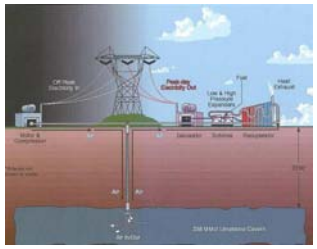

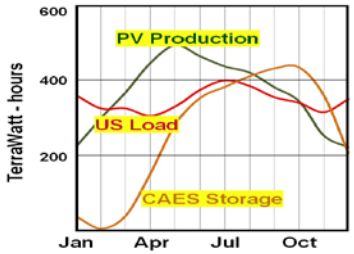


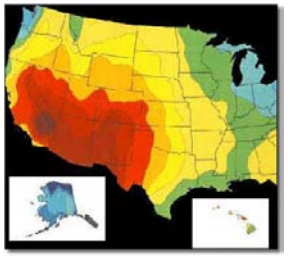

# Solar Energy and Water Use in Arizona

WRRC Brown Bag Seminar
September 16 , 2010

Ardeth Barnhart
Co-Director, Arizona Research Institute for Solar Energy (AzRISE)
University of Arizona – www.azrise.org

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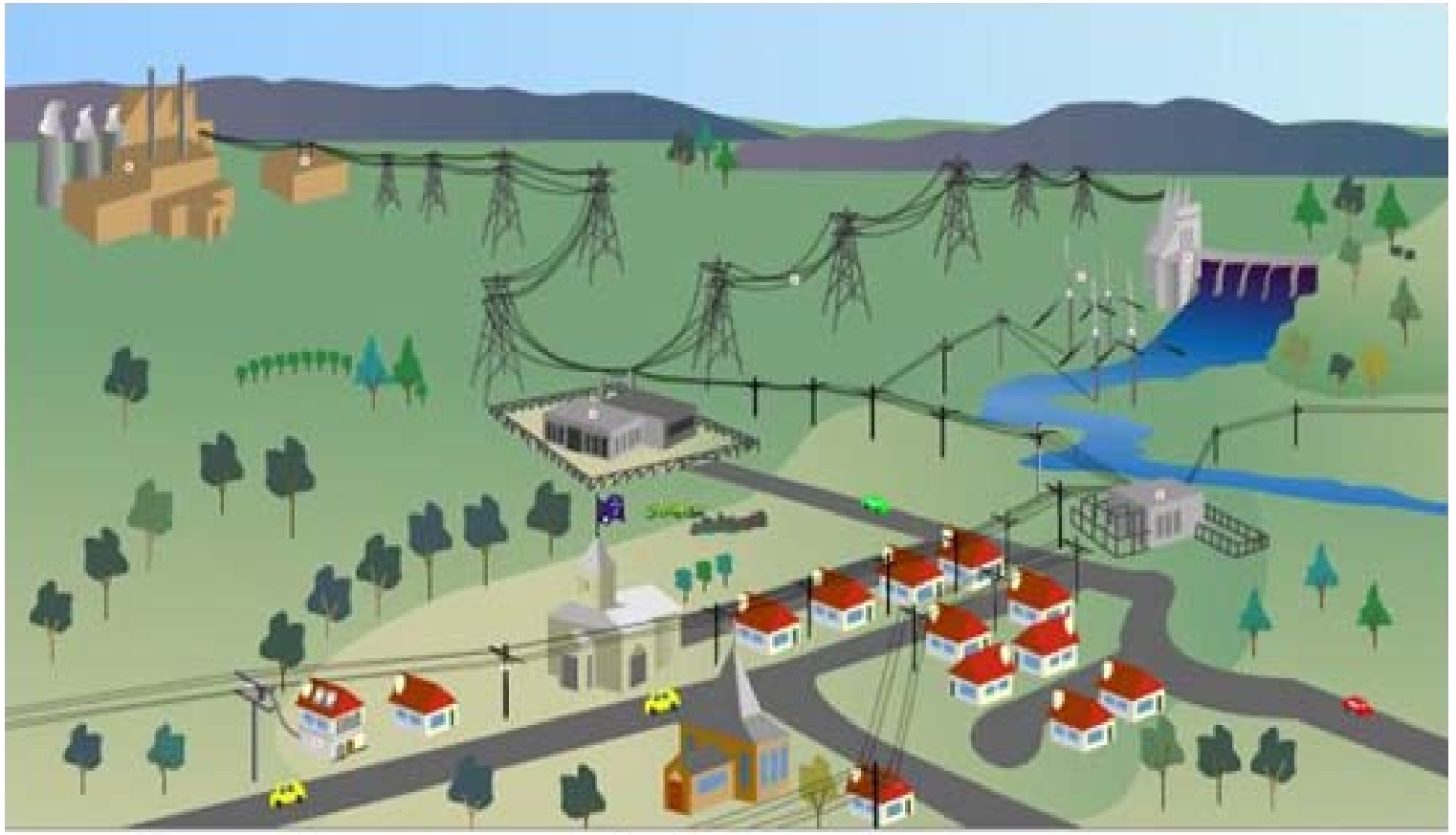
# Overview

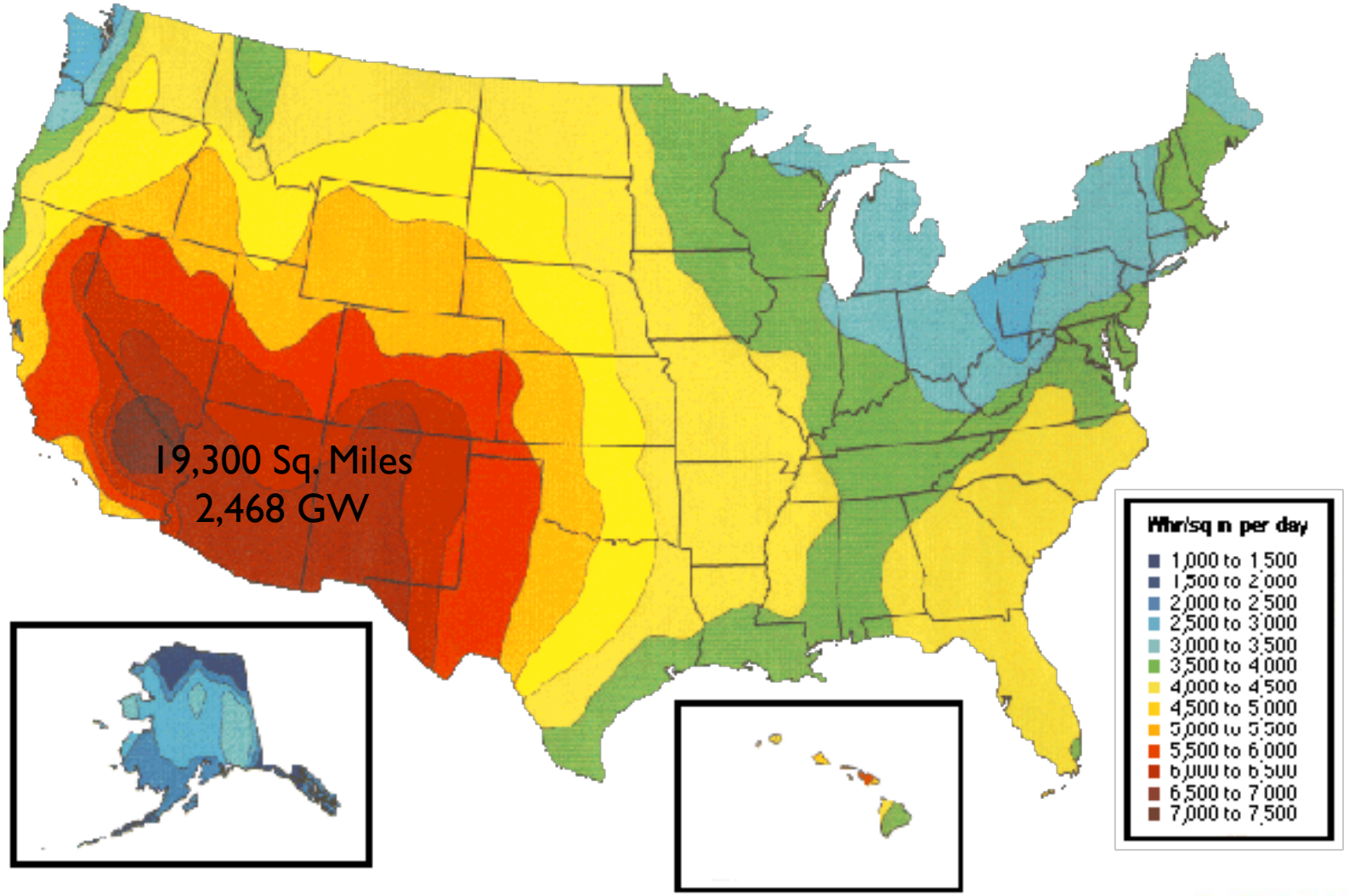
- Arizona Resource and Demand
- Water Use in Electrical Energy Generation
- Electricity Generation Technologies
- Water Use Analysis
- Conclusion



Electricity network

*www.aemogas.com.au*

# Solar Insolation Data for the U.S. (NREL)




(Source: www.nrel.gov)

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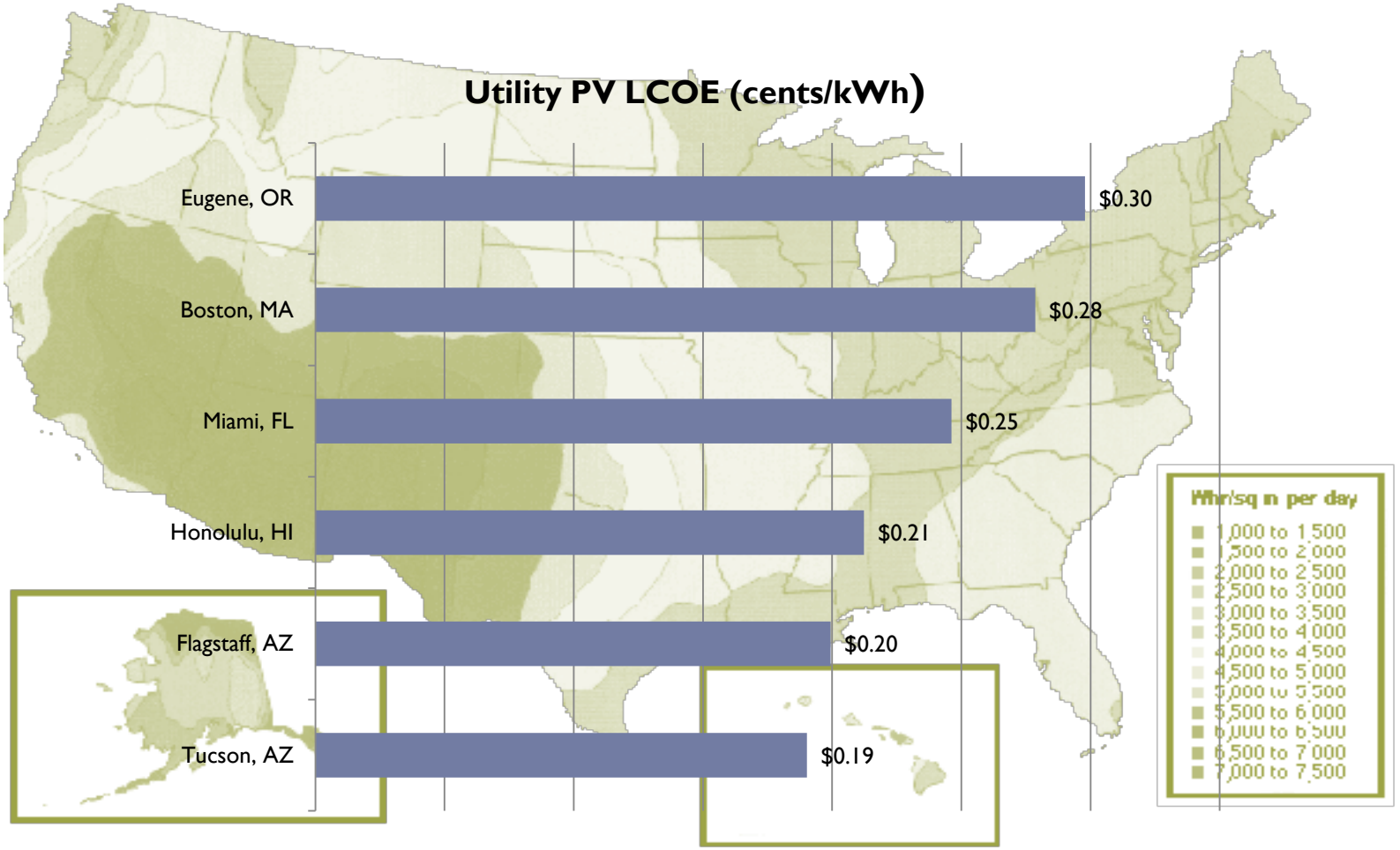
# LCOE as a function of Solar Insolation




(Source : NREL – Solar Advisor Model 2010 – Flat Plate PV - Federal ITC incentive only)

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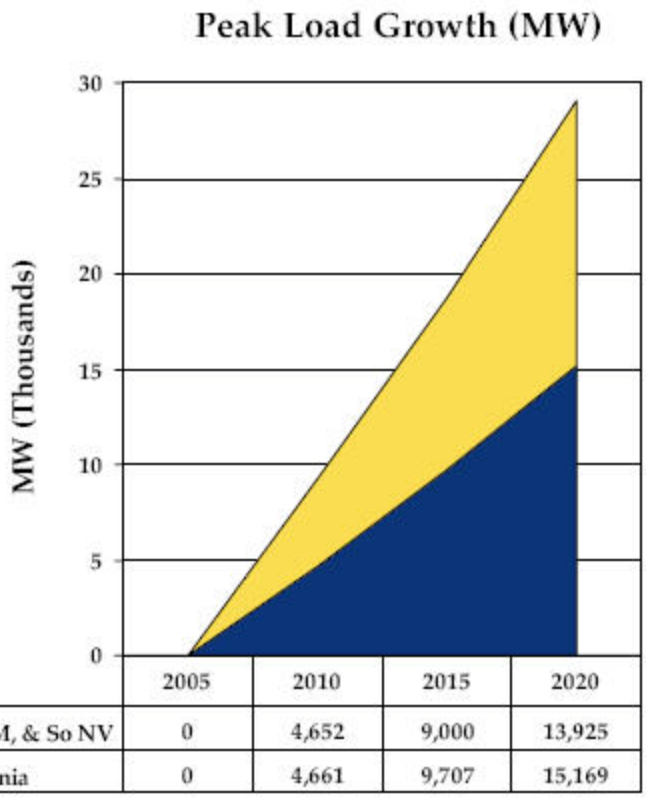
# Arizona Peak Load Growth

| NERC Sub-Region | Expected Peak Load (MW) 2005-2020 | | | |
|---|---|---|---|---|
| | 2005 | 2010 | 2015 | 2020 |
| AZ, NM, South NV | 26,972 | 31,624 | 35,972 | 40,897 |
| CA | 57,324 | 61,985 | 67,031 | 72,492 |
| Total | 84,296 | 93,609 | 103,003 | 113,389 |

Peak growth in the desert southwest is forecasted to be nearly the same as CA.




Source: WECC, CA Energy Commission, NCI Analysis

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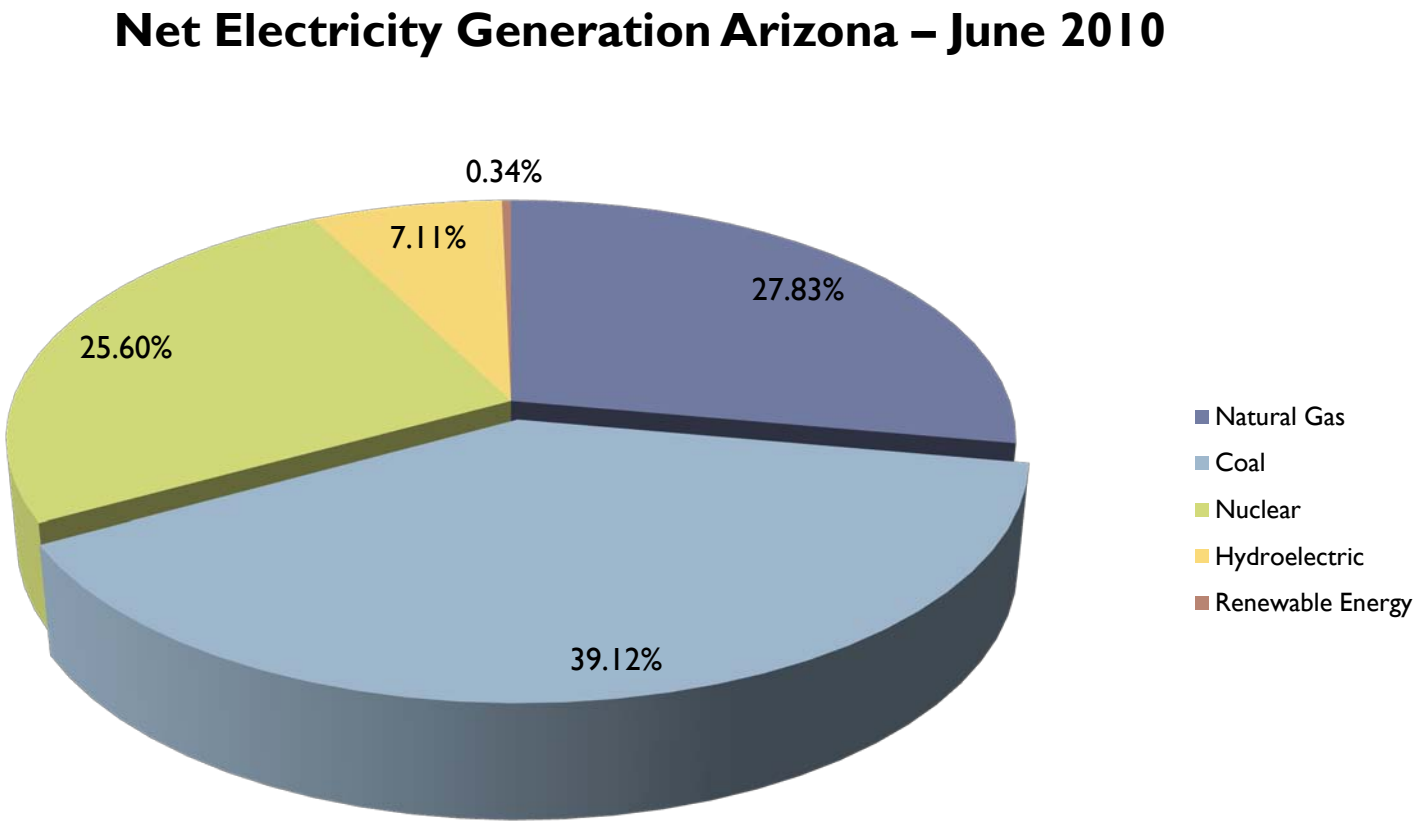
# Thermoelectric Generation is Dominant




Source: U.S. Energy Information Administration (EIA)

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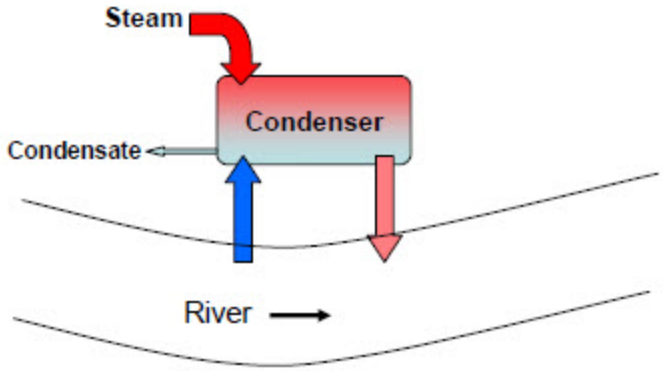
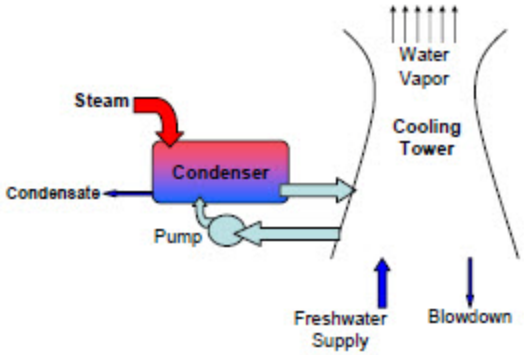
# Water Use for Thermoelectric Power




Open-Loop Cooling System




Closed-Loop Cooling System

- Withdraw water for cooling and discharge back to source
- 31% US generating capacity with 10 yrs generating life
- Availability of water is critical
- Discharge warm water

- Most plants installed since 1970 use evaporative cooling
- Withdraws less than 5% of water in open-loop
- Most water is lost to evaporation, consumes more water
- Total freshwater consumption in US 3.3 Billion gals/day – 20% non-agriculture water use

(Source: US DOE, *Energy Demands on Water Resources*, 2006)

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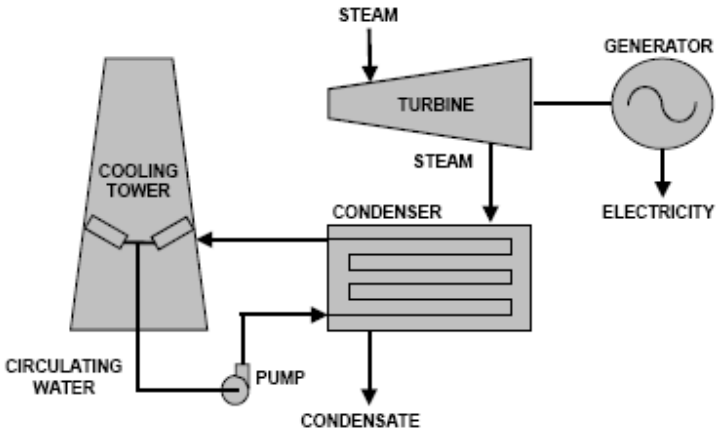
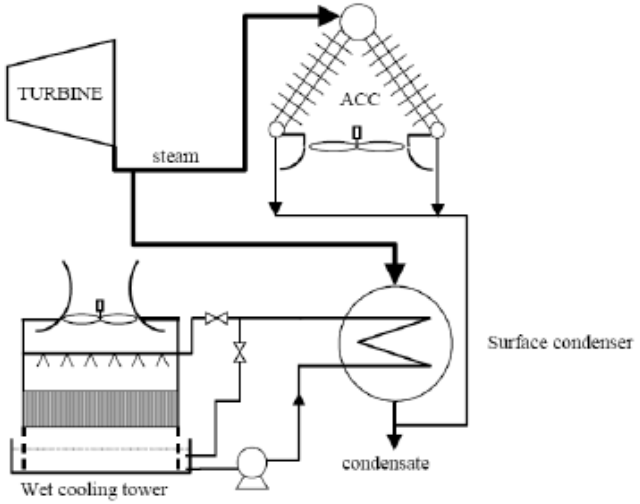
# Water use for CSP Cooling




**Dry Cooling System**




**Hybrid wet/dry Cooling (DOE, 2009)**

- Cooled only by air, impacts plant efficiency
- Can only approach ambient air temperature
  - -As outlet temperature increases, efficiency drops
- Hot and dry climates, drop up to 25% which means more fuel use and emissions

- Wet-cooled only on hot days
- Parallel wet and dry cooling facilities
- In the Southwest , hybrid cooling uses 50% of wet cooling and maintain 99% performance

(Source: US DOE, *Energy Demands on Water Resources*, 2006)

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| | | Water intensity (gal/MWh$_e$) | | | |
|---|---|---|---|---|---|
| Plant-type | Process | Steam Condensing | | Other Use | |
| Steam | | Withdrawal | Consumption | Withdrawal | Consumption |
| Coal | Mining | | | | 5–74 |
| | Slurry | | | 110–230 | 30–70 |
| Fossil/ biomass/ waste | OL Cooling | 20,000–50,000 | ~300 | ~30** | |
| | CL Tower | 300–600 | 300–480 | | |
| | CL Pond | 500–600 | ~480 | | |
| | Dry | 0 | 0 | | |
| Nuclear | Mining and Processing | | | | 45–150 |
| Nuclear | OL Cooling | 25,000–60,000 | ~400 | ~30** | |
| Nuclear | CL Tower | 500–1,100 | 400–720 | | |
| Nuclear | CL Pond | 800–1,100 | ~720 | | |
| Nuclear | Dry | 0 | 0 | | |
| Geothermal Steam | CL Tower | ~2000 | ~1400 | Not available | |
| Solar trough | CL Tower | 760–920 | 760–920 | 8** | |
| Solar tower | CL Tower | ~750 | ~750 | 8** | |
| **Other** | | | | | |
| Natural Gas | Supply | | | | ~11 |
| Natural Gas CC | OL Cooling | 7,500–20,000 | 100 | 7–10** | |
| | CL Tower | ~230 | ~180 | | |
| | Dry | 0 | 0 | | |
| Coal IGCC* | CL Tower | ~250 | ~200 | 7–10 + 130 (process water)** | |
| Hydro-electric | Evaporation | | | | 4500 (ave) |

OL = Open loop cooling, CL = Closed Loop Cooling, CC = Combined Cycle
*IGCC = Integrated Gasification Combined-Cycle, includes gasification process water
Other Use includes water for other cooling loads such as gas turbines, equipment washing, emission treatment, restrooms, etc.
**References did not specify whether values are for withdrawal or consumption.

Mining of coal consumes 0.07 to 0.26 billion gallons per day

Thermo-electric power generation withdraws 136 billion gallons per day and consumes 3.3 billion gallons per day

(Source: U.S. DOE, *Energy Demands on Water Resources*, 2006)

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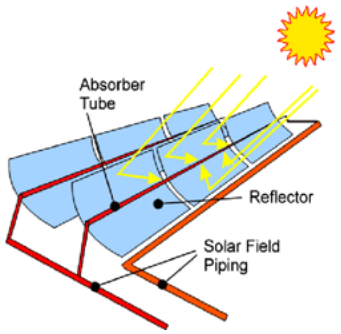
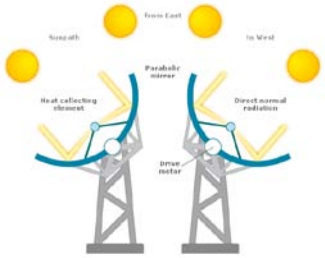
# Solar Energy Technologies - Thermal

- Water demand is dependent on location and type of CSP system



## Parabolic Trough

- Abengoa Solar "Solana" Plant – Gila Bend AZ
- Large-scale solar systems
- Steam turbine cycle
- 6 hour storage – molten salt - dispatchable
- 250 MW on 1250 acres – agricultural land
- Generates 600,000 MWh/yr
- Wet cooling – 928 gal/MWh
- future trough technology could yield capacity factors greater than 70% - possible baseload generation
- $1.45 billion load guarantee DOE

Source: DOE, 2006/ NREL, 2010

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# Solar Energy Technologies - Thermal

Solar Two power tower in Daggett, California.
*Credit: Sandia National Laboratories / PIX 00036*

## Power Tower

- BrightSource Energy, Ivanpah generating station
- Large-scale solar systems
- Thousands of mirrors (heliostats) track the sun in two dimensions and reflect the sunlight to a boiler that sits atop a tower – super heats water to create steam to turn a turbine
- 468 MW on 4, 073 acres
- Generate 1, 079, 232 MWh/yr
- Closed-loop dry-cooling technology, which reduces water use by 90 percent. Will use 100 acre feet per year
- Integrates with molten salt storage
- $1.37 billon loan guarantee DOE

Source: BrightSource, Inc.

# Concentrating Solar Power

(Source: www.srpnet.com)

## Dish Stirling Engine

- SunCatcher Solar Plant
- Modular 25 kW units
- Focuses sunlight onto engine/generator to produce electricity
  - Stirling thermodynamic cycle
- Annual efficiency 23%
- Water use for cleaning surfaces
- No thermal storage
- SRP – Tessera Solar 1.5 MW system in Peoria, AZ (1 acre foot/year)

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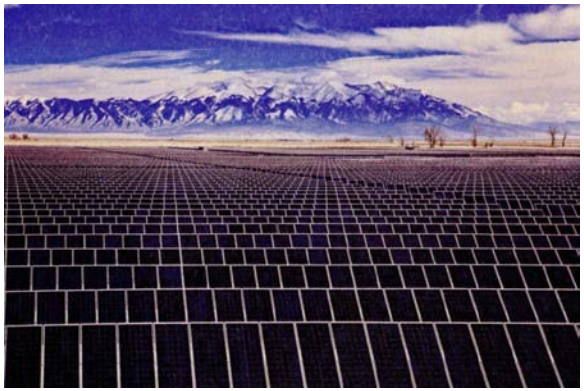
# Solar Energy Technologies - PV



Alamosa, Colorado 8.2 MW SunEdison for Xcel Energy.

## Photovoltaic

- Commercial and large-scale solar systems
- Silicon-based and Thin-Film Photovoltaic technologies
- 5 acres per MW
- Tracking systems
- Water used only for washing surfaces

## Davis Monthan Air Force Base - Tucson

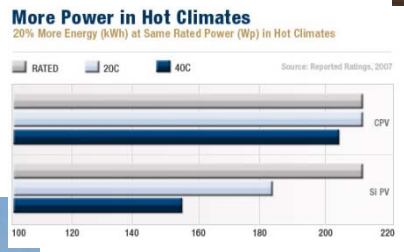
- 14.5 MW ground-mounted installation 130-acre plot
  - plus over 6 MW solar energy on housing
- Power Purchase Agreement (PPA)
- The project is expected to produce about 31.5 million kWh of power per year, enough to meet about 35% of the base's electricity needs.
- Largest solar-generating capacity base in DOD
- 25% by 2025 renewable energy goal - DOD

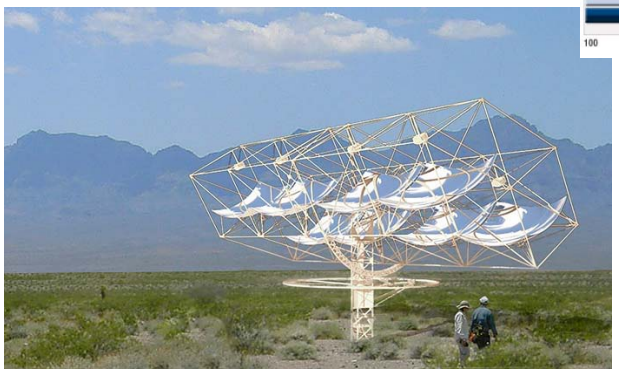
# Concentrating Photovoltaics (CPV)

## Solfocus

- Commercial and large-scale solar systems
- Concentrate the sun 500 times onto PV cells
- Dual-axis tracking
- 6 Acres for 1 MW – 2.5M kWh/Year
- 3 months to deploy - $0.07/kWh
  - (CREBS)

(Solfocus Solar - California)



(REhnu- Dr. Roger Angel (UA) CPV)

## REhnu

- Commercial and large-scale solar systems
- 30 kW system
- Concentrate the sun 1000 times onto PV cells - triple-junction PV cells have 35% conversion efficiency
- Active cooling system

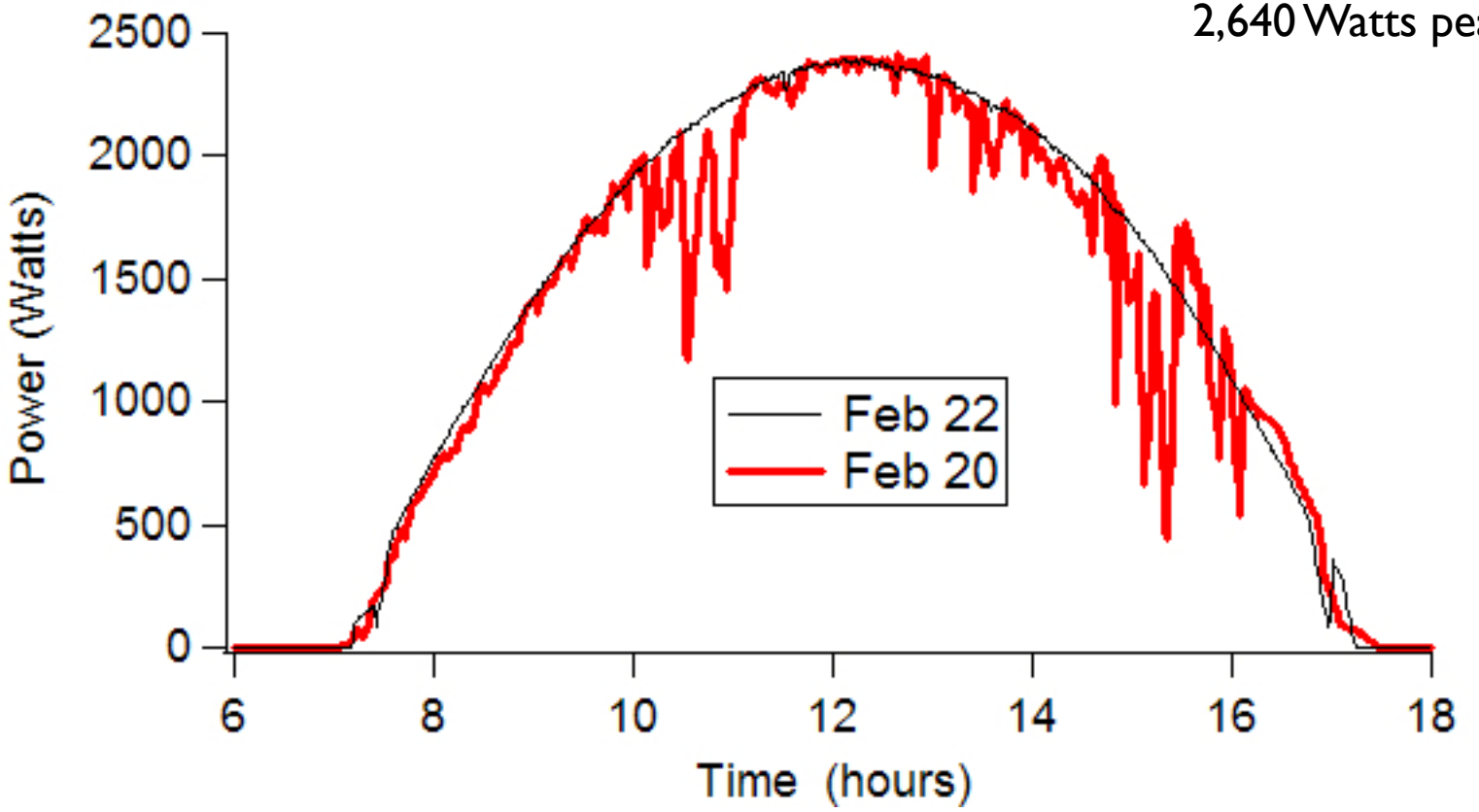
# 4.6 MW Springerville Generating Station (TEP)

- generates enough electricity to power 700 homes

Source: www.tep.com

# Solar has short-term intermittency due to weather

Rated Power
2,640 Watts peak




Data from TEP Test Yard – Dr. Alexander Cronin

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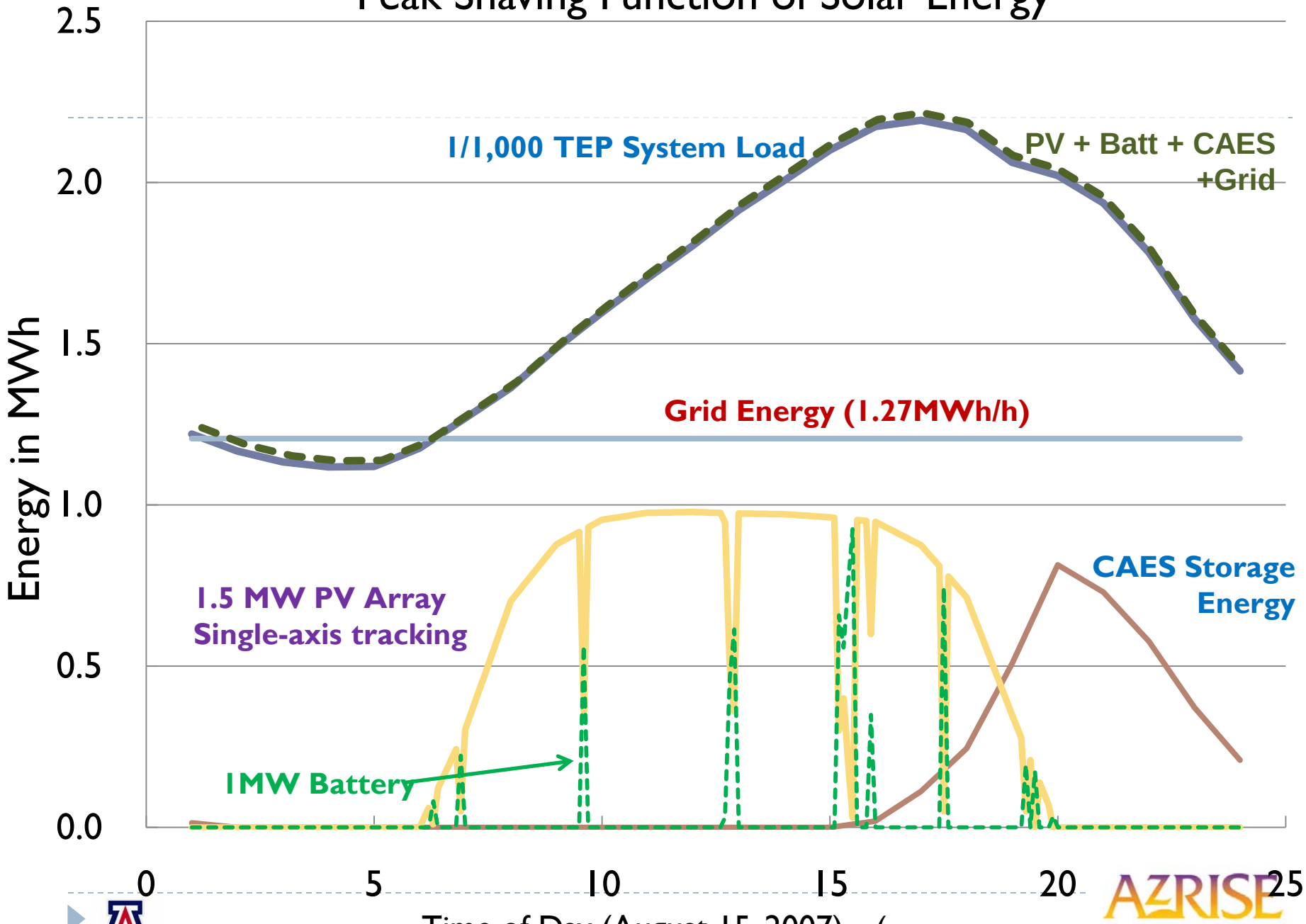
# Peak Shaving Function of Solar Energy




(Source: Dr. Simmons, AzRISE)

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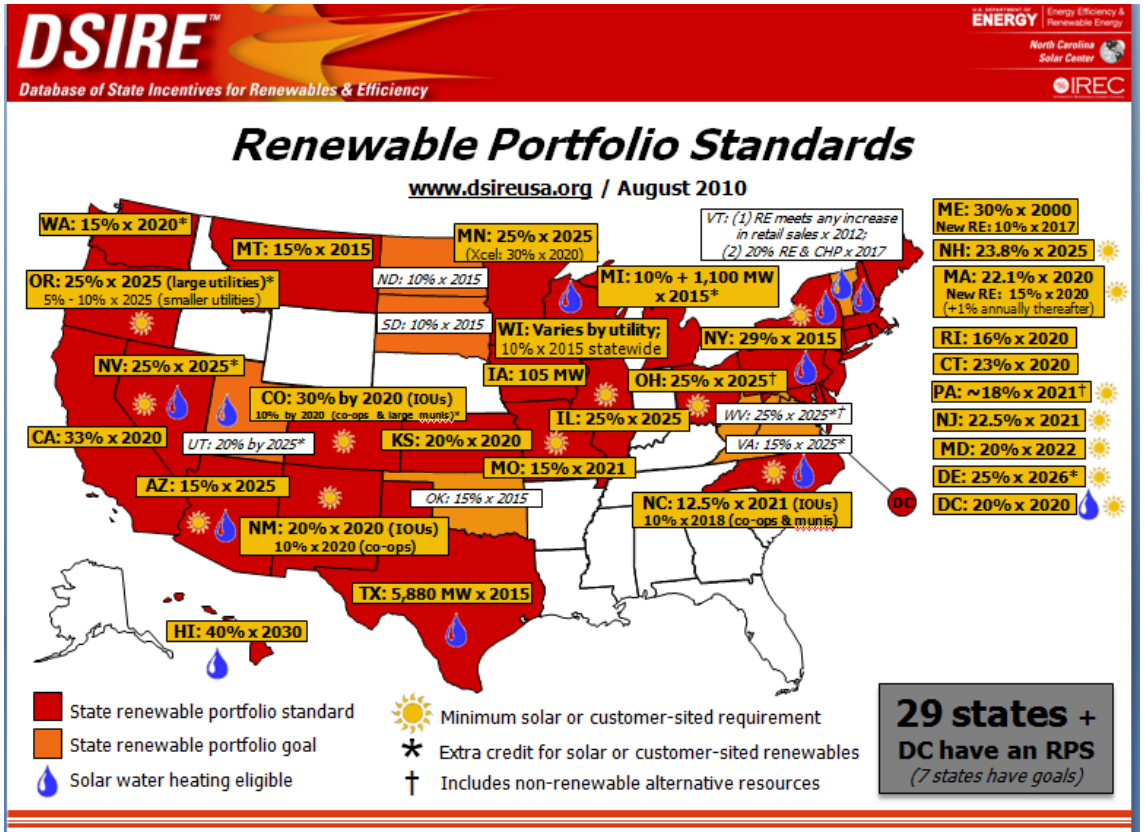
# Arizona Renewable Energy Standard & Tariff

- Arizona REST – 15% by 2025 and 30% Distributed Generation
- Annual solar energy generation equal to 9.54 TWh by 2030

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- For information on incentives and rules and regulations for solar energy in the United States. *The Database of State Incentives for Renewables & Efficiency (DSIRE)*. North Carolina State University. www.dsireusa.org
- Solar Energy Companies:
  - Abengoa Solar, S.A.. www.abengoasolar.com
  - Brightsource Energy, Inc. – www.brightsourcenergy.com
  - SunEdison – www.sunedison.com
  - SolFocus, Inc. – www.solfocus.com
  - Rehnu, LLC. – www.rehnu.com
  - Tucson Electric Power Company (TEP) – www.tep.com

- Ardeth Barnhart

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www.azrise.org


"Not all chemicals are bad. Without chemicals such as hydrogen and oxygen, for example, there would be no way to make water, a vital ingredient in beer."
— **Dave Barry**