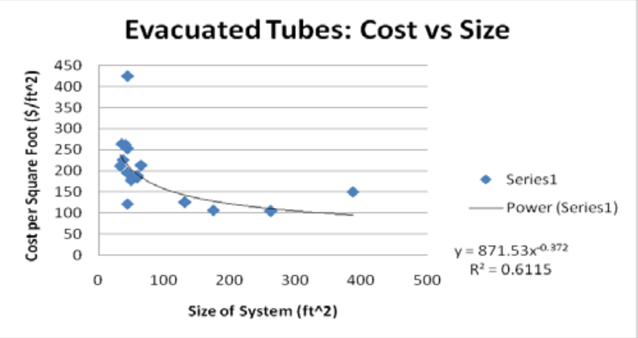


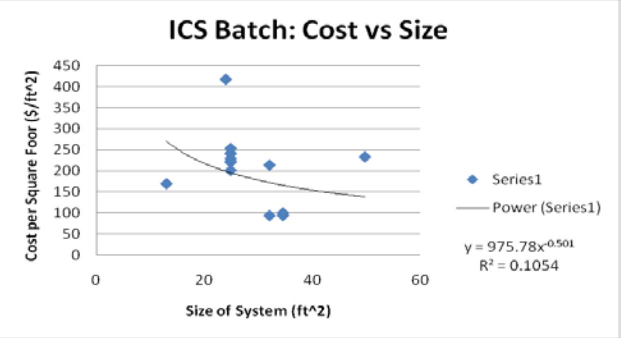
Solar Water Heating System Cost



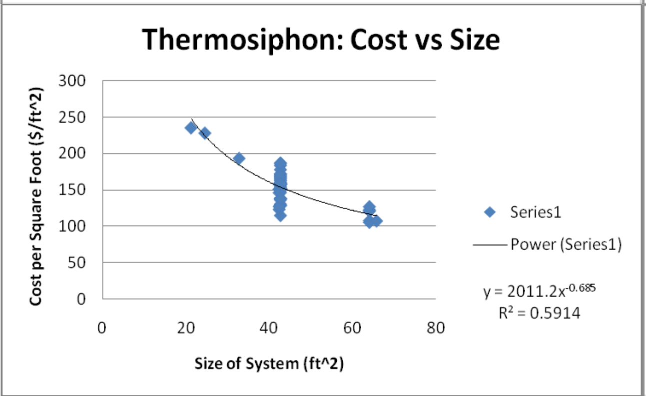


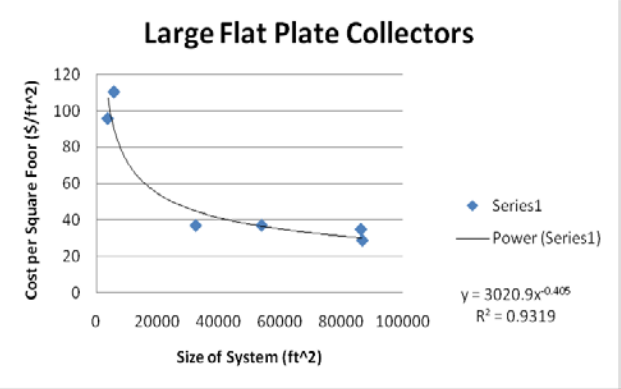






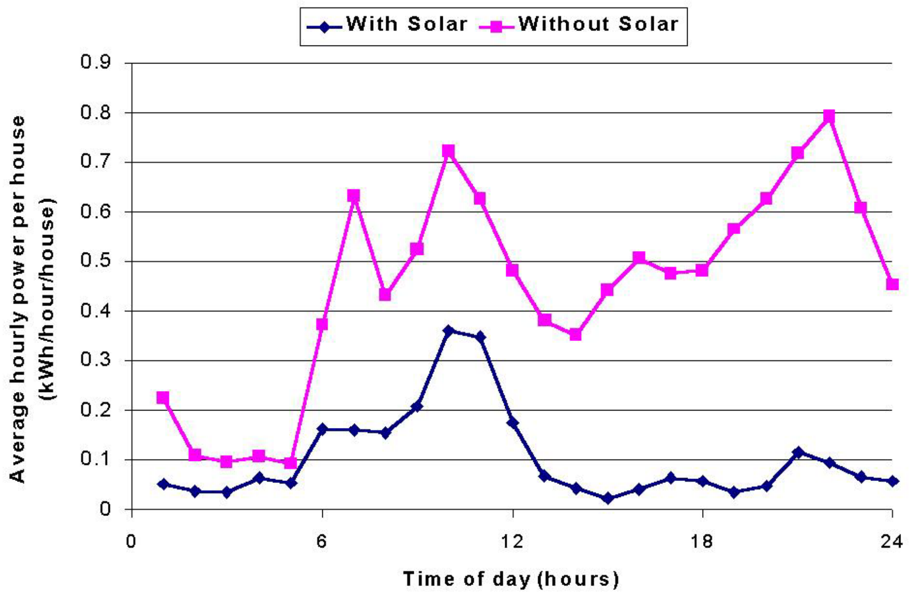
Average:
Around $150/sf

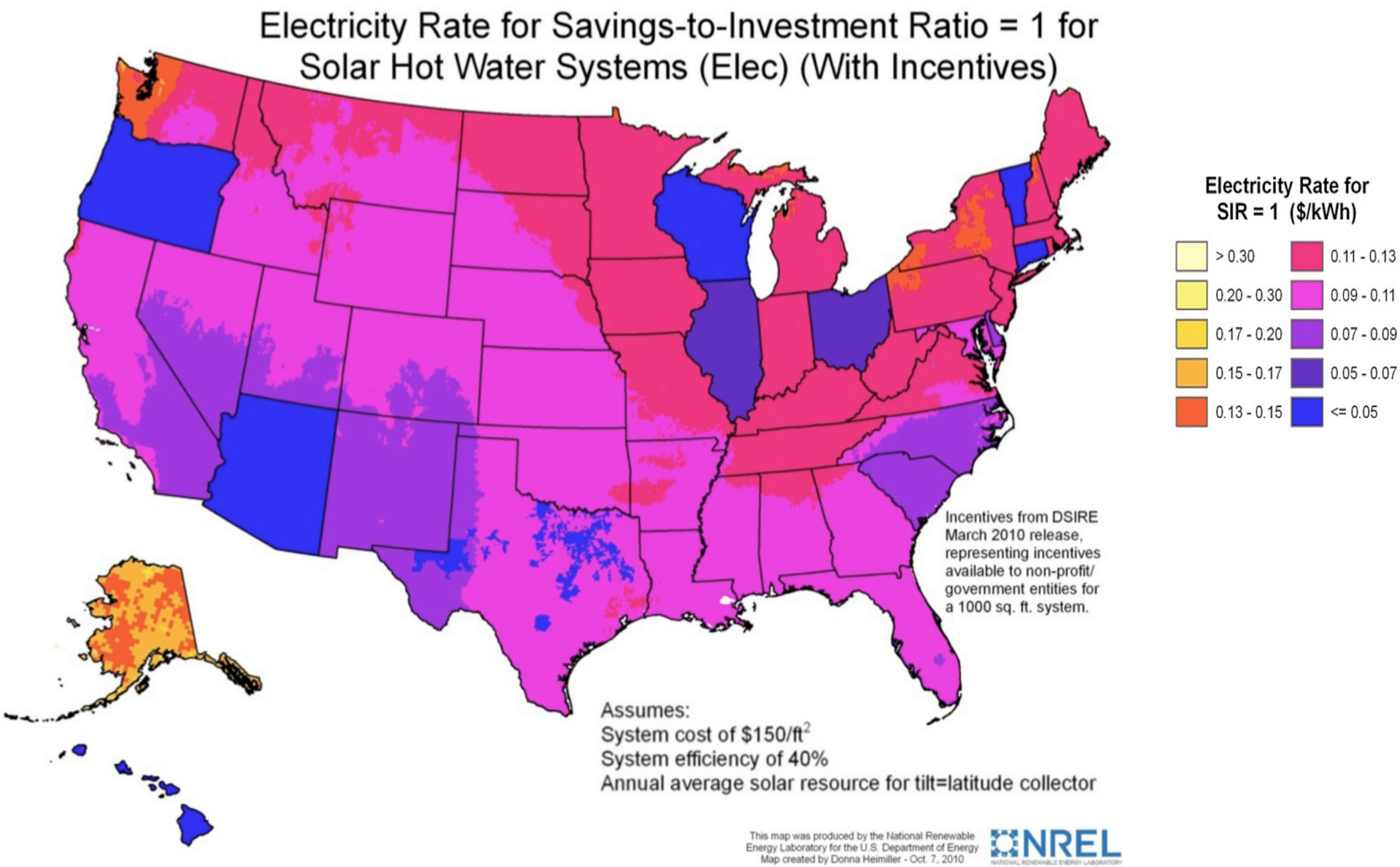




USCG Housing, Honolulu HI

- 62 units installed 1998
- Savings of 9,700 kWh/yr and $822/yr per system
- $4000/system cost
- Simple payback of 4 years (with rebate)




Electricity Rate for Savings-to-Investment Ratio = 1 for Solar Hot Water Systems (Elec) (With Incentives)
Electricity Rate for SIR = 1 ($/kWh)
> 0.30
0.20 - 0.30
0.17 - 0.20
0.15 - 0.17
0.13 - 0.15
0.11 - 0.13
0.09 - 0.11
0.07 - 0.09
0.05 - 0.07
<= 0.05
Incentives from DSIRE March 2010 release, representing incentives available to non-profit/ government entities for a 1000 sq. ft. system.
Assumes:
System cost of $150/ft²
System efficiency of 40%
Annual average solar resource for tilt=latitude collector
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 7, 2010
NREL

Solar Water Heating Resources

- **Design Tools**
  - RETScreen - Solar Hot Water
    - http://www.retscreen.net/ang/g_solarw.php
- **Fchart – Active and Passive Systems Analysis**
  - http://www.fchart.com/fchart/
- **Resources**
  - DOE Energy Efficiency and Renewable Energy Solar Energy Technologies Program
    - http://www1.eere.energy.gov/solar/solar_heating.html
  - FEMP Federal Technology Alerts
    - www.eere.energy.gov/femp/pdfs/FTA_solwat_heat.pdf
    - www.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf
  - FEMP Case Studies
    - www.eere.energy.gov/femp/technologies/renewable_casestudies.html
  - Resource maps
    - http://www.nrel.gov/gis/solar.html
  - Solar Radiation Data Manual
    - http://rredc.nrel.gov/solar/pubs/redbook

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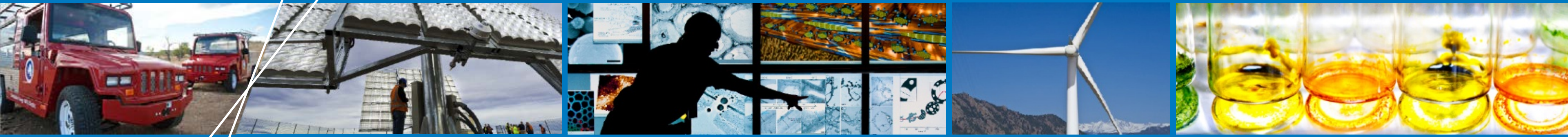


Concentrating Solar Power

Concentrating Solar Power Technology

Mirrors are used to reflect and concentrate sunlight onto receivers that collect this solar energy and convert it to heat.

Tower

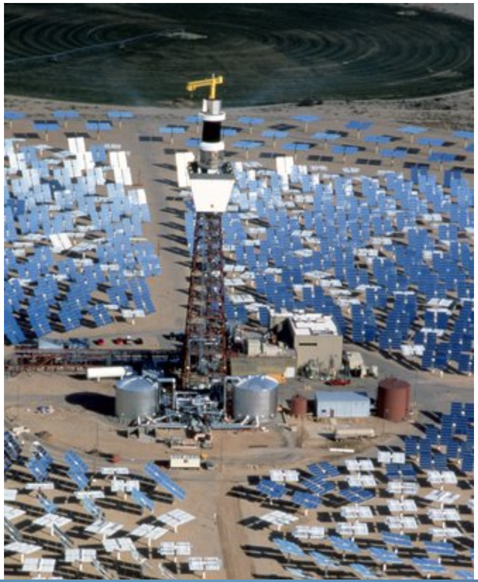


Photo by Hugh Reilly, NREL/PIX 02186

Trough

Photo by Warren Gretz, NREL/PIX 00327

Dish

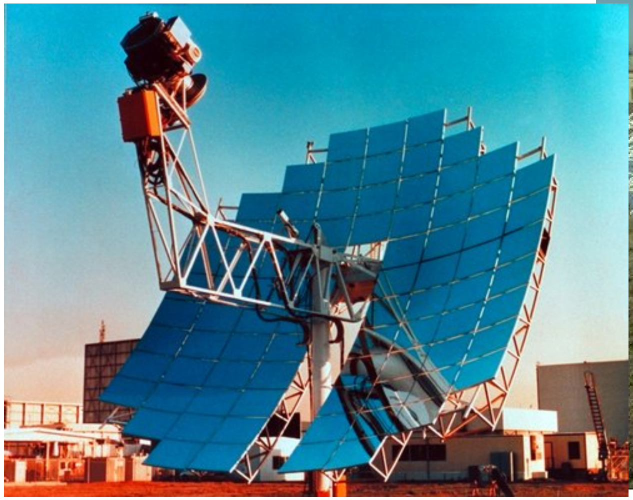


Photo from Sandia, NREL/PIX 08469

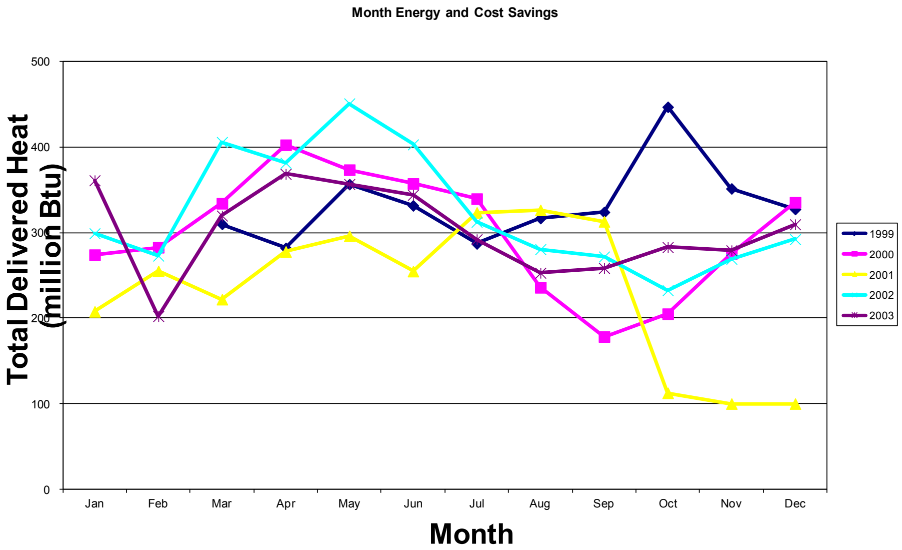
CSP Applications

- **Typically utility-scale applications**
- **Heat from CSP**
  - Generate hot water or steam
- **Steam**
  - Generate electricity

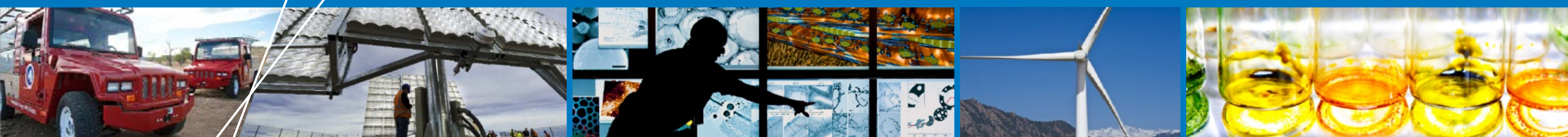
Photo by Geri Kodey, NREL/PIX 14383

RE in ESPC Example

Concentrating Solar Thermal (Industrial Process Heat)
Federal Correctional Institution - Phoenix, AZ



- 17,040 square feet of parabolic trough collectors
- 23,000 gallon storage tank
- Installed cost of $650,000
- Delivered 1,161,803 kWh in 1999 (87.1% of the water heating load).
- Saved $77,805 in 1999 Utility Costs



Solar Ventilation Air Pre-heat

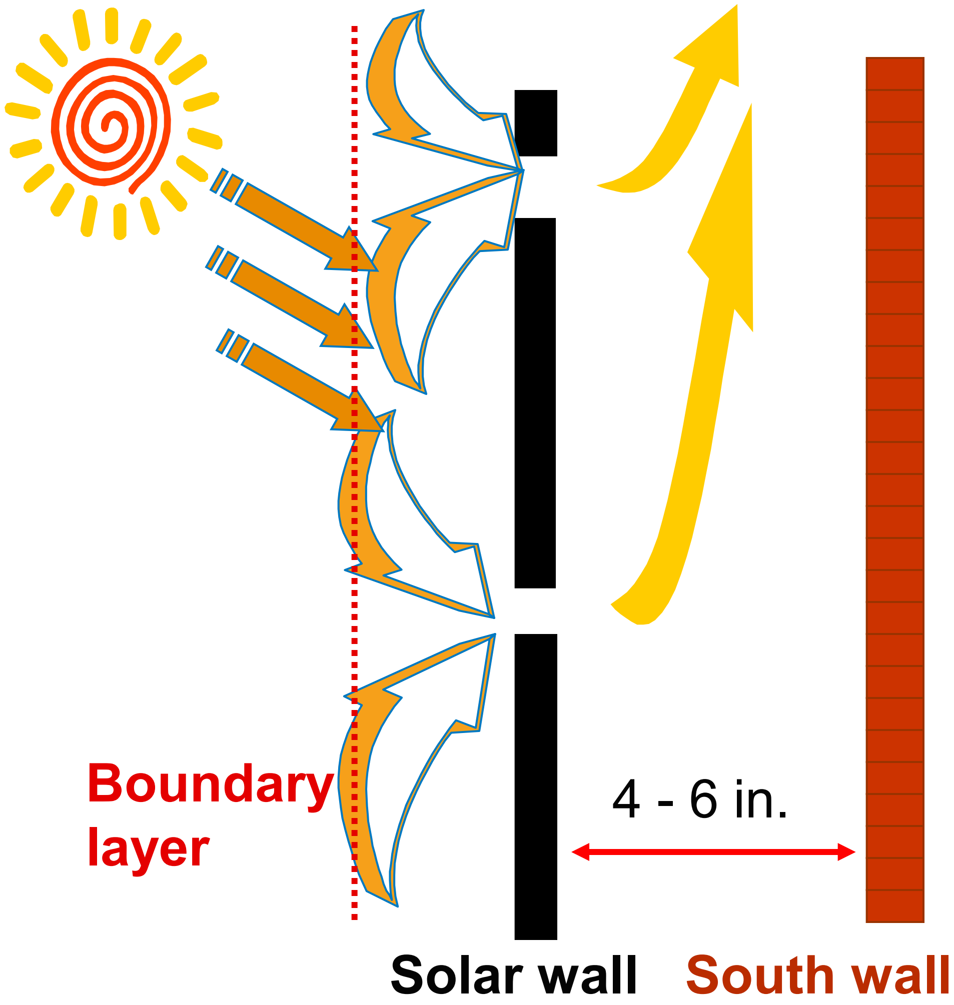
Project Considerations

- **Panels are aluminum or steel**
- **Roll-punch slots with three porosity options**
- **Corrugated to increase structural rigidity**

Photo by Warren Gretz, NREL/PIX 14383

- **High outdoor air ventilation requirement in heating dominated climate**
- **South-facing wall surface is best**
  - 45° of south gives 80%
- **Unshaded surface**
  - Especially during low winter sun angles
- **Dark collector color**
  - Black is best, other colors have efficiency loss up to 10%

Solar Vent Preheat Principle

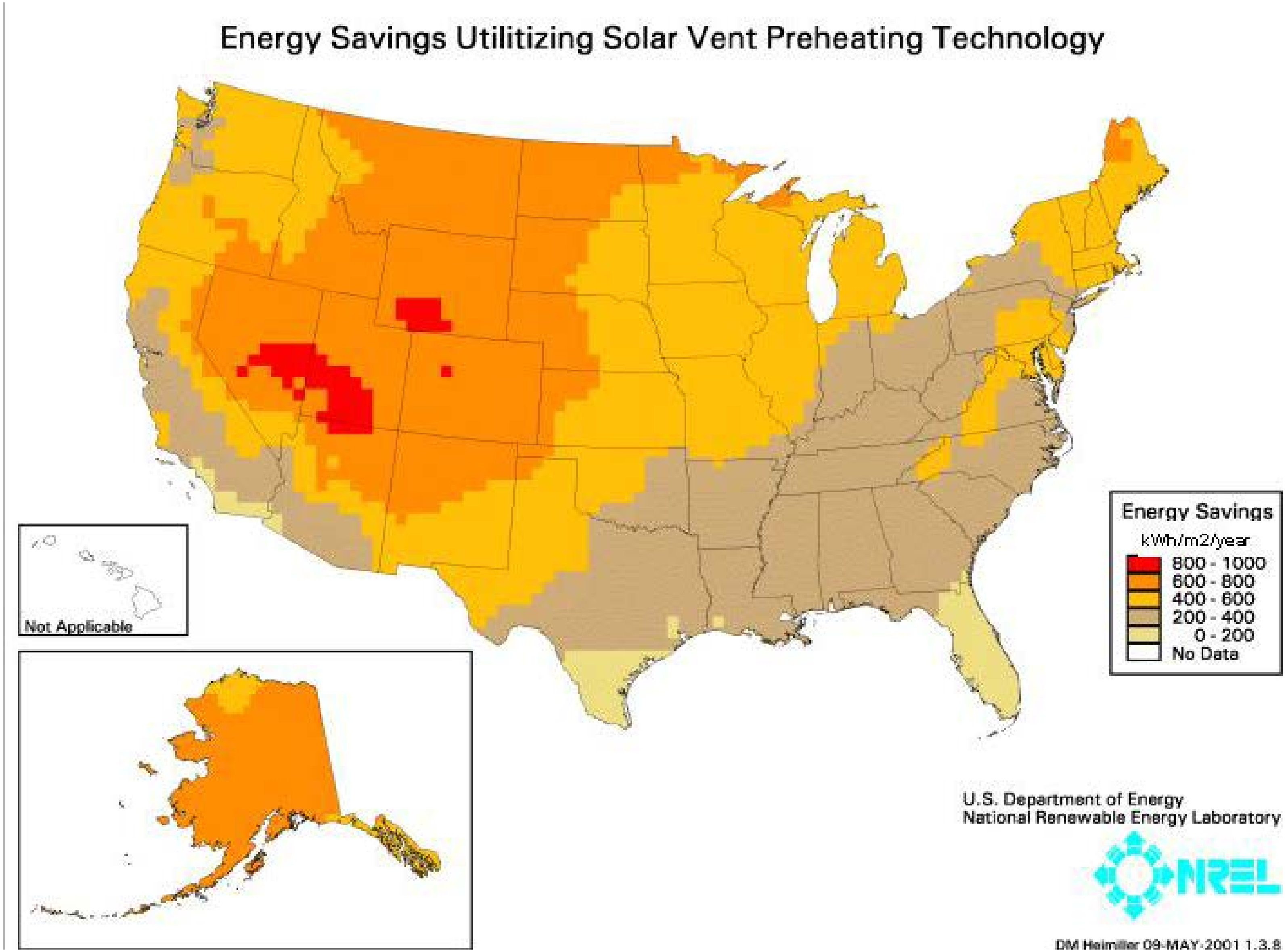


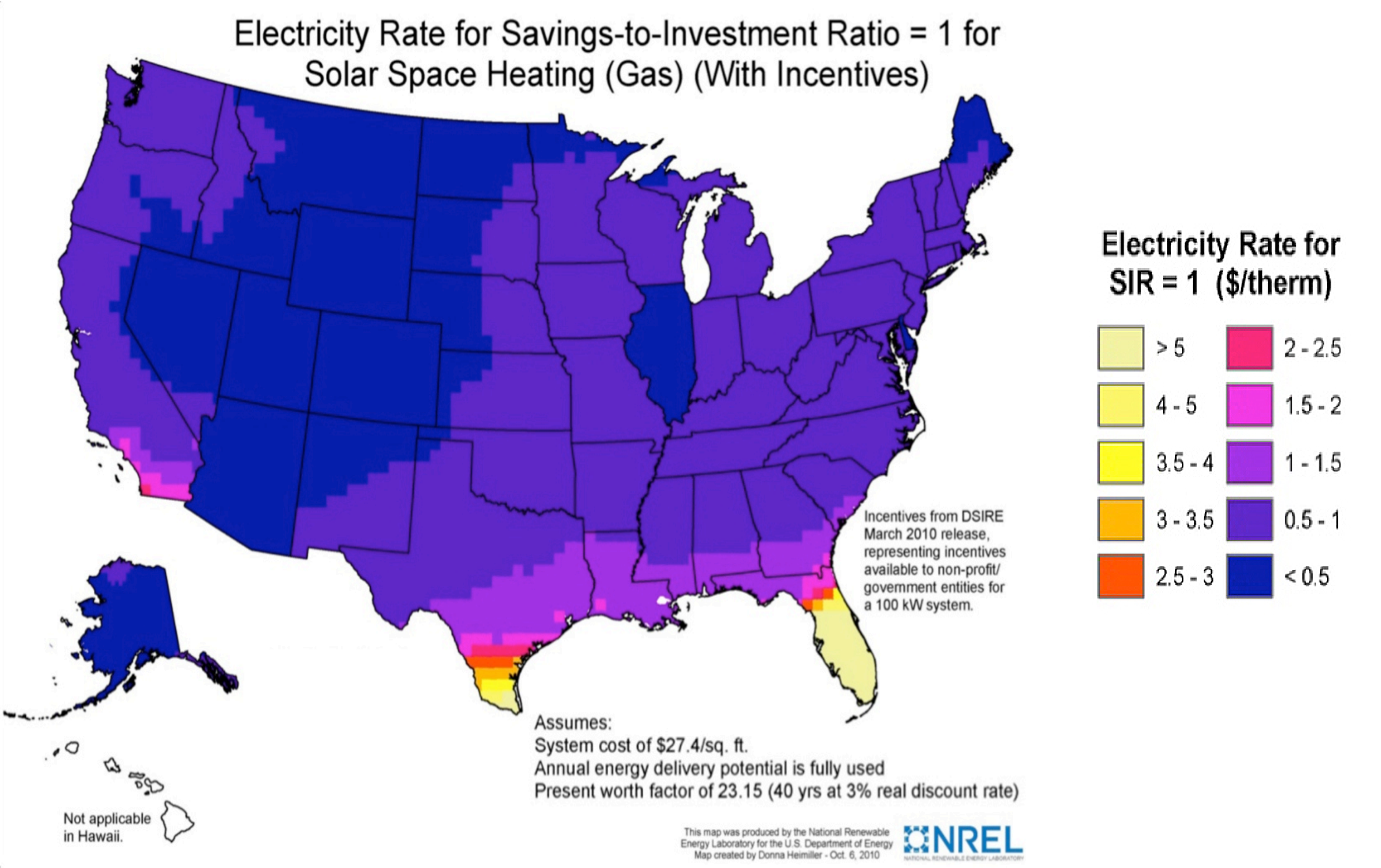
- Sun warms the collector surface
- Heat conducts from collector surface to thermal boundary layer of air (1 mm thick)
- Boundary layer is drawn into perforation by fan pressure before heat can escape by convection

System Components

- **Transpired solar collector**
  - Perforated sheet of corrugated metal
- **Air distribution**
  - Ductwork, fan and bypass damper
- **Controls**
  - Temperature and timeclock, or EMCS

Solar Vent Preheat Resource




Electricity Rate for Savings-to-Investment Ratio = 1 for
Solar Space Heating (Gas) (With Incentives)
Electricity Rate for
SIR = 1 ($/therm)
> 5
4 - 5
3.5 - 4
3 - 3.5
2.5 - 3
2 - 2.5
1.5 - 2
1 - 1.5
0.5 - 1
< 0.5
Incentives from DSIRE
March 2010 release,
representing incentives
available to non-profit/
government entities for
a 100 kW system.
Assumes:
System cost of $27.4/sq. ft.
Annual energy delivery potential is fully used
Present worth factor of 23.15 (40 yrs at 3% real discount rate)
Not applicable
in Hawaii.
This map was produced by the National Renewable
Energy Laboratory for the U.S. Department of Energy
Map created by Donna Heimiller - Oct. 6, 2010
NREL

Solar Ventilation Air Preheating: EPA Lab (Golden, CO)

- **Hazardous material storage building**
- **Installed in 2001**
- **296 sf, 2000 cfm**
- **58% measured efficiency**
- **Saves 60 Mil Btu/yr and $450/yr of natural gas**
- **Payback = 13 years**

Advantages

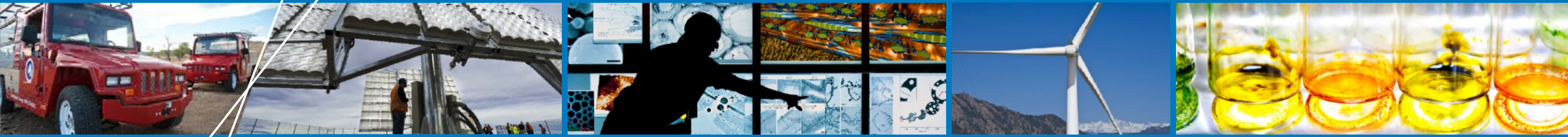
- **Relatively low cost for on-site renewable energy utilization**
- **Reliability of equipment and system**
  - Only moving part is the fan
  - Operates at ambient temperature
- **Very low maintenance**
- **High efficiency**
- **No storage**

Photo by Patrick Corkery, NREL/PIX 17424

Photo by Dennis Schroeder, NREL/PIX 17825

Solar Vent Preheat Resources

- **FEMP Federal Technology Alert**
  - www.eere.energy.gov/femp/pdfs/FTA_trans_coll.pdf
  - Solar Ventilation Preheating Resources and Technologies
    - http://www1.eere.energy.gov/femp/technologies/renewable_svp.html
- **NREL**
  - Solar Process Heat
    - http://www.nrel.gov/learning/re_solar_process.html
  - Solar Space Heating Maps
    - http://www.nrel.gov/gis/femp.html#space
- **Conserval Systems, Inc.: SOLARWALL®**
  - www.solarwall.com/sw/solarwall.html
- **ATAS International, Inc.: InSpire™**
  - www.atas.com
- **American Solar Inc.: Solar Thermal Tile System**
  - www.americansolar.com
- **RETScreen® International Clean Energy Project Analysis Software**
  - www.retscreen.net



Passive Solar in New Construction

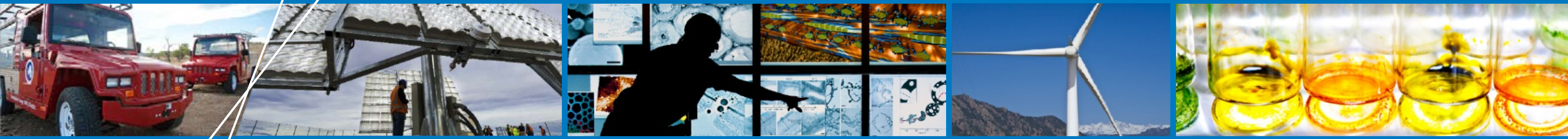
Passive Solar

- **Types:**
  - Direct Gain
  - Sunspace
  - Thermal Storage Wall (Trombe Wall)
- **For new construction, in areas with low internal heat gain**
- **South-facing Solar Apertures**
- **Added thermal mass to absorb heat and release at night**
- **Controls such as operable shades and windows**

Trombe Wall, NREL. *Photo by Warren Gretz, NREL/PIX 01693,*

Daylighting

- Lighting accounts for 25% of total electricity used in Federal sector
- Daylighting uses windows & skylights in conjunction with automatic light controls to minimize the need for electric lighting during daylight hours
- Daylighting combined with lighting controls can reduce lighting energy consumption by 40 -60%



Wind

Wind Sizes and Applications

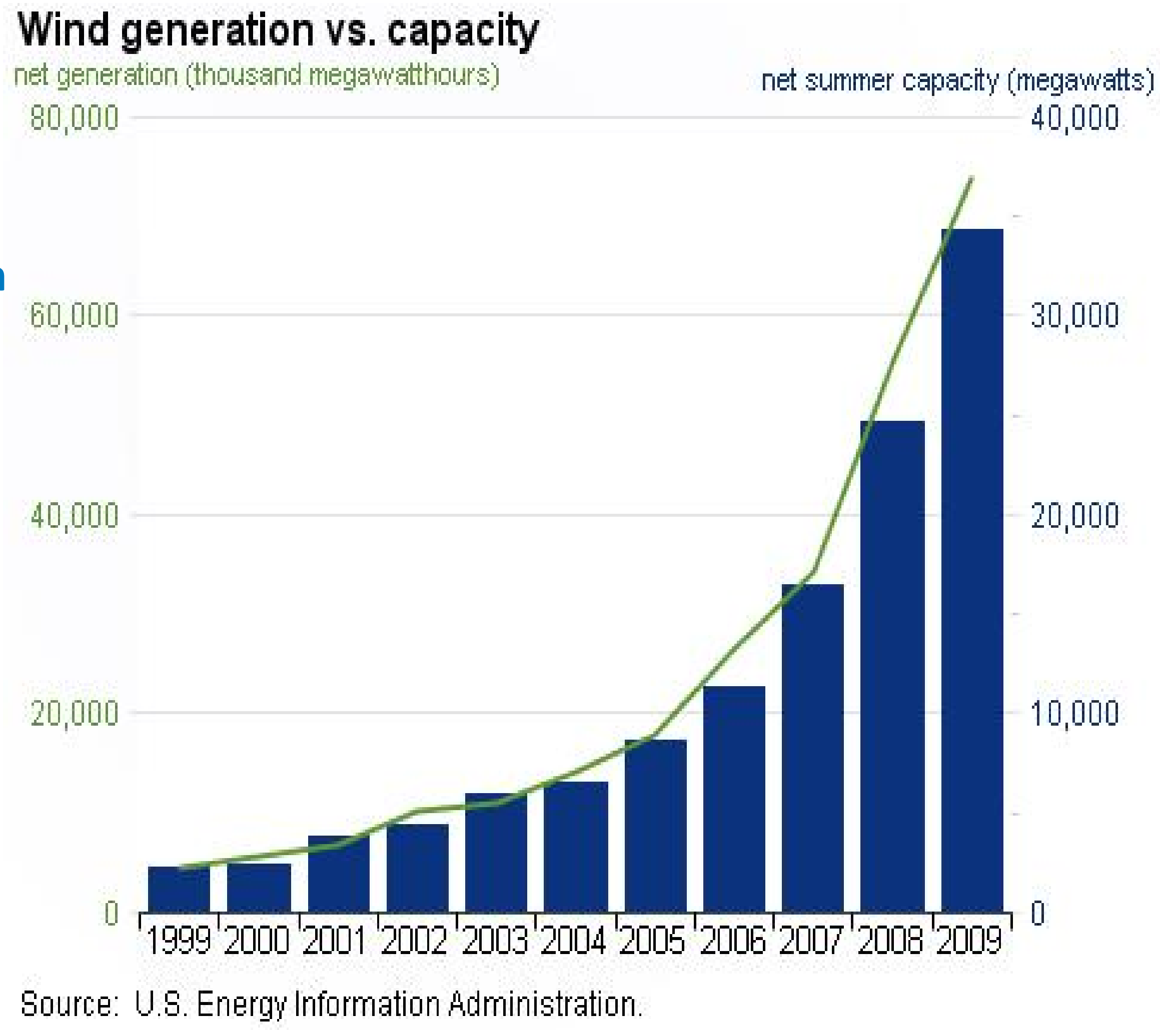
Small (≤10 kW)
- Homes
- Farms
- Remote Applications

  (e.g. water pumping, telecom sites, icemaking)

Intermediate (10-250 kW)
- Village Power
- Schools, businesses
- Hybrid Systems
- Distributed Power

Large (660 kW - 2+MW)
- Central Station Wind Farms
- Distributed Power
- Community Wind

Wind Generation in the U.S.

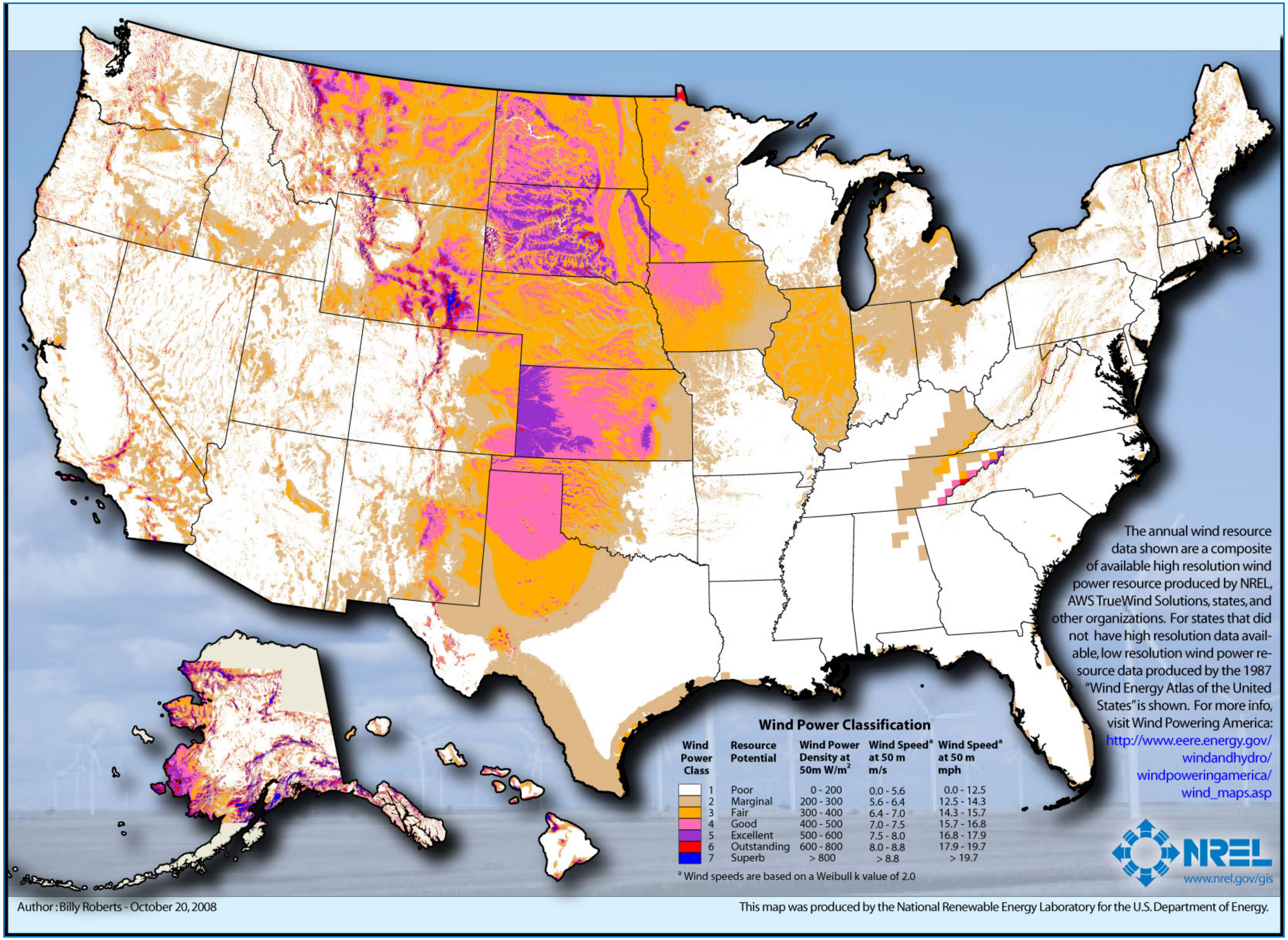


Warren Air Force Base, Cheyenne

- 600 kW wind turbines
- $2.5 million installed
- Generates energy to power 522 households on base
- Avoids 5,000 tons/year in GHG emissions
- Saves $3 million in energy costs
  over 20 years
- Additional capacity planned

RE in ESPC Example - BOP Federal Correctional Institution - Victorville, CA

- **Awarded 09/03**
- **Initial capital investment $5.4M, 19 year term with NORESCO**
- **Scope includes HVAC controls upgrade, 750 kW wind turbine, and 74.5KW PV Carport**
- **First ESPC financed wind turbine**
- **SCE provided RE generation financial incentive $4/W**
- **Escrow account for wind turbine maintenance**



The annual wind resource data shown are a composite of available high resolution wind power resource produced by NREL, AWS TrueWind Solutions, states, and other organizations. For states that did not have high resolution data available, low resolution wind power resource data produced by the 1987 "Wind Energy Atlas of the United States" is shown. For more info, visit Wind Powering America:
http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_maps.asp
Wind Power Classification
Wind Power Class | Resource Potential | Wind Power Density at 50m W/m² | Wind Speed[a] at 50 m m/s | Wind Speed[a] at 50 m mph
1 Poor 0 - 200 0.0 - 5.6 0.0 - 12.5
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb > 800 > 8.8 > 19.7
[a] Wind speeds are based on a Weibull k value of 2.0
NREL
www.nrel.gov/gis
Author: Billy Roberts - October 20, 2008
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.

Installed Costs and O&M Costs

Installed Costs	
< 500kW	$2500 to $3500/kW
>500kW	$2000/kW
Operation and Maintenance Costs	
< 500kW	$0.035/kWh
>500kW	$0.025/kWh

These numbers can be used for feasibility calculations. There is huge variability depending on the current market and the site selected.

Wind for the Coast Guard

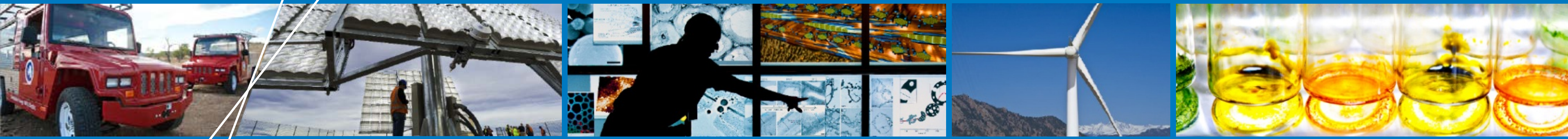
- Generate 2.4 kW at 24 mph wind
- 1 kW for augmenting power at telecom sites

Wind Resources

- **AWEA Web site**
  - http://www.awea.org
- **NWTC Web site**
  - http://www.nrel.gov/wind
- **National Wind Coordinating Collaborative**
  - http://www.nationalwind.org
- **Utility Wind Interest Group site**
  - http://www.uwig.org
- **WPA Web site**
  - http://www.windpoweringamerica.gov
- **Homepower Web Site**
  - http://www.homepower.com
- **Windustry Project**
  - http://www.windustry.com
- **Best Links**
  - www.fresh-energy.org

Other Wind Resources

- **American Wind Energy Association http://www.awea.org/**
  - AWEA Small Wind Toolbox
    - **www.awea.org/smallwind/**
- **AWS Scientific Inc. "Wind Resource Assessment Handbook" produced for the National Renewable Energy Laboratory, Subcontract number TAT-5-15283-01, 1997**
  - http://www.nrel.gov/publications
- **Wind Energy Explained;J. F. Manwell, J. G. McGowan, A. L. Rogers; John Wiley & Sons Ltd. 2002.**
- **Wind Power; Gipe, Paul; Chelsea Green Publishing, 2004**



Biomass

What is Biomass in Terms of Renewable Technologies?

- Wood and wood waste
- Agricultural waste
- Bagasse
- Food processing residues
- Animal wastes
- Municipal solid waste
- Energy crops
- Landfill gas
- Methane from waste and wastewater treatment

Photo by Warren Gretz NREL/PIX 11597

Range of Bioenergy

Photo by Warren Gretz, NREL/PIX 11597

- Trees
- Grasses
- Agricultural Crops
- Residues
- Animal Wastes
- Municipal Solid Waste
- Algae
- Food Oils, Waste Oils

Conversion Processes

- Combustion
- Gasification
- Pyrolysis
- Co-firing
- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Trans-esterification

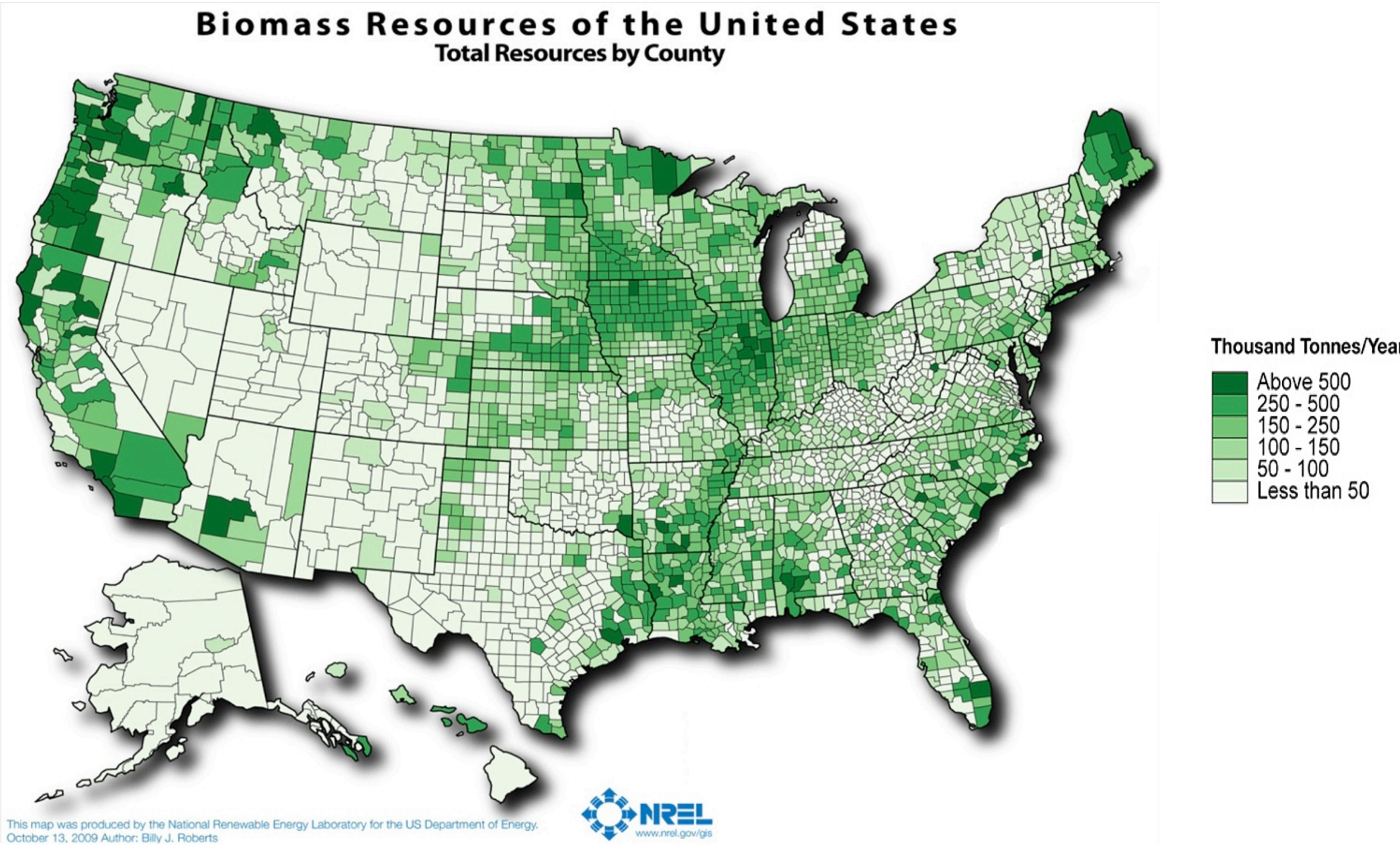
Products

Fuels
- Ethanol
- Biodiesel
- "Green" Gasoline & Diesel

Power
- Electricity
- Heat

Chemicals
- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty Acids
- Acetic Acid
- Carbon Black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed



Biomass Resources of the United States
Total Resources by County
Thousand Tonnes/Year
Above 500
250 - 500
150 - 250
100 - 150
50 - 100
Less than 50
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts
NREL
www.nrel.gov/gis

Commercial Technologies

- Almost all commercial power systems are combustion/steam turbine
- Efficiencies in 15% – 30% range power only, (60%-70% CHP)
- Stokers and fluidized bed
- 500+ facilities in U.S
- Installed costs $1,700 - $3,500/kW
- Smaller systems (< 5 MW) still have poor economics
- LCOE = $0.06 - $0.20/kWh

NREL Renewable Fuels Heating Plant (Golden, CO)

- $3.3 million cost under an ESPC
- Pine beetle waste wood
- 75% of the 50,000 million Btus to heat campus.
- Cost savings projected $400,000/year
- The wood chips cost $29 per ton or $2.42 per million BTUs
- During cold weather, plant burns a truckload of wood chips per day; produces 600 gallons of hot water per minute
- Stores four days of wood chip fuel

RE in ESPC Example - DOE Savannah River Site

- New 20 MW wood waste cogeneration plant and two biomass heating plants with local fuel source
- 19 year contract
- Includes performance guarantee and O&M
- Annual Savings of $34 M project cost of $183 M
- Task order signed 5/15/09
- Construction completed December 2011
- Important project to meet federal renewable goal/DOE Order 230.2b

RE in ESPC Example - USCG Baltimore, Maryland Landfill Gas

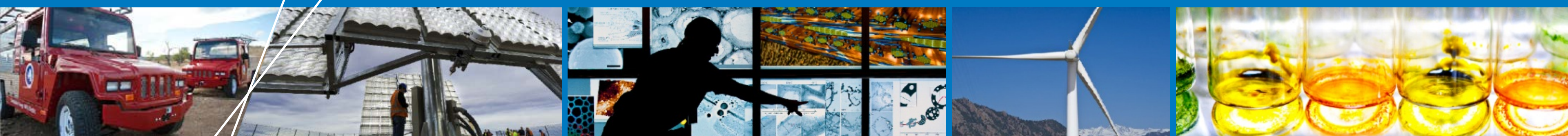
- **Boiler Conversion to LFG**
  - Cogeneration Plant
  - 4 MW Electricity
- **8,000 lb/hr Steam**
- **15 year contract length**
- **Project Investment : $15.0 million**
- **Annual Savings: $2.5 million**
- **Offsets 18,000,000 kWh/yr and 71,000 decatherms/yr of Natural Gas**
- **Operational: April 2009**

Biomass in Kodiak, AK

- **Wood pellets in Coast Guard boilers in place of expensive fuel oil**
  - Pellets from wood waste and second-growth trees from local Tongass National Forest
- **Benefits**
  - Save taxpayer dollars
  - Improve operations and resiliency
  - Support energy independence
  - Foster environmental stewardship

Biomass Resources

- **DOE Energy Efficiency and Renewable Energy**
  - http://www1.eere.energy.gov/biomass/
- **NREL**
  - http://www.nrel.gov/biomass/



Geothermal

Geothermal Energy Technology Overview

Application opportunities include:

- **Direct Use - Using hot water from springs or reservoirs near the surface.**
- **Electricity generation – Using steam, heat or hot water from deep inside the earth to drive turbines.**
- **Geothermal heat pumps – Using the earth, groundwater, or surface water as a heat source and heat sink**

Geothermal Application

Heat Production

- District Heating
- Process Heat
- Agriculture
- Aquaculture

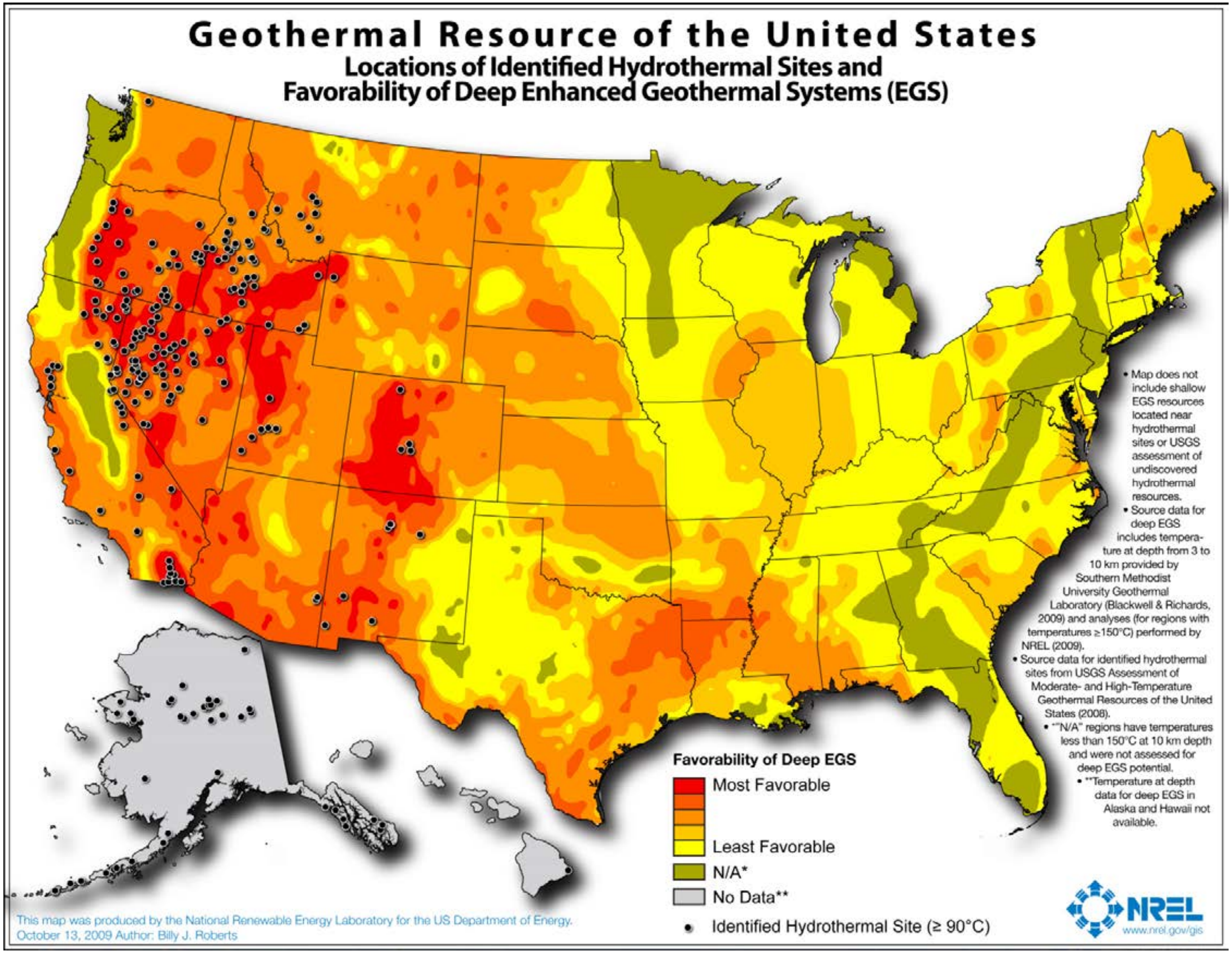
Electricity Generation

- Distributed Power
- Central Station Power

Ground Source Heat Pumps Marine Corps Air Station, Beaufort, SC

- **Geothermal heat pump technology is the energy-saving centerpiece of this Marine housing facility.**
- **Energy-efficient geothermal heat pumps replaced 2,500 tons of existing HVAC systems and hot water heaters.**
- **These heat pups provide space heating, cooling, and domestic hot water for 1,235 family housing units at the Beaufort Marine Corps installation.**

Photo by Belton Tisdale, NREL/PIX 12372

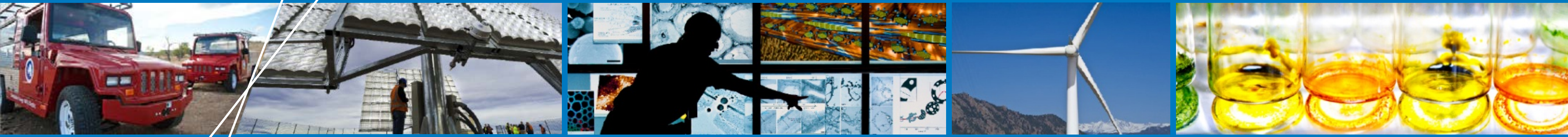


Geothermal Resource of the United States
Locations of Identified Hydrothermal Sites and
Favorability of Deep Enhanced Geothermal Systems (EGS)
• Map does not include shallow EGS resources located near hydrothermal sites or USGS assessment of undiscovered hydrothermal resources.
• Source data for deep EGS includes temperature at depth from 3 to 10 km provided by Southern Methodist University Geothermal Laboratory (Blackwell & Richards, 2009) and analyses (for regions with temperatures ≥150°C) performed by NREL (2009).
• Source data for identified hydrothermal sites from USGS Assessment of Moderate- and High-Temperature Geothermal Resources of the United States (2008).
• *"N/A" regions have temperatures less than 150°C at 10 km depth and were not assessed for deep EGS potential.
• **Temperature at depth data for deep EGS in Alaska and Hawaii not available.
Favorability of Deep EGS
Most Favorable
Least Favorable
N/A*
No Data**
Identified Hydrothermal Site (≥ 90°C)
This map was produced by the National Renewable Energy Laboratory for the US Department of Energy.
October 13, 2009 Author: Billy J. Roberts
NREL
www.nrel.gov/gis

Geothermal Resources

- **Western Area Power Administration**
  - http://www.wapa.gov/es/pubs/fctsheet/GHP.pdf
- **DOE Geothermal Technologies Program**
  - http://www1.eere.energy.gov/geothermal/faqs.html
- **Resource Maps**
  - http://www.nrel.gov/gis/geothermal.html

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Hydro and Ocean Energy

What are the Hydropower and Ocean Energy Options?

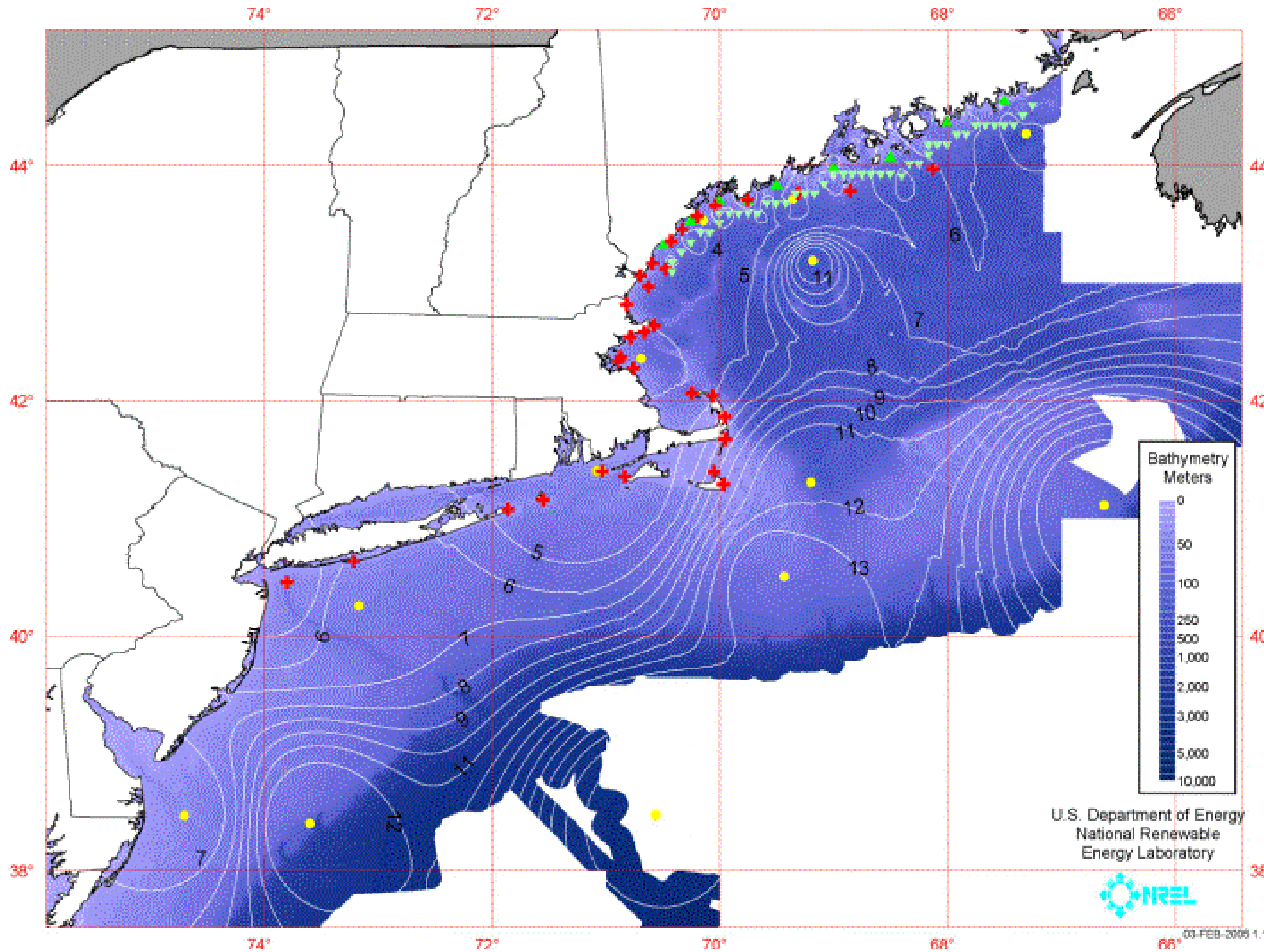
- Small projects use turbines in place of pressure reducing valves
- Large Hydropower is typically not cost-effective unless the site has access to existing hydroelectric dam
- Hydropower is a common form of Renewable Energy Credits

Ocean Energy

- **Wave power**
- **Marine current power**
- **Tidal Energy**
- **Ocean Thermal Energy Conversion**
    - Relatively immature

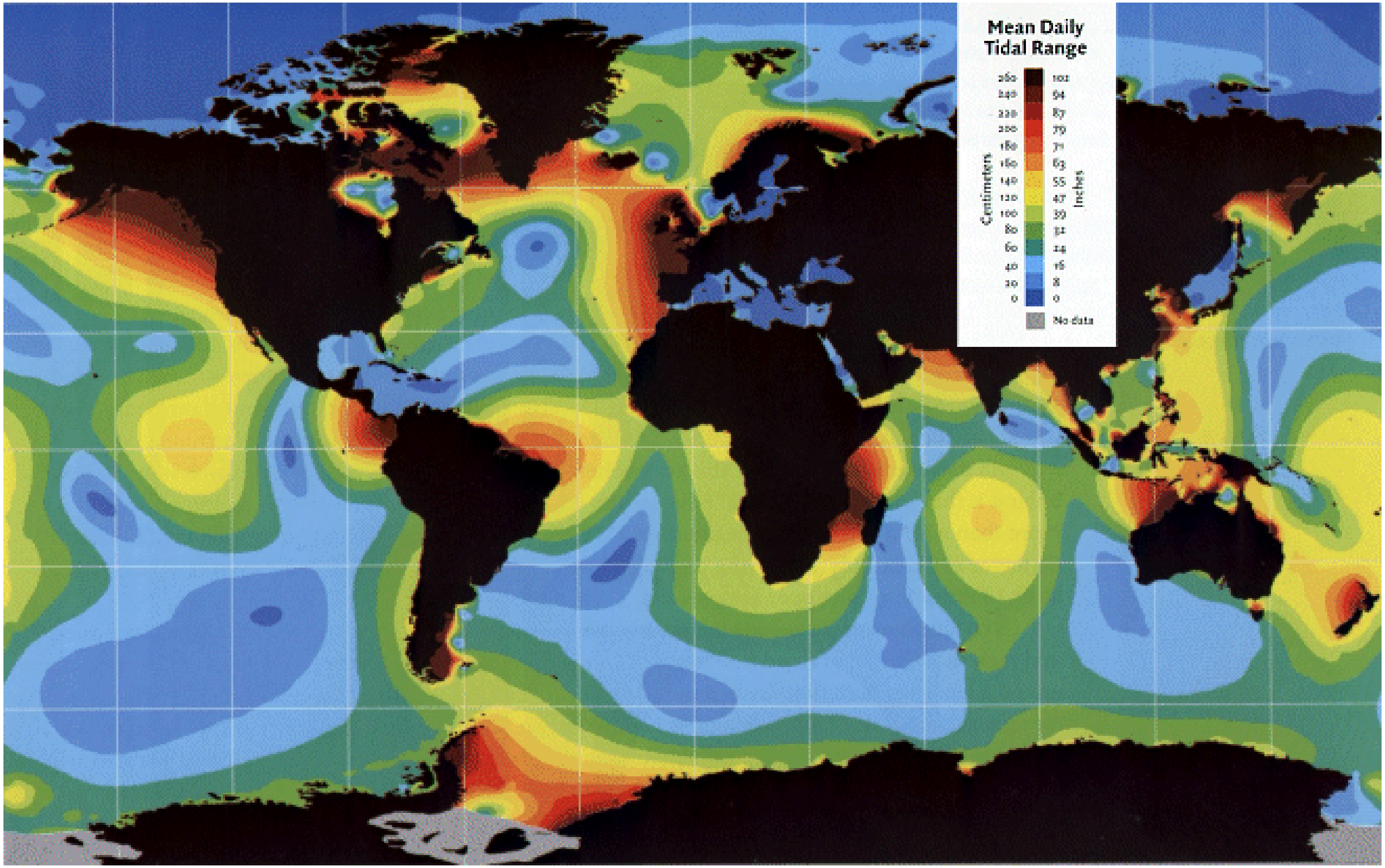
Wave Energy Technology

Wave Power for U.S. Coast Guard 1st District Lighthouses



Marine Current Technology

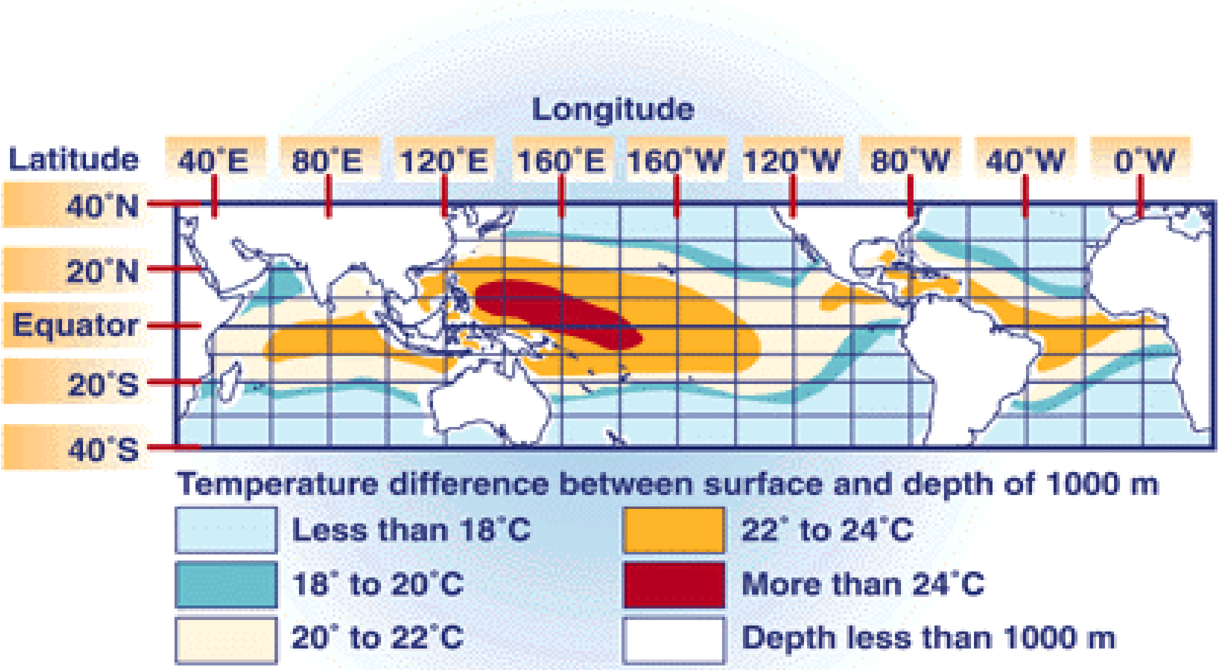
Tidal Energy Resource

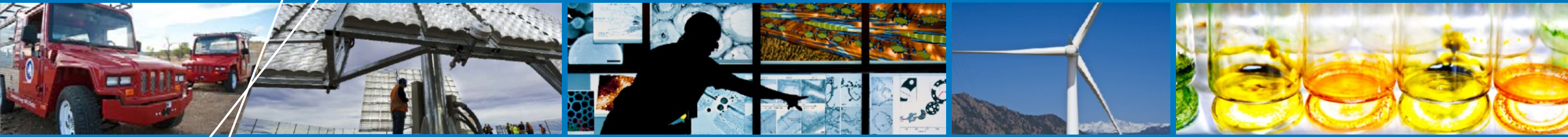


Ocean Thermal Technology

OTEC functions best when there is a 36° F (20°C) difference

The OTEC energy resource constitutes an estimated 10^{13} W (876,000TWh/yr) for potential base load power generation.





Integration Issues

DSIRE

Database of State Incentives for Renewables & Efficiency

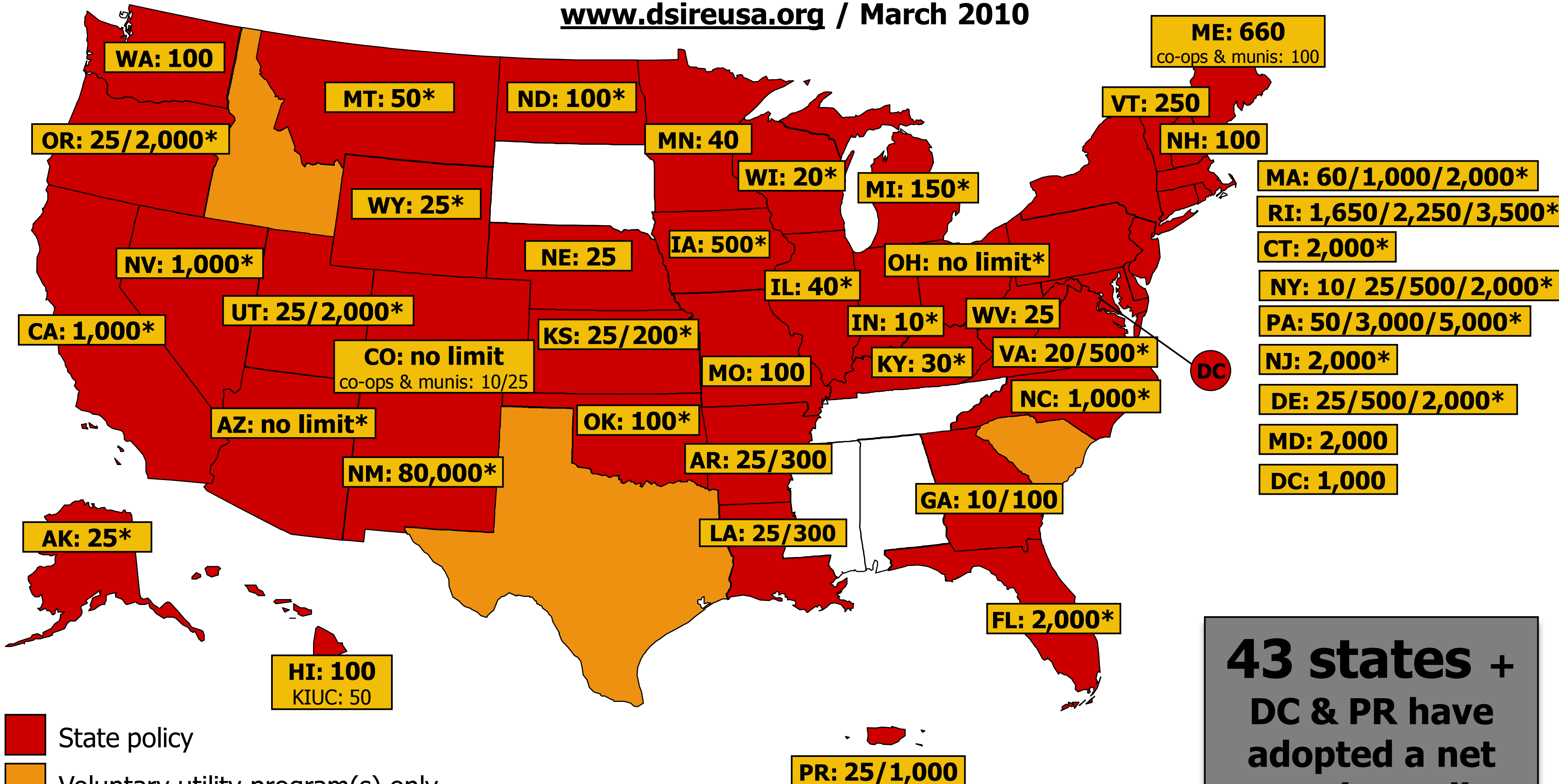
U.S. Department of Energy Energy Efficiency and Renewable Energy

North Carolina Solar Center

IREC

Net Metering

www.dsireusa.org / March 2010



43 states + DC & PR have adopted a net metering policy

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.

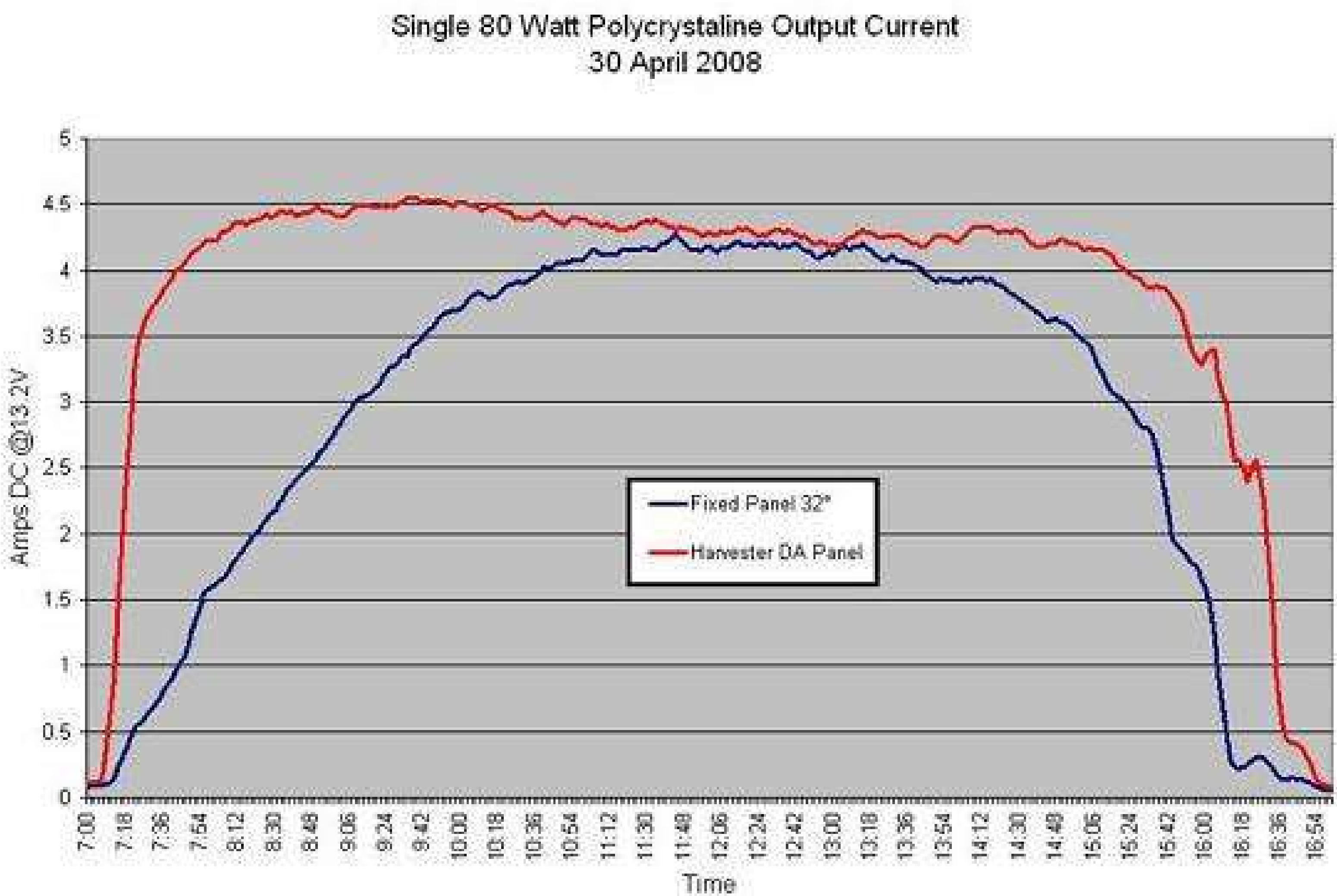
Problems with "Net" Metering

- **Pros:**
  - Incentive for RE
  - Saves Some Fuel (up to a limit)
- **Cons:**
  - Limits to Fuel Savings
  - Doesn't save any other utility operating costs
  - RE may be curtailed; limits on installations (eg 15% in HI)
  - Socio-economic problem: foists utility costs on those least able to afford it.
- **Utility Cost Recovery**
  - Spinning Reserve
  - Retail/buy-back spread (c/kWh)
  - Stand-by Charges ($/kW/month)

Zero = EE+RE+Microgrid

- **Strategies for "Zero" rather than "Net Zero"**
  - Tracking Solar
  - Solar on different orientations (East-South-West)
  - Spatial Diversity
  - Diversity of RE Measures (Solar, Wind, Etc)
  - Dispatchable RE (biomass, hydro, geothermal, landfill gas)
  - Flexible Grid Layout (circuits) to route power around
  - Isolate Critical Circuits: exercise Demand Control
  - Energy Storage (short and long term, electric and thermal)
  - Micro-grid controls
    - Control requirement: maintain required frequency and voltage levels
    - Grid disconnect and seamless resynchronization
    - Micro-grid start-up ("black start")
    - Load control (interfaces with SCADA and EMCS)
    - Supply control (optimized operation of DERs)

Tracking the Sun



Zero = EE+RE+Microgrid

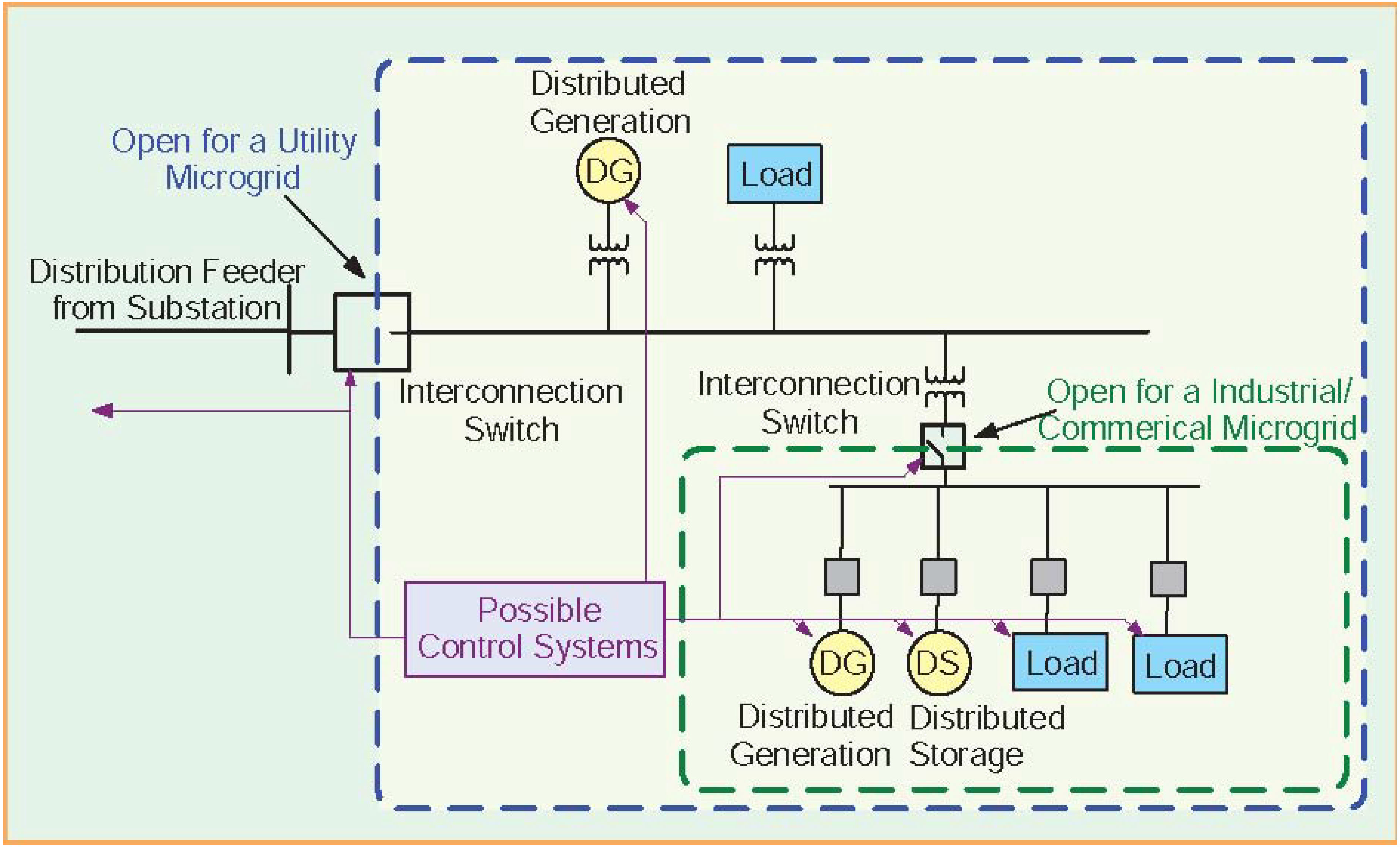
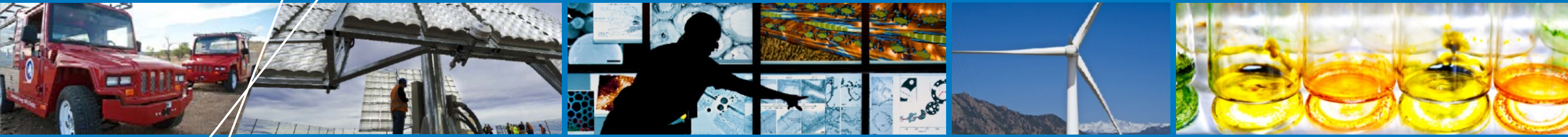


Figure by Ben Kroposki, NREL



RE Project Planning

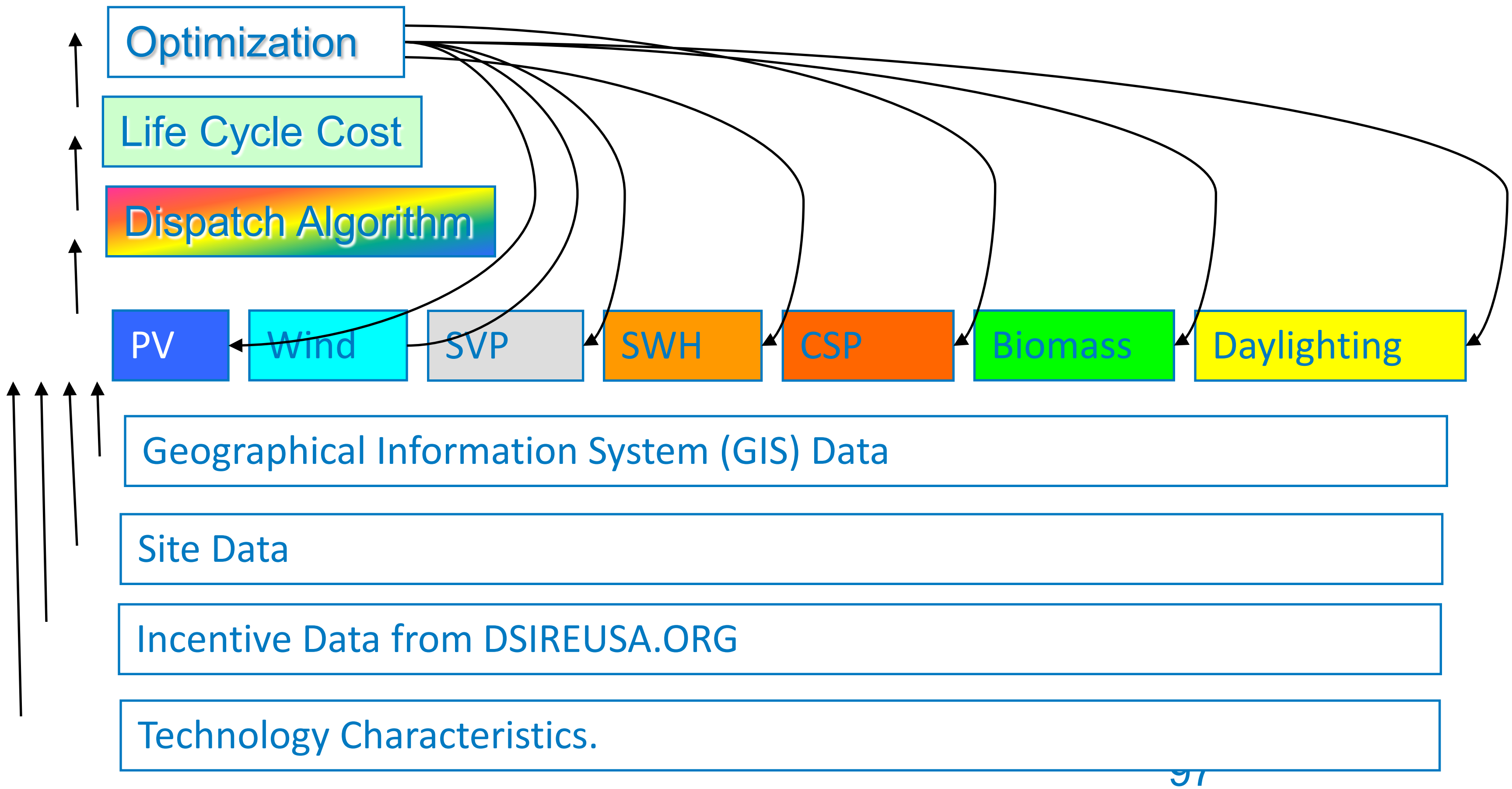
Best Mix of Renewable Energy Technologies Depends on:

- **Renewable Energy Resources**
- **Technology Characterization**
  - Cost ($/kW installed, O&M Cost)
  - Performance (efficiency)
- **Economic Parameters**
  - Discount rates
  - Fuel Escalation Rates
- **State, Utility and Federal Incentives**
- **Mandates (Executive Order, Legislation)**

Summary Comparison

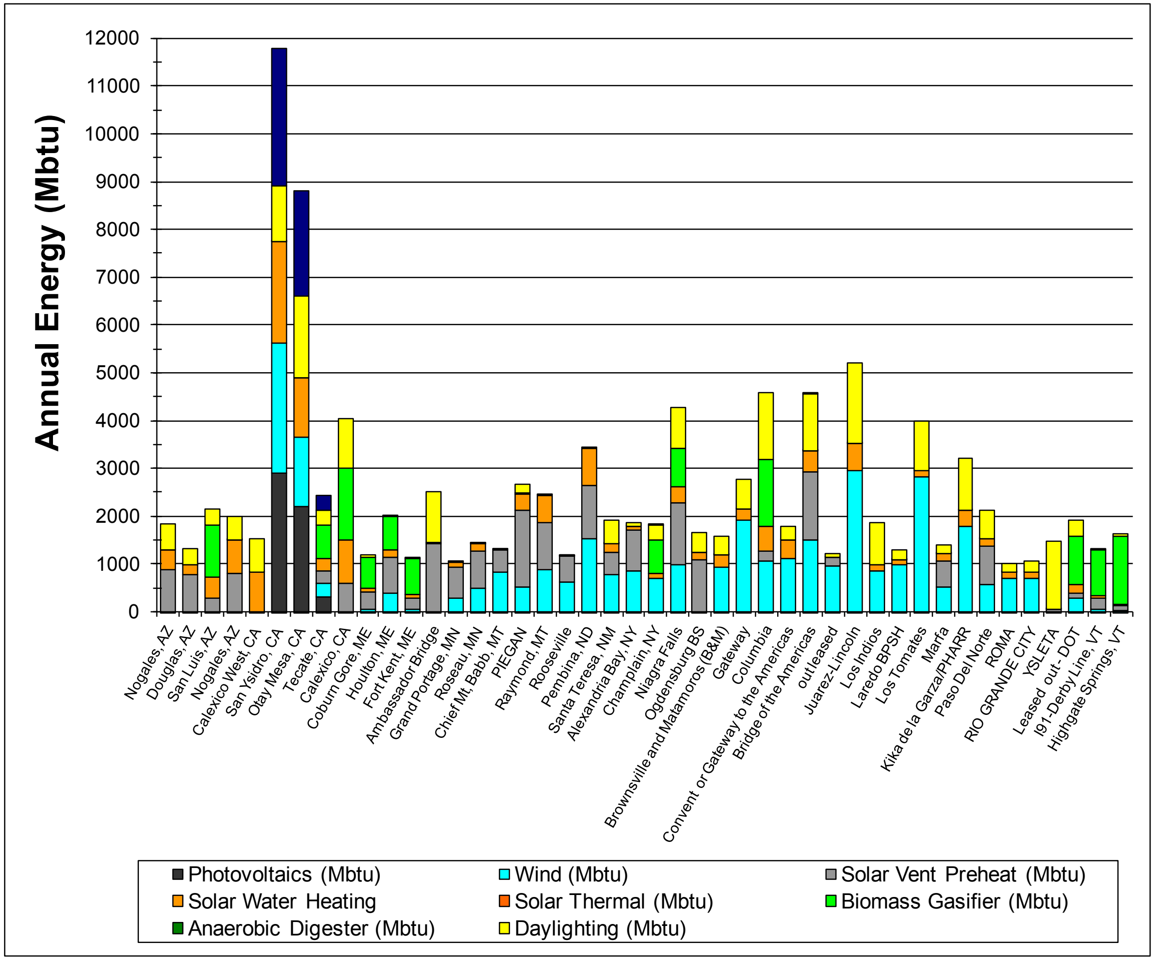
Technology	Level of Commercialization.	LCOE with tax incentives	Capital Cost ($) 2011	Level of Site Impact
Photovoltaics;	Mature	$0.128/kWh to $0.154/kWh	$6,870/kW	Low, most buildings.
Solar ventilation air preheating ;	Underutilized	$0.064/kWhthermal	$27.40/sf	Medium, limited to low-heat-gain buildings
Solar water heating;	Mature	$0.08 to $0.20/kWhthermal	$75-225/sf	Medium, hot water loads only.
Solar thermal and solar thermal electric;	Mature	$0.090 to $0.145/kWh	$5,132/kW	HIgh
Biomass thermal and electric	Mature	$0.050 to $0.094/kWh	$3,995/kW	High
Geothermal Power;	Early	$0.042 to $0.069/kWh	$4,000/kW	High
Ground Source Heat Pump	Mature	$0.027/kWhthermal	$835/ton	Medium
Landfill gas;	Mature	$0.0493/kWh	$2,100/kW	Medium, virtual power from landfill
Fuel Cells;	Early	$0.115 to $0.125/kWh	$3,800/kW	Low
Wind;	Mature	$0.044 to $0.091/kWh	$1,966/kW	High

REO: Renewable Energy Optimization



REO for Land and Ferry Points of Entry

	Without Tax Incentives	With Tax Incentives
PV (kW)	0	737
Wind Energy (kW)	2,491	3,689
Solar Ventilation Air Preheat (sf)	93,265	119,652
Solar Water Heating (sf)	28,464	90,703
Solar Thermal Parabolic Trough (sf)	0	0
Solar Thermal Electric (kW)	0	0
Biomass Gasification Boiler (MBH)	1.3	1.8
Biomass Gasification Cogen (kW)	134	193
Biomass Anaerobic Digester (ft3)	0	0
Biomass Anaerobic Digester Cogen (kW)	0	0
Skylight Area (sf)	190,951	209,666



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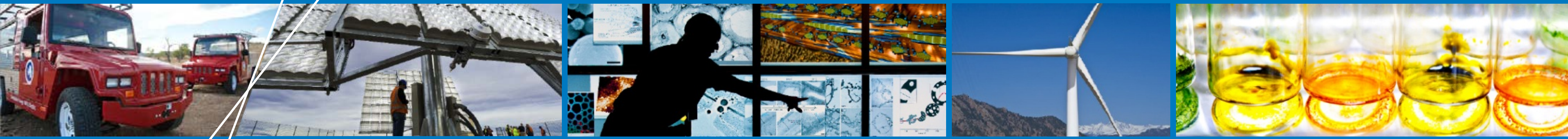

Questions?

Thank you!

Andy Walker
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