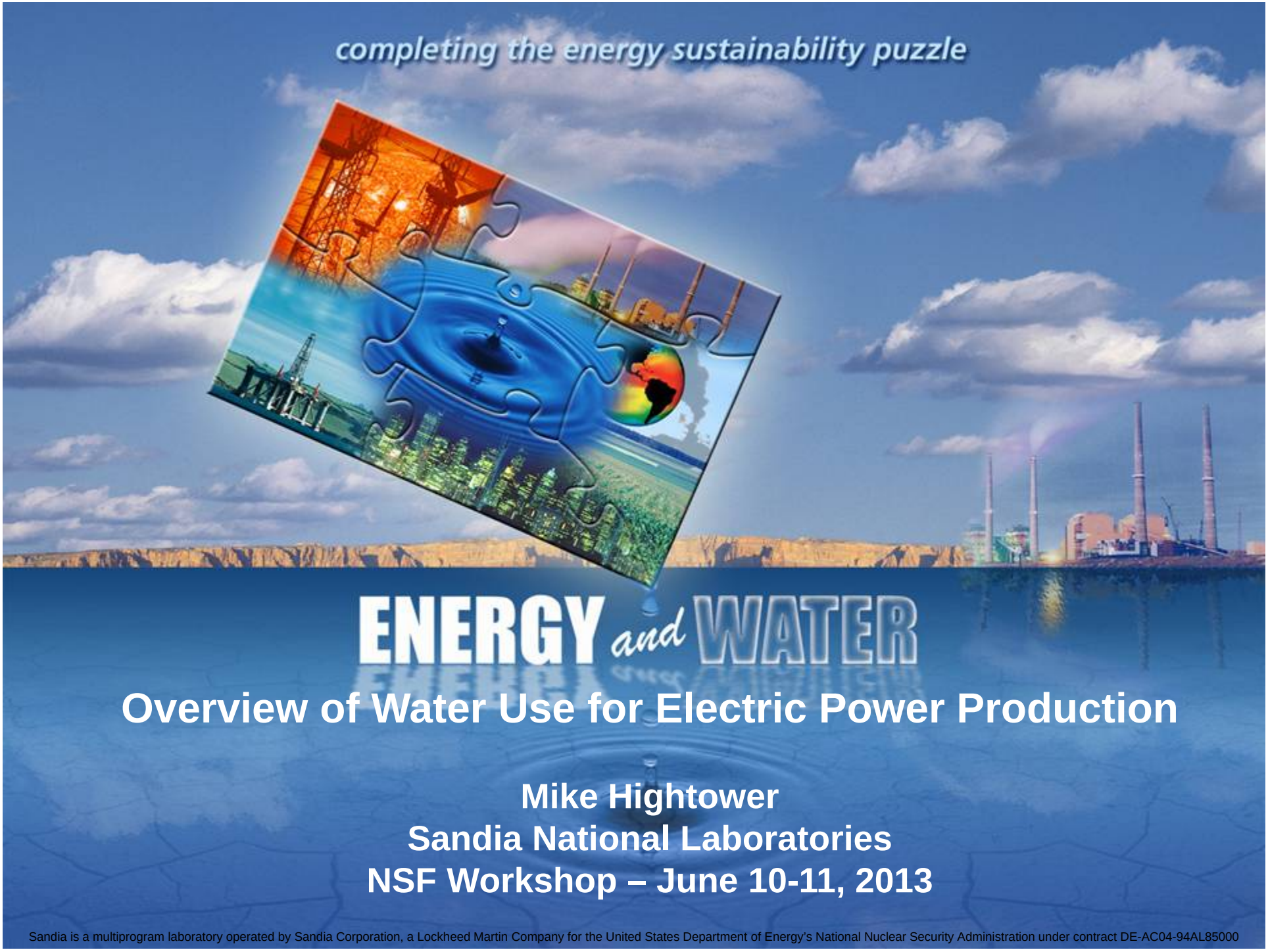


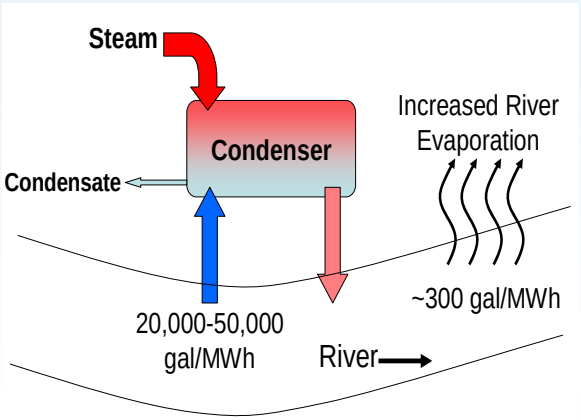

# Overview of Water Use for Electric Power Production

**Mike Hightower**
**Sandia National Laboratories**
**NSF Workshop – June 10-11, 2013**

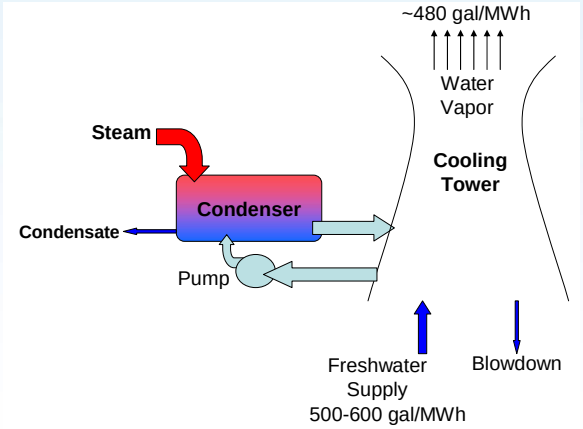
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000

# Thermoelectric Power Generation Cooling Options

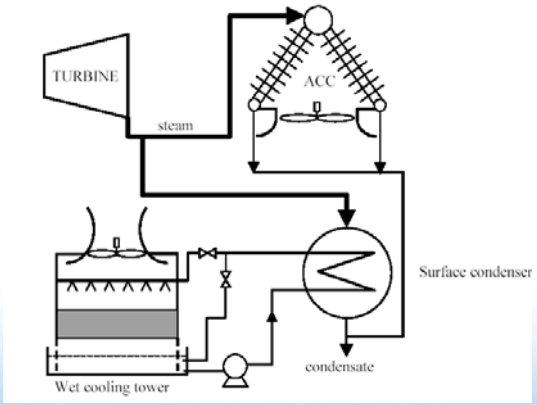
## Once-Through Cooling




## Closed-Loop (Evaporative) Cooling




Dry-Cooled Power Plant




Hybrid Cooling

ENERGY and WATER

# 500 MW Coal Thermoelectric Power Plant - Steam Cycle

Evaporation & Drift
3,891 gpm

3,804,950 lb/hr
Steam

Boiler

Turbine

520 MW

Generator

Cooling Tower

Warm Water
187,600 gpm

25 ºF Rise

Cool Water

Steam Condenser

Condensate

Boiler Feedwater
7,645 gpm

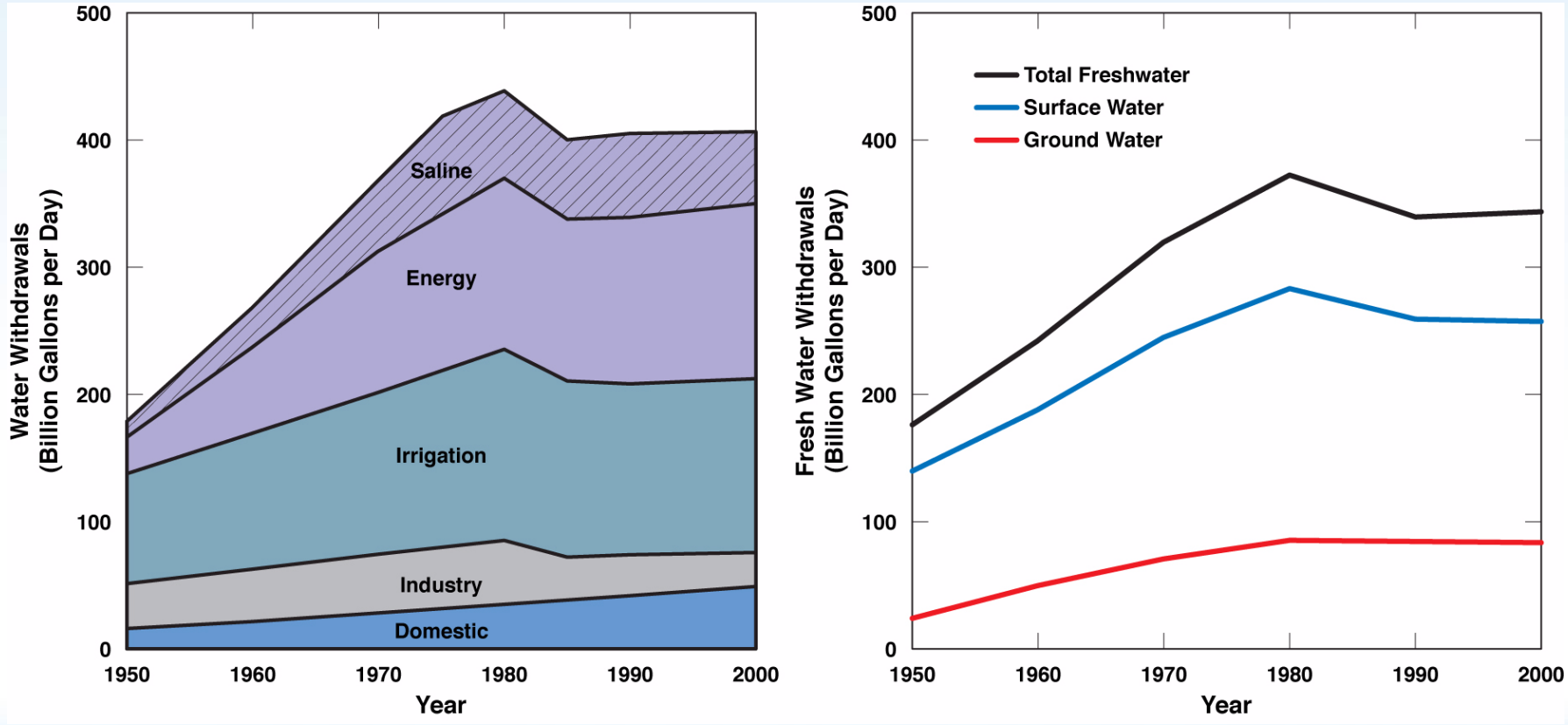
Make-up Water
5,188 gpm

Blowdown Water
1,297 gpm

*Reference: NETL Power Plant Water Consumption Study, May 2007*

ENERGY and WATER

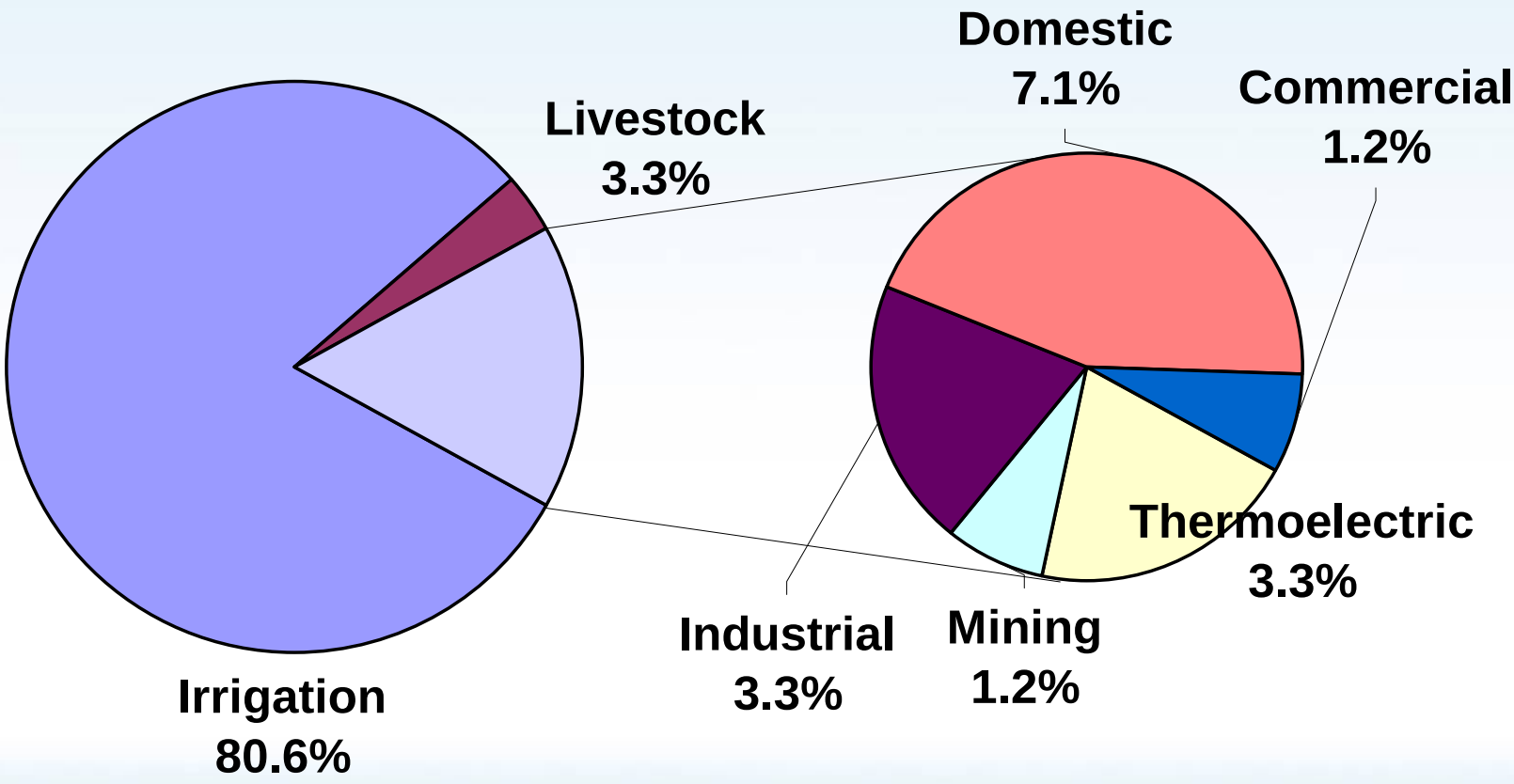
# Water Withdrawal Trends by Sector




[USGS, 2004]

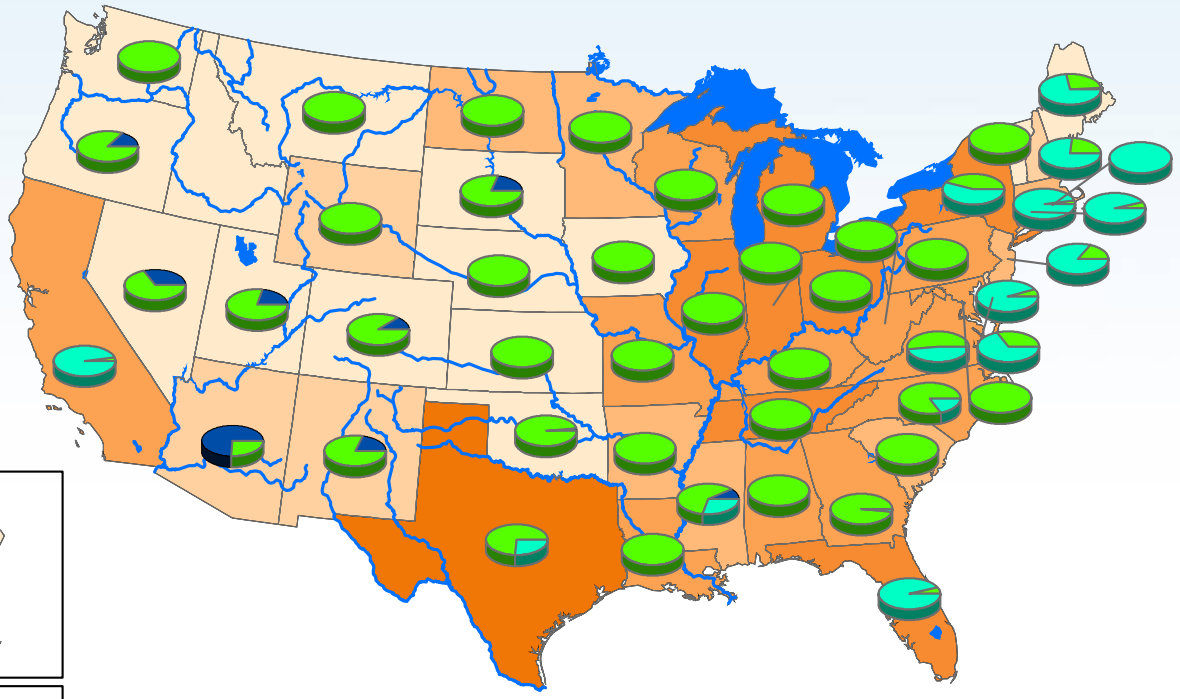
# Water Consumption by Sector

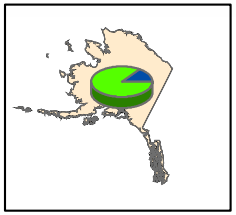
## U.S. Freshwater Consumption, 100 Bgal/day




[USGS, 1998]

# Total Water W/D for Thermo Generation (mgd)
# Water Source for Thermo Generation: SW, GW, Saline (%)





**Sources:**
**Water W/D: USGS 2000**
**Source water: USGS 2000**

4

0 150 300 600 900 1,200
Miles

**Legend**

- staterivers
- Major Lakes (National)

**states**

**Water W/D (mgd)**

- 0 - 165
- 166 - 787
- 788 - 2236
- 2237 - 6254
- 6255 - 10830
- 10831 - 17882

**source_water**

- GW
- SW
- Saline

Los Alamos NATIONAL LABORATORY

NETL

Sandia National Laboratories

ENERGY and WATER

# Electric Power Generation Water Withdrawal and Consumption

| Plant-type | Cooling Process | Water Use Intensity (gal/MWh$_e$) | | |
|---|---|---|---|---|
| | | Steam Condensing[a] | | Other Uses[b] |
| | | Withdrawal | Consumption | Consumption |
| Fossil/ biomass steam turbine[c] | Open-loop | 20,000–50,000 | ~200-300 | ~30-90[d,i] |
| | Closed-loop | 300–600 | 300–480 | |
| | Dry | 0 | 0 | |
| Nuclear steam turbine[c] | Open-loop | 25,000–60,000 | ~400 | ~30[d] |
| | Closed-loop | 500–1,100 | 400–720 | |
| | Dry | 0 | 0 | |
| Natural Gas Combined-Cycle[c] | Open-loop | 7,500–20,000 | 100 | 10[e] |
| | Closed-loop | ~230 | ~180 | |
| | Dry | 0 | 0 | |
| Coal Integrated Gasification Combined-Cycle[c] | Closed-loop | 200 | 170 | 150[c,e] |
| | Dry | 0 | 0 | 150[c,e] |
| Geothermal Steam[f] | Closed-loop | 2000 | 700-1350 | NA |
| Concentrating Solar[g,h] | Closed-loop | 750 | 740 | 10 |
| | Dry | 10 | 0 | 10 |
| Wind and Solar Photovoltaics[j] | N/A | 0 | 0 | 1-2 |
| **Carbon sequestration for fossil energy generation** | | | | |
| Fossil or biomass[k] | All | ~85% increase in water withdrawal and consumption | | |

ENERGY and WATER

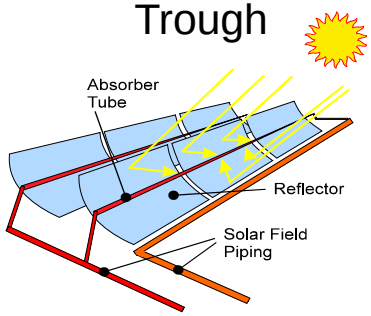
(NETL, EPRI, NREL, UCS, Argonne, DOE, UT)

# Concentrating Solar Power Technology

Steam Turbine Generator
Dispatchable, Integrates with Storage

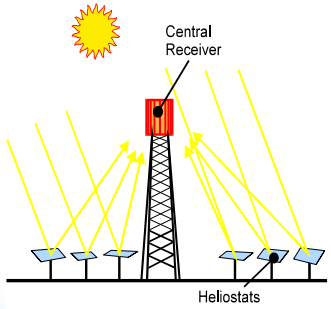
Stirling Engine-Alternator
High Efficiency, no Storage

## Trough



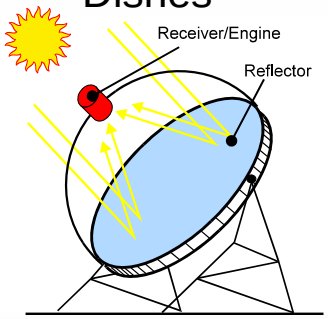

- Most cost effective >250MW
- Operating temp: 400C
- Annual efficiency: 14%

## Towers




- Most cost effective >250 MW
- Operating temp: 560C
- Annual efficiency: 18%

## Dishes



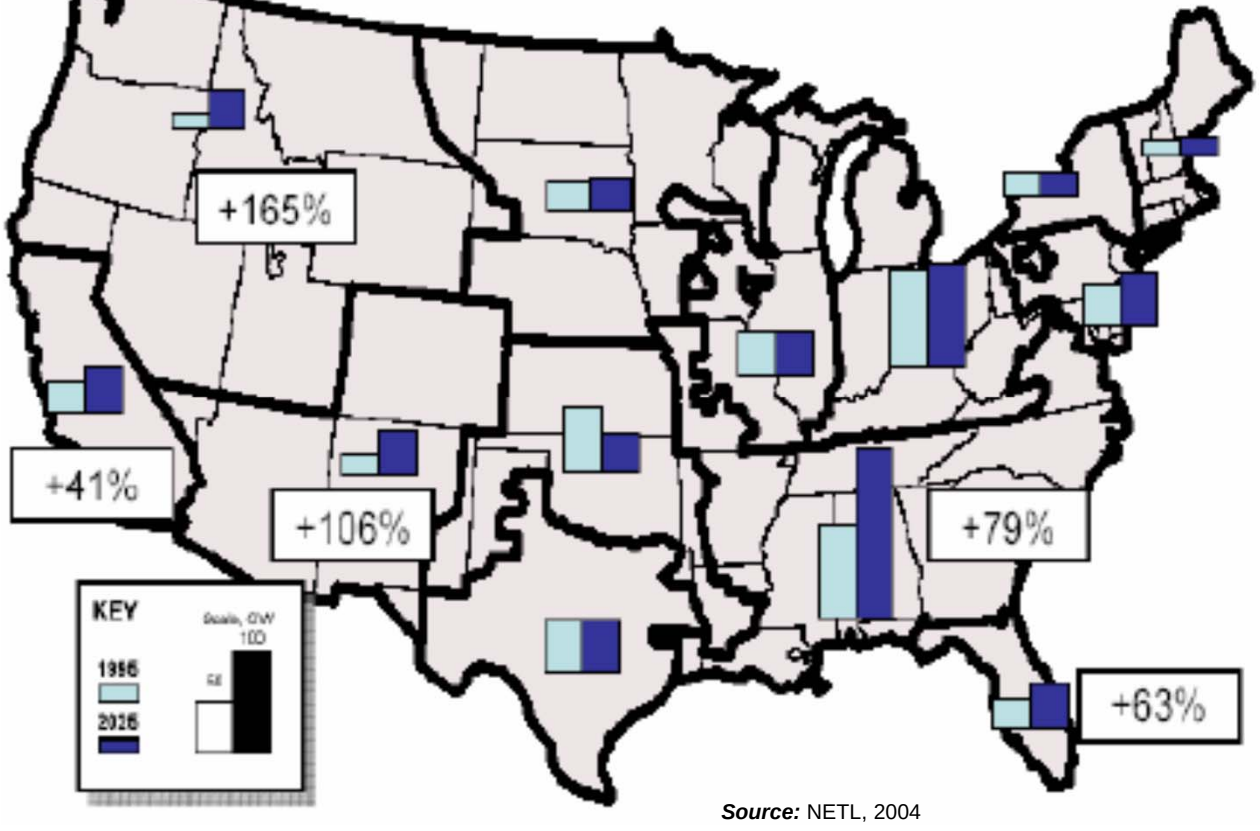

- Modular 30 kW units – more flexibility in siting
- Operating temp: 800C
- Annual efficiency: 23%

ENERGY and WATER

# Energy Growth/Technology Predictions will Impact Regional Water Demand Estimates

- Estimated most growth in water stressed regions
- Estimated low natural gas, low nuclear, low renewable use
- Estimated most new plants to use evaporative cooling

***Projected Thermoelectric Increases***
(Capacity in 2025 vs 1995)




***Source:*** NETL, 2004

**"2004 Estimate Example"**

ENERGY and WATER

# Projected Generation Mix Impacts Estimated Water Demands in 2035 – 2007 Example

- Coal
  - 350, 400 MW steam turbine plants (140,000 MW)
- Natural Gas
  - 150, 100 MW natural gas combined cycle (15,000 MW)
- Renewables
  - 125, 200 MW wind or solar farms (25,000 MW)
- Nuclear
  - 5, 1000 MW nuclear reactors (5,000 MW)
- Hydroelectric
  - None (~40,000-60,000 MW available)

ENERGY and WATER

# Dry and Hybrid Cooling Issues and Opportunities

- 90% Less water consumption
- 6 % loss in production
- 20% reduced capacity at hottest hours
- 10% increase in capital cost
- 1-2 ¢ /kWh increase in cost of power

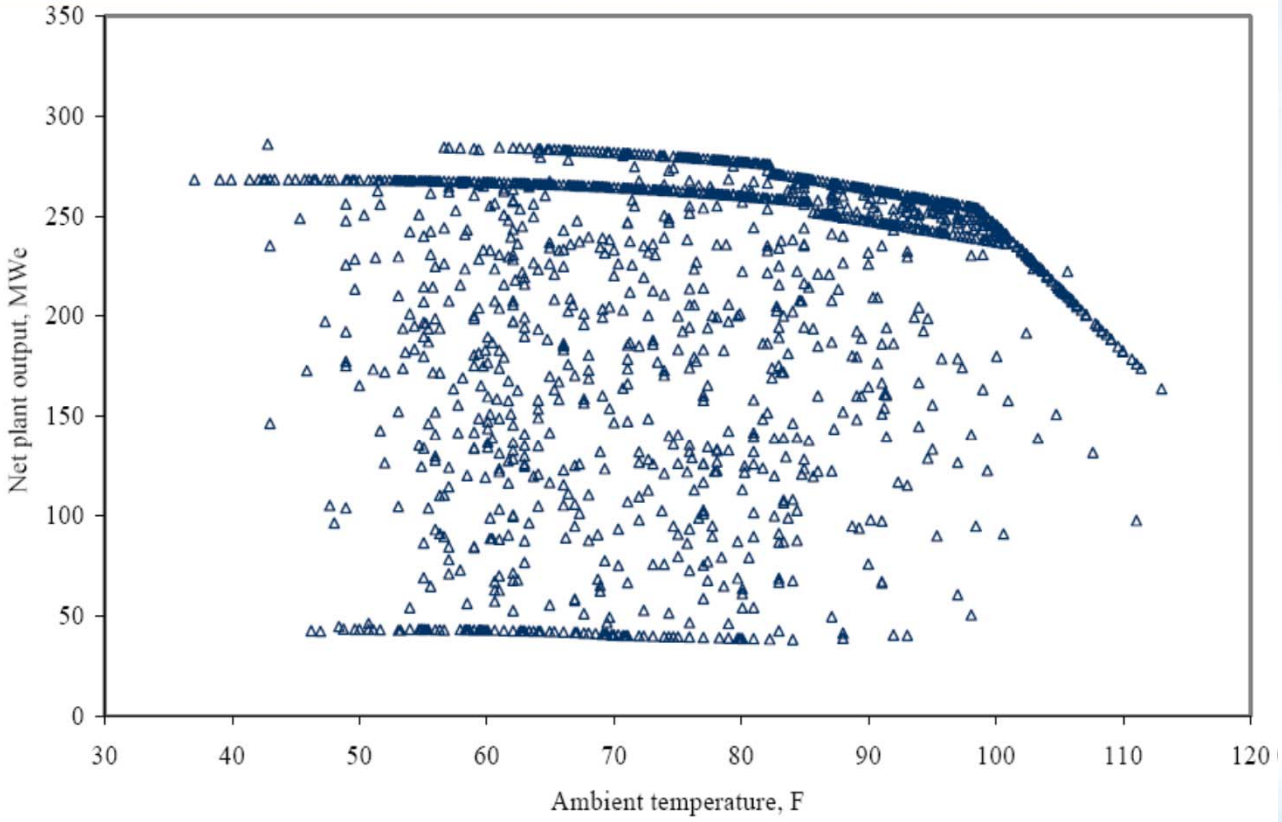



Figure 5 Net Plant Output as a Function of Ambient Temperature; Dry Heat Rejection

# Thermoelectric Power Plant Water Quality Requirements

- Power Plant Cooling Tower Systems
  - Do not require very good makeup water
    - Mine water, sea water, waste water
  - Can use recycled waters replacing fresh water
  - Many have converted to municipal wastewater
    - 50-60 using municipal or industrial waste water
  - Knowledge of cooling system design, construction and operation, recycled water quality, and improved water treatments make it successful and economical
  - Requires matching water quality with system
    - Chlorides, ammonia, phoshates, biological, corrosion foulants, scale
  - Has often saved water but not always costs
  - Drift of particulate is a growing issue

(Puckorius, Veil, EPRI, NETL)