Energy – Water Nexus

April 8, 2010

Background
Regulatory/Reliability
Water For Power
Power For Water
Lunch Break
Work Performed in Other States
Discussion

Energy-Water Relationship

Looking Backwards

Water & Energy are Inextricably Linked

Water ⟷ **Energy**

2003 Heat Wave Impact on French Electric Power Generation

- Loss of 7 to 15% of nuclear generation capacity for 5 weeks
- Loss of 20% of hydro generation capacity
- Large-scale load shedding and shut off transmission to Italy
- Sharp increase of spot-market prices: 1000 to 150 $ / MWh for most critical days

Bort-les-Orgues Réservoir

Normal conditions in August

August 27, 2003

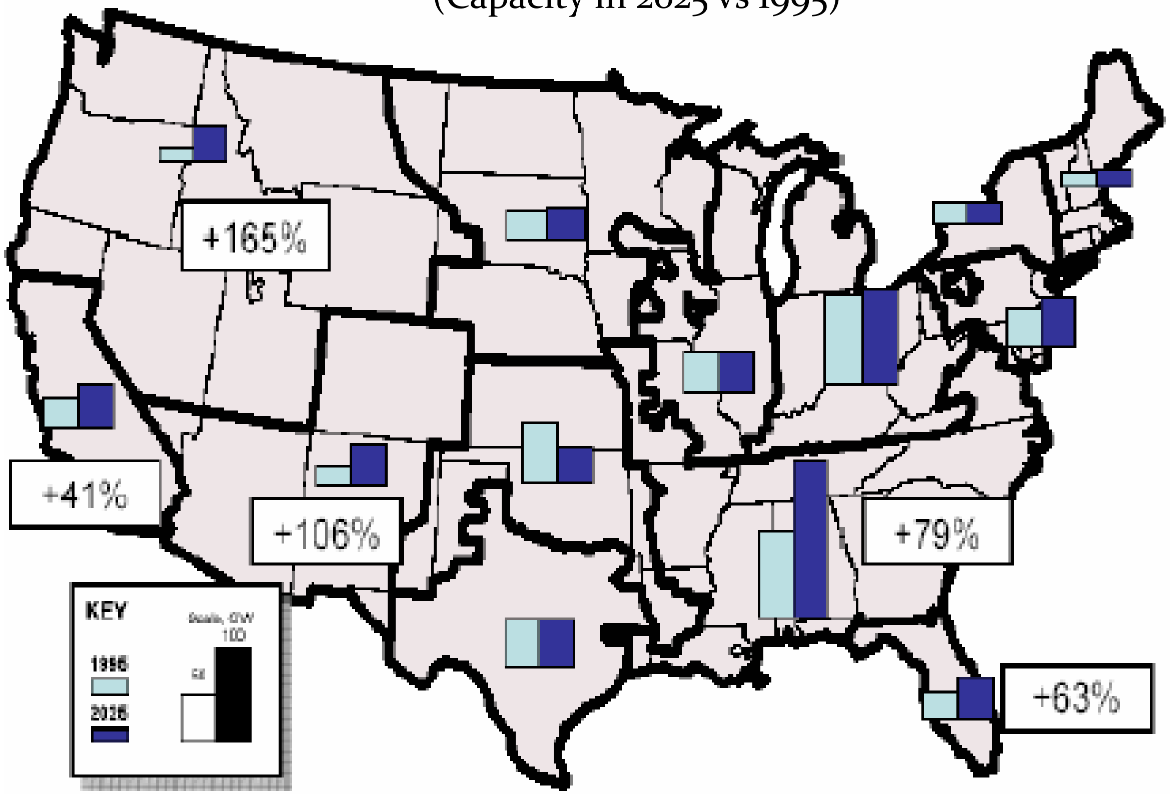
Headlines 2007-2008

- **Southeastern Drought May Last Longer Than Expected**
- **Southeast drought worst in 100 years**
- **Some cities may run out of water**
- **The Effects of the 2007 Drought on Georgia's Water Supply**
- **Drought Plagues Southeastern U.S.**

Growth in Thermoelectric Power Generation

- Most growth in water stressed regions
- Most new plants expected to use evaporative cooling

Projected Thermoelectric Increases
(Capacity in 2025 vs 1995)



Source: NETL, 2004

Energy Demands on Water Resources

- US DOE Report to Congress – 2006
  - Nationwide 4% of US power generation is used for water supply (acquisition, treatment, delivery)
  - EIA projects US population to grow by 70 million in 25 years and electricity demand to grow by 50%
  - Energy planning and water planning are done separately
  - New power plants have been opposed because of negative impacts on water supply (Arizona, Nevada, Georgia, Texas, and others)

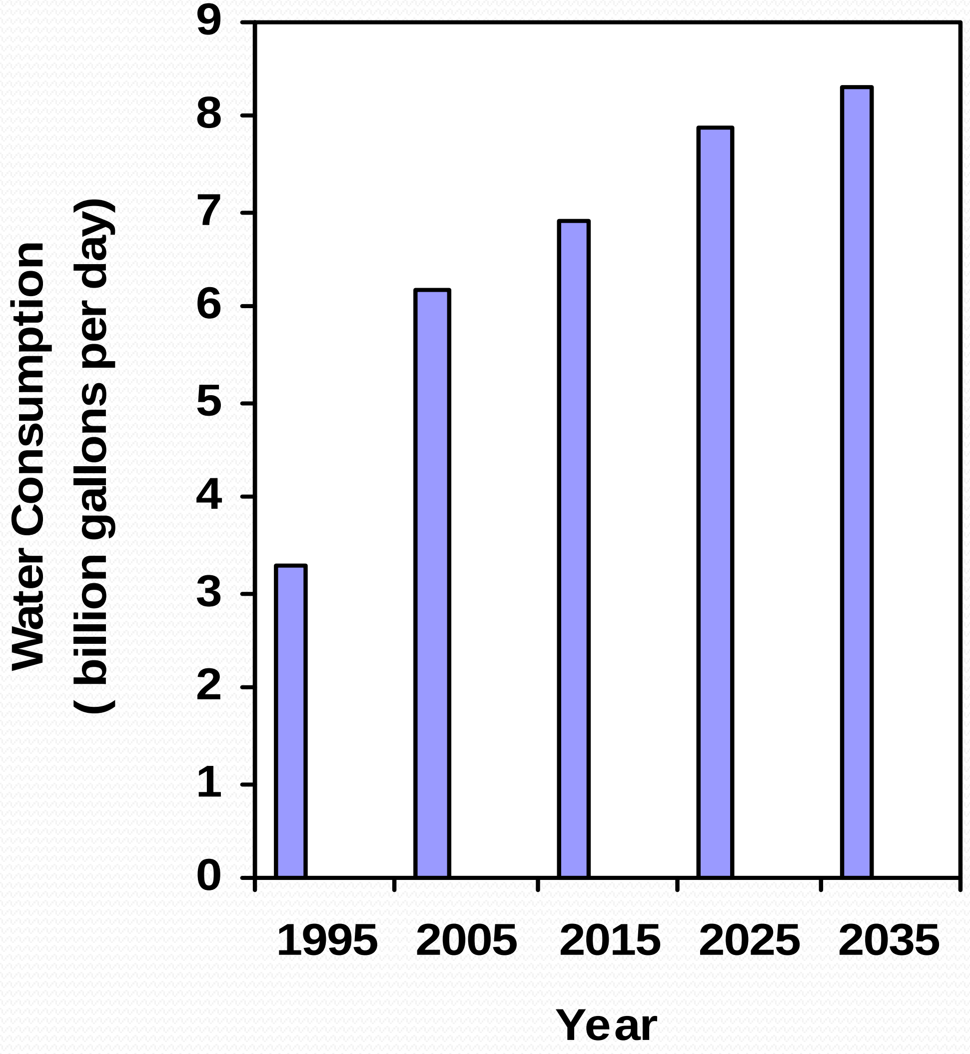
Energy Demands on Water Resources

- DOE/NETL (2006, 2008)– Estimating Freshwater Needs To Meet Future Thermoelectric Generation Requirements
  - 45% increase in thermoelectric capacity by 2030 in the western United States and a 27% increase in the southeast, compared to an 18% increase nationally.
  - Clean Water Act Sections 316(a, b) – will reduce once-through cooling (withdrawal, most water is returned to the source) and drive use of more water consumptive cooling towers (water is released to the atmosphere)
  - Freshwater withdrawal in 2030 will decrease by 5.0 – 23.0% and freshwater consumption will increase by 30.7 – 49.0%.
  - This will increase the nationwide use of water for power generation from 4% up to 5%, or more

Water Demands for Future Electric Power Development

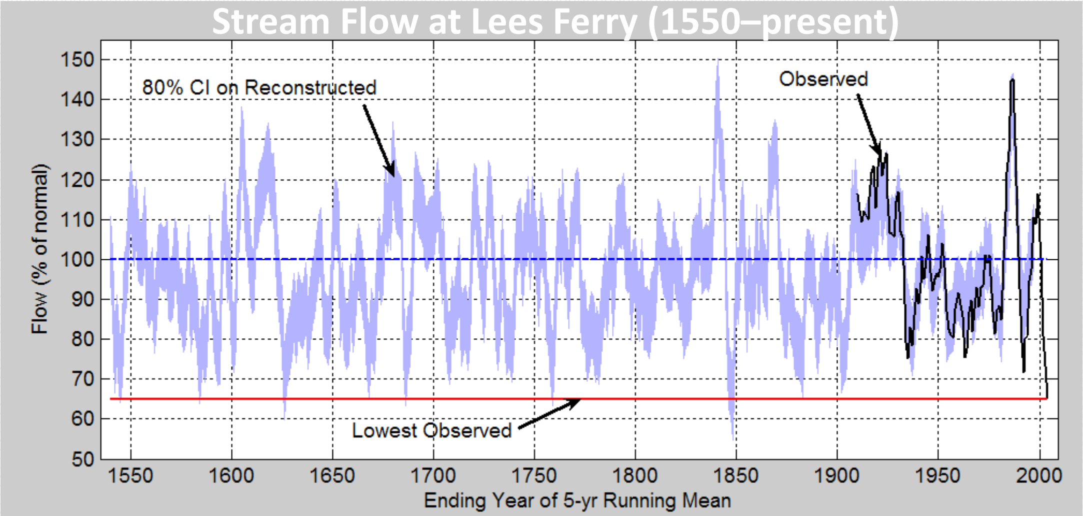
- Water demands could almost triple from 1995 consumption for projected mix of plants and cooling
- Carbon emission requirements will increase water consumption by an additional 1-2 Bgal/day

Source: NETL 2006



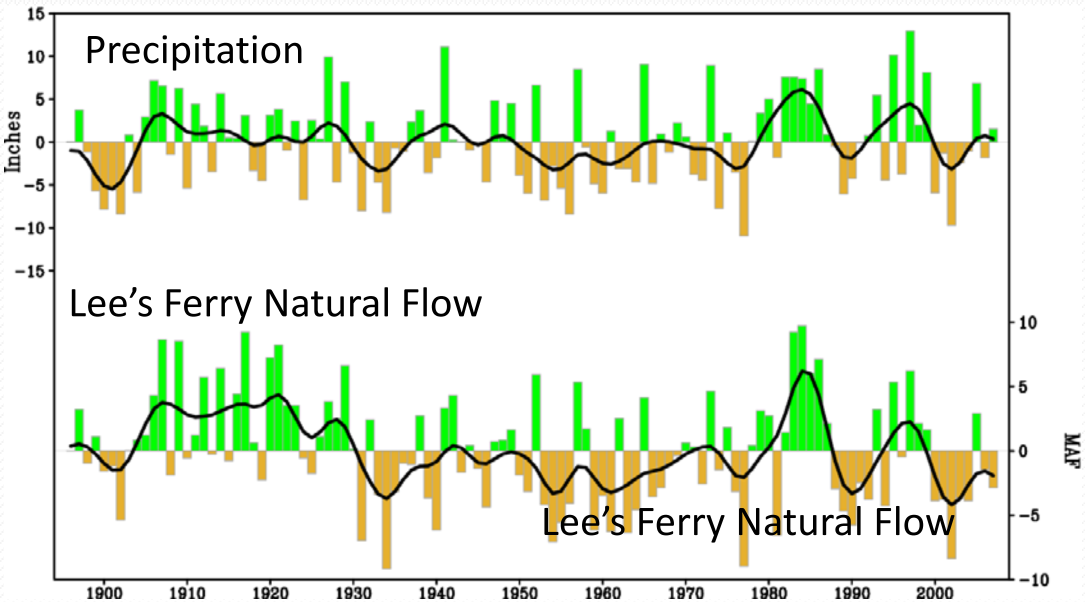
Drought

Drought has been less frequent & less severe compared with the last 1000 years



- Historical low flows can be attributed mainly to **changes in precipitation**

- Recent **warming has contributed** to the severity of drought in the southwest United States



Will future droughts be qualitatively different because of projected warming?

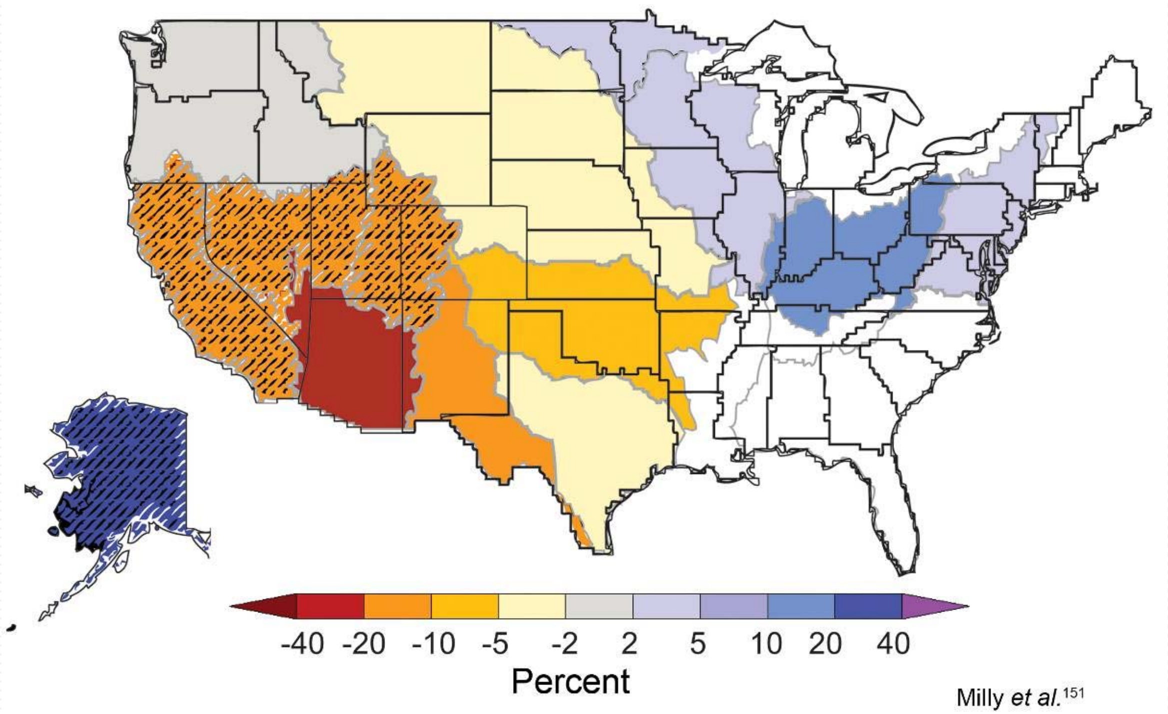
Source: CO Climate Report, 2008

Regional Focus:
Southwest & Colorado River Basin

- Provides water for 25 million people, 38 million by 2020
- Serves Phoenix, Denver, LA, Santa Fe, SLC, Albuquerque
- Major Transmountain Diversions
- Supports $1.2 trillion economy
- 15% of area provides 85% of water

Regional Water Resources

% change in runoff (2041–2060)



- 90% of models agree at least a 10% decline in annual runoff across the Upper CRB to California by 2050

"…requirements of the CO River Compact may only be met 60–75% of the time by 2025…." (IPCC Technical Report on Water, 2008)

The "Perfect Storm"

- The southwest is the fastest growing area in the US
- The southwest is arguably the most water challenged area in the US
- The majority of 'new' water will come from reclaimed waters
- Competition for reclaimed waters will be intense
- New power demands will increase pressure on available water supplies
- New water and wastewater treatment technologies are energy intensive (UF,MF,RO, ozonation) – increased pressure on energy supplies
- Water and power utilities don't plan together

Regulatory Issues Reliability/Cost of Power/ Water Use

Regulatory Issues

- ADWR (Water) - Third Management Plan requires a minimum of 15 cycles of concentration of cooling water prior to discharge/disposal (case specific relief is possible)
- Maricopa County Air Pollution Control Rules and Regulations (Air) – emissions are regulated depending on the plant type, size, emissions potential, …
  - Palo Verde TDS limits in circulation water – 30,000 mg/l (monthly average) – ensures meeting PM-10 limits
  - Redhawk TDS limits in circulation water - 20,000 mg/l (monthly average)
- Regulated entity must comply with both rules

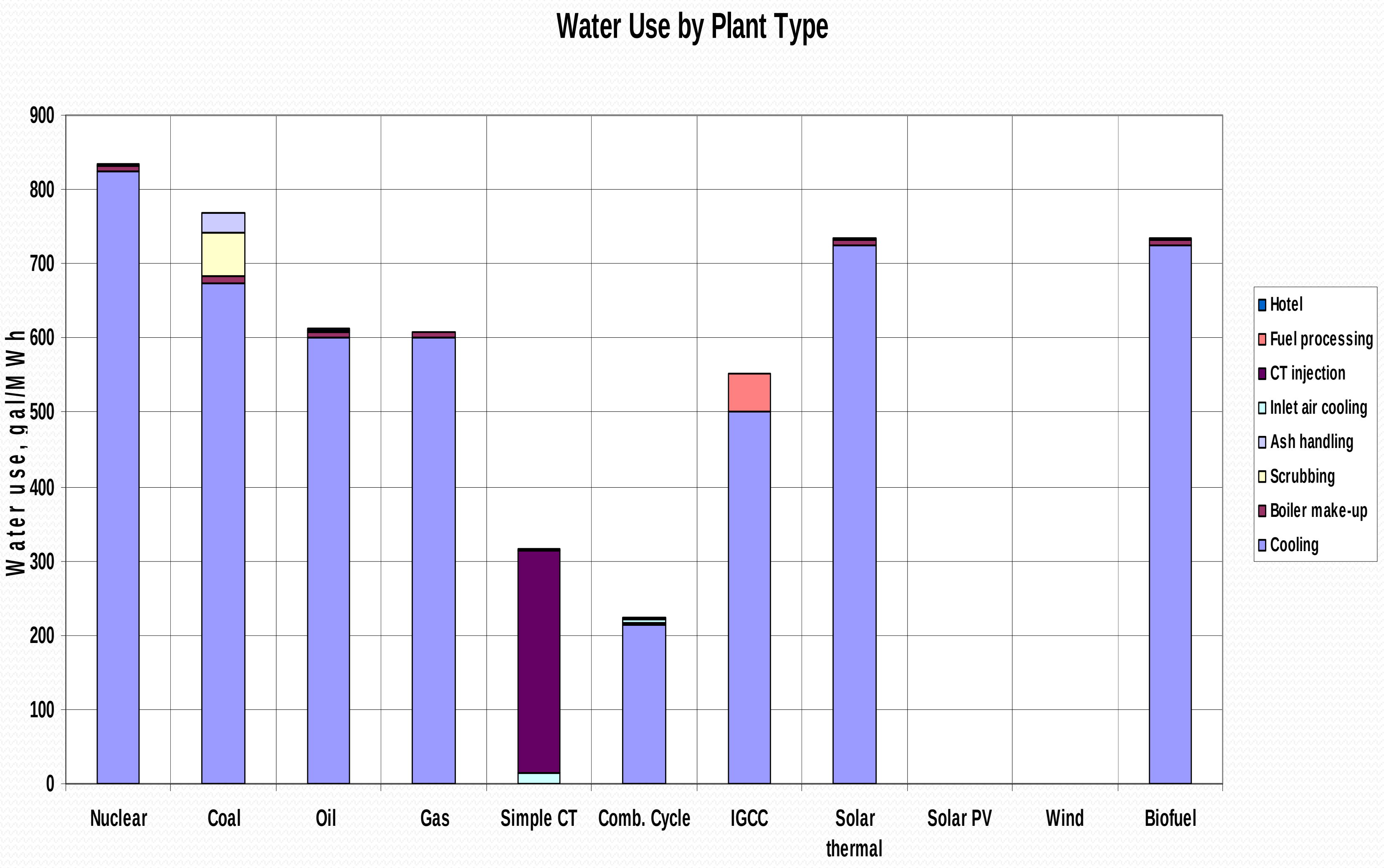
What Plant Type is Best?

Reliability/Cost of Power/Water Use

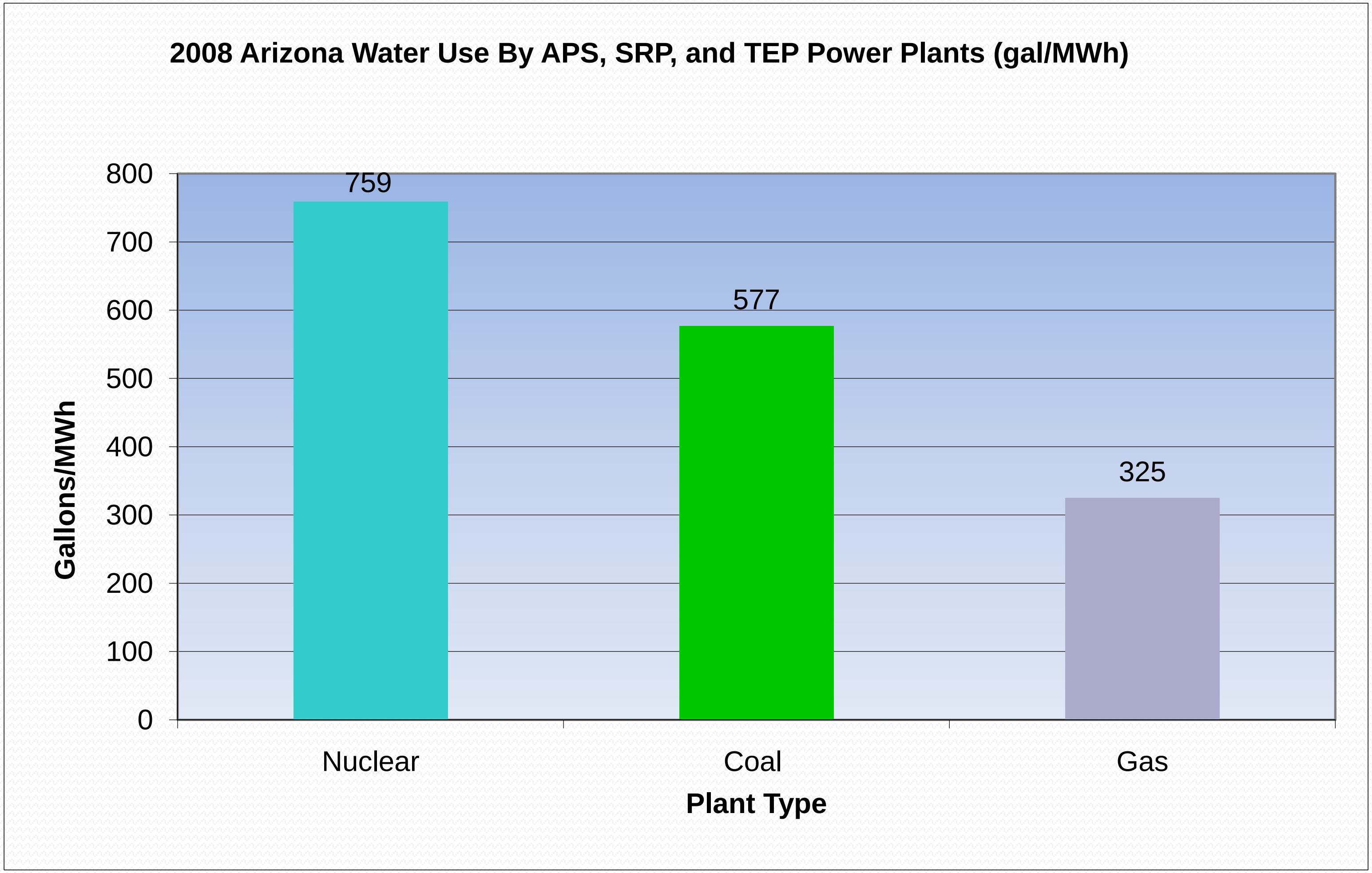
- Nuclear and coal are baseload power – highest capacity factors, operate 24/7
- Gas plants are peaking plants or are intermediate supplies
- Wind, solar thermal, and solar photovoltaic are intermittent sources
- Relative cost of power production varies; renewable energy is expected to become more competitive. From least cost to most expensive to produce:
  - Nuclear, coal, gas, solar thermal, wind, solar photovoltaic
- Relative water use from most to least water intensive:
  - Solar thermal, nuclear, coal, gas, wind, solar photovoltaic

Water For Power

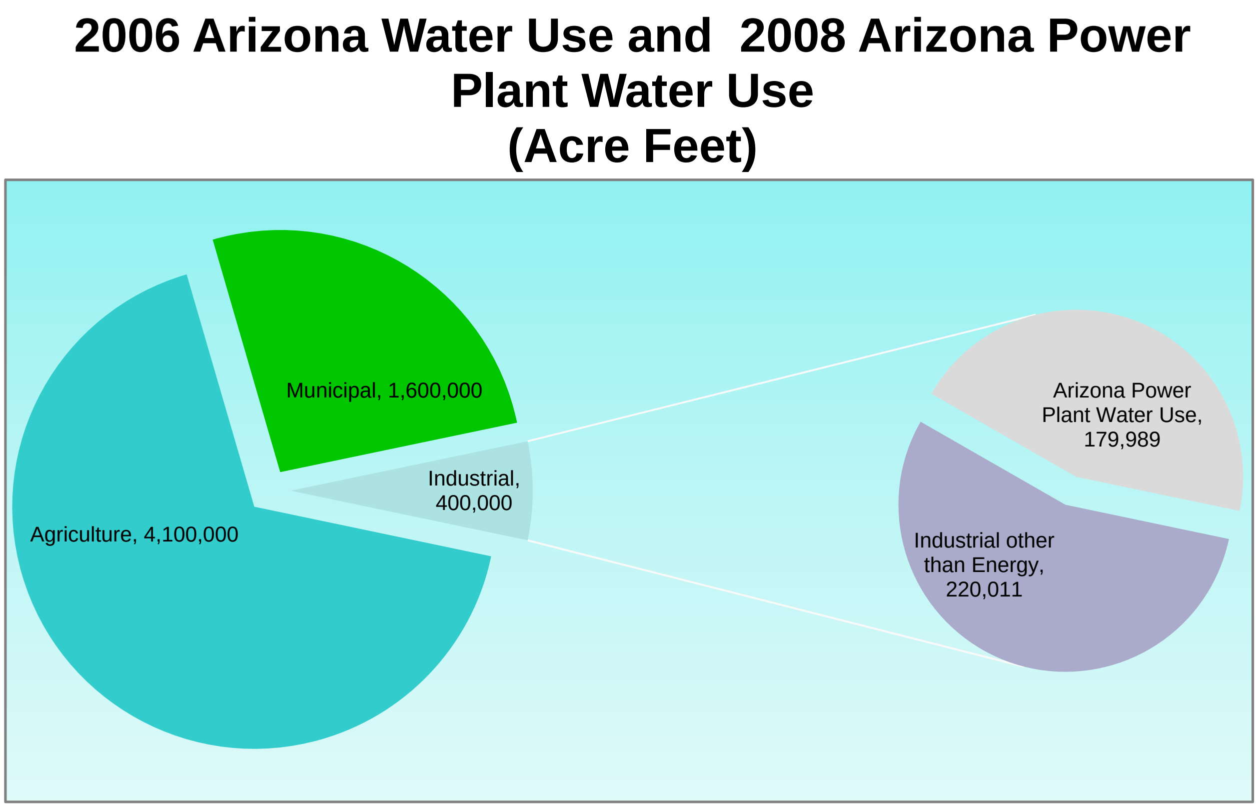
Water Use Efficiency (Steam Cycle Plants are Using Wet Cooling Tower)



Arizona Power Plant Water Usage



State of Arizona Water Uses



Arizona Power Plant Use = 3% of Total State Water Use

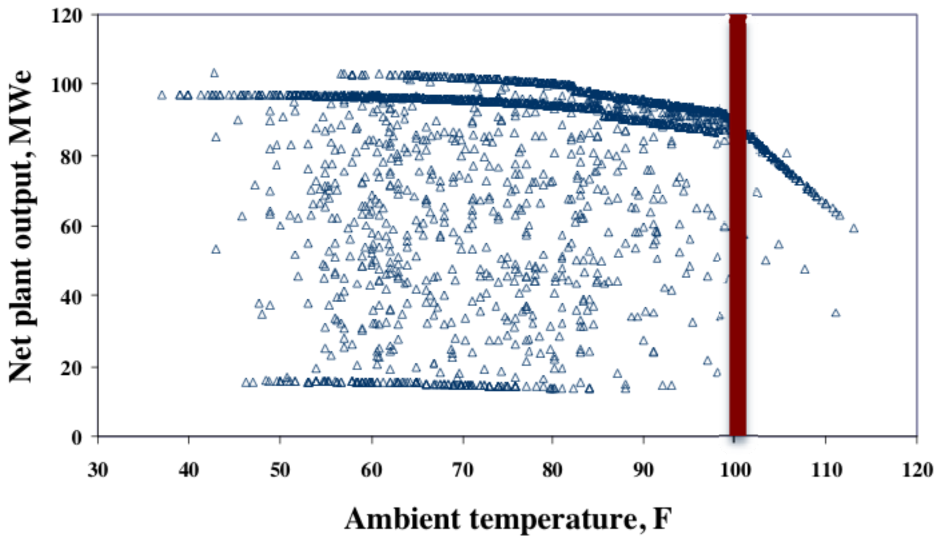
Alternative Cooling Issues and Challenges

Pilot Spray-enhanced Dry Cooling

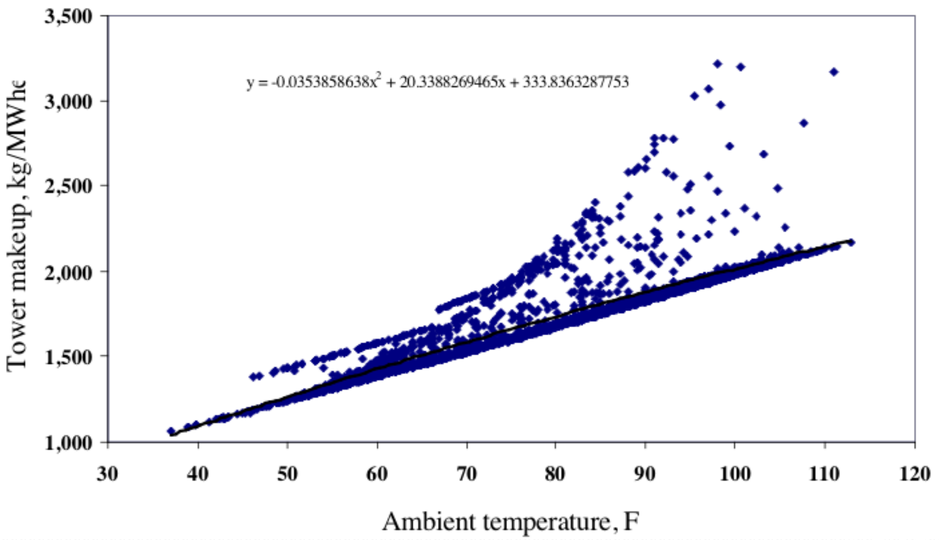
Dry-Cooled Power Plant

- High capital cost and large footprint
- Hot weather penalties
  - Power capacity reduced during peak summer electricity demand
- Wind effects reduce cooling efficiency
- Not currently licensed for nuclear power plants

Dry or Wet Cooling?



Dry Cooling:
Efficiency vs.
Ambient Temperature



Wet Cooling:
Water Consumption vs.
Ambient Temperature

Water Requirements for Carbon Capture – Ultra Supercritical (USC) Coal Plant

- Results from recently published EPRI study:

	USC without PCC	USC with PCC
Water Balance: (in Gallons Per Minute)		
Lake Michigan Water	6,652	9,232
Municipal Water	222	222
Total Water In	6,874	9,454
Cooling Tower Blowdown	652	1,342
Sanitary Waste to Sewer	2	2
Water in Exported Solid Wastes	101	101
Evaporative/Drift Losses	6,020	7,910
Sootblowing & Other Losses	99	99
Total Water Out	6,874	9,454
Net Export MW	750.0	492.1
Water usage GPM/MW	9.16	19.2

- Water consumption increase with PCC ~38% in GPM
- However, PCC parasitic power leads to double hit!

The Utility Balancing Act

- Can conserve up to 90+ percent water use in plants, but what cost to ratepayer?
- Compliance with environmental regulatory requirements
- How best to expand generation and efficiency options to meet demand
- Respond to regional water constraints and stakeholders

Degraded Water Use – the Promise and the Problems

Possible Sources

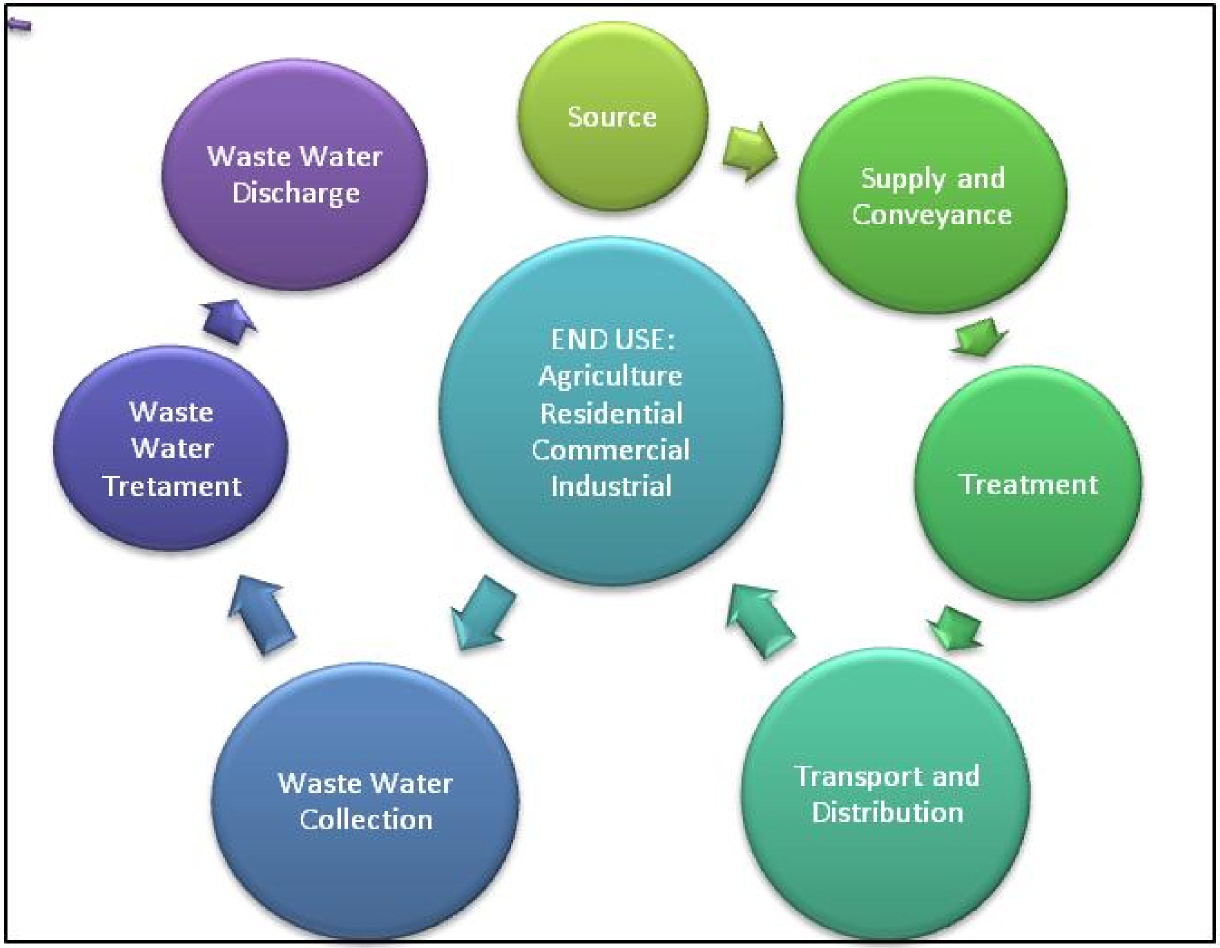
- Sewerage effluent
- Produced water (oil/gas)
- Storm water
- Mine drainage
- Agricultural runoff
- Saline aquifers
- Coastal waters

Problems

- Inconsistent quantity/quality
- Transport costs/feasibility
- Treatment costs
- Materials of construction
- Scaling/fouling/corrosion
- Blowdown disposal
- Drift issues

Power For Water

Energy Inputs to Water System



California Got Active in Research

"…water-related energy use consumes 19% of the state's electricity, 30% of its natural gas, and 88 billion gallons of diesel fuel every year…"

California Energy Commission

California's Water-Energy Relationship - Nov 2005

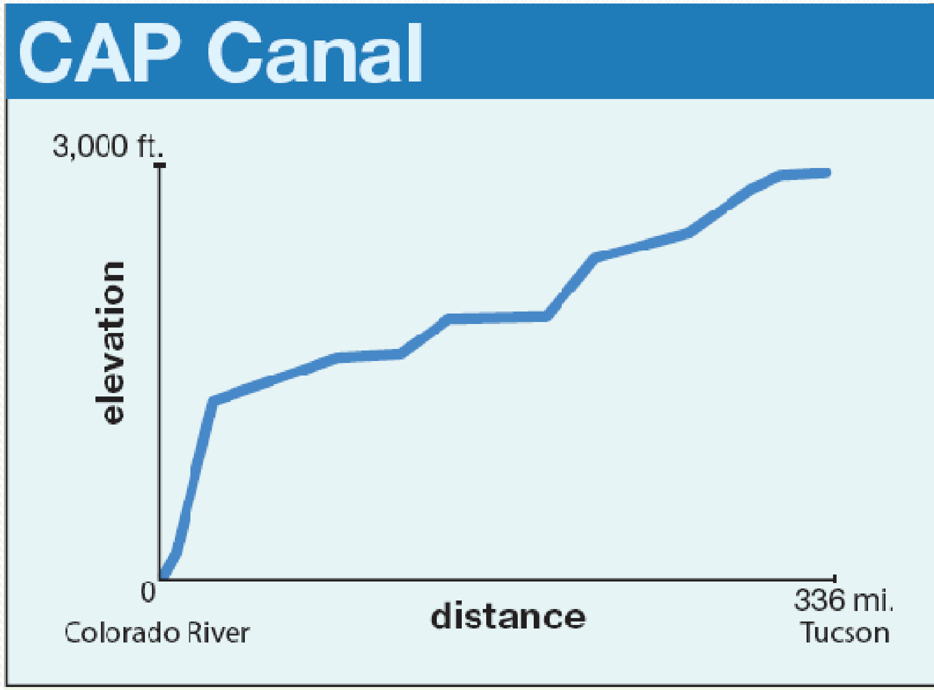
"95% of the energy efficiency goals could be met in water efficiency programs at 50% of the cost"

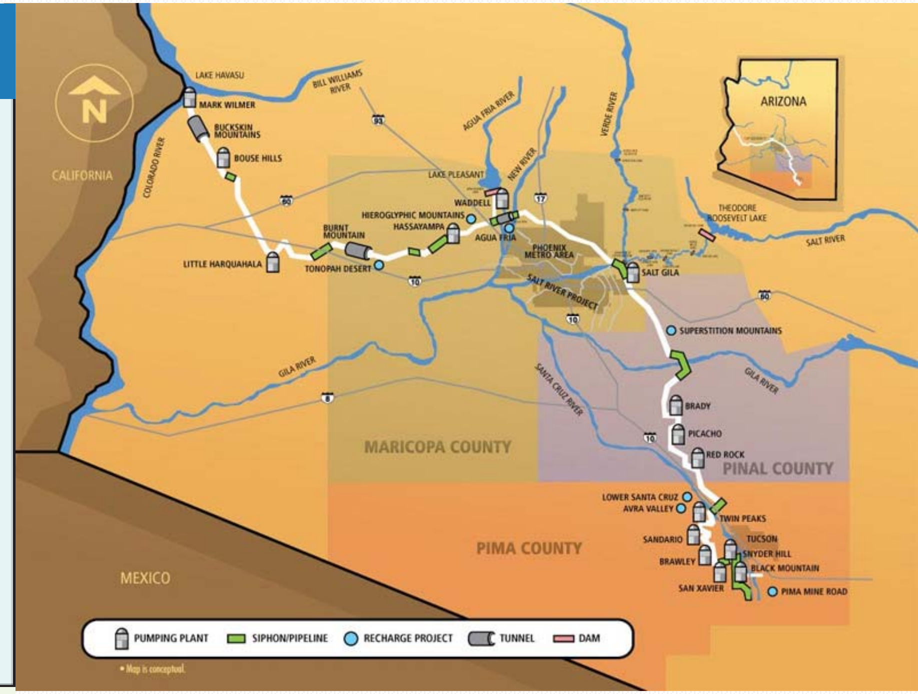
Mary Ann Dickinson

CA Urban Water Conservation Council

Central Arizona Project

Largest Arizona Power User

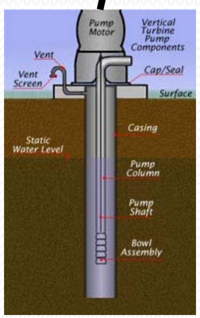


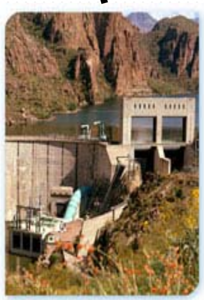


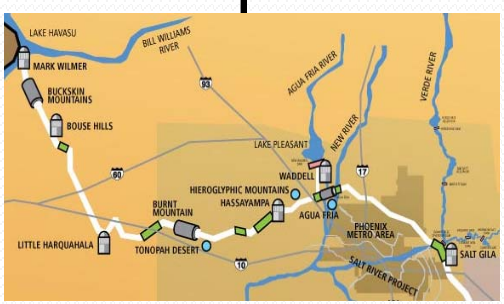
3200 kWh to pump one acre-foot of CAP water from the Colorado River to Tucson.

CAP consumes nearly 3 million MWHs annually

Phoenix Water Supply Assumptions

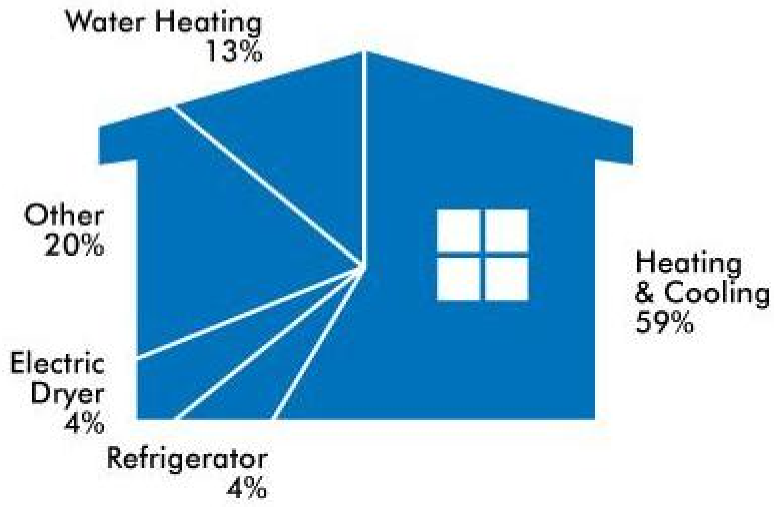






- COP water supply:
  - Residential deliveries ~66% of total
  - Single-family homes ~77% of residential
- "Normal" year residential supply mix:
  - 97% surface water
    - ✓ 54% SRP, 46% CAP
  - 3% groundwater (COP wells)
- Groundwater well *extraction*:
  - COP pump factor = 1,156 kWh/AF
  - SRP pump factor = 437 kWh/AF
- Canal system *conveyance*:
  - CAP pump factor = 1,602 kWh/AF

End-Use Assumptions



- City of Phoenix home
  - ✓ Single-family detached
  - ✓ 1,500 square feet
  - ✓ Total electric
  - ✓ No pool
  - ✓ Family of 4
- 35% of water is used indoors
- 30% of indoor water is heated
- Water heating is the only water-related energy use

Electricity Use and Carbon Emissions – Annual Home Water Use

(one "typical" single-family Phoenix household)

Component of Water Use Cycle	Water Use (kgal)	Electricity Use (kWh)	Emissions (lbs CO_2e)
A. Water supply (pumping / conveyance)	141	419	617
B. Water treatment	133	23	34
C. Water distribution	133	161	236
D. Home water use (heated and unheated)	122	2,788	4,099
E-F. Wastewater collection / treatment	43	69	101
Total		3,460	5,087

Summary of Embedded Electricity - System vs. Home Water Use

System

Component	Intensity
Water supply (pumping / conveyance)	3.0 kWh / 1000 gal
Water treatment / distribution	1.4 kWh / 1000 gal
Wastewater collection / treatment	1.6 kWh / 1000 gal
Overall system *	**4.8 kWh / 1000 gal**

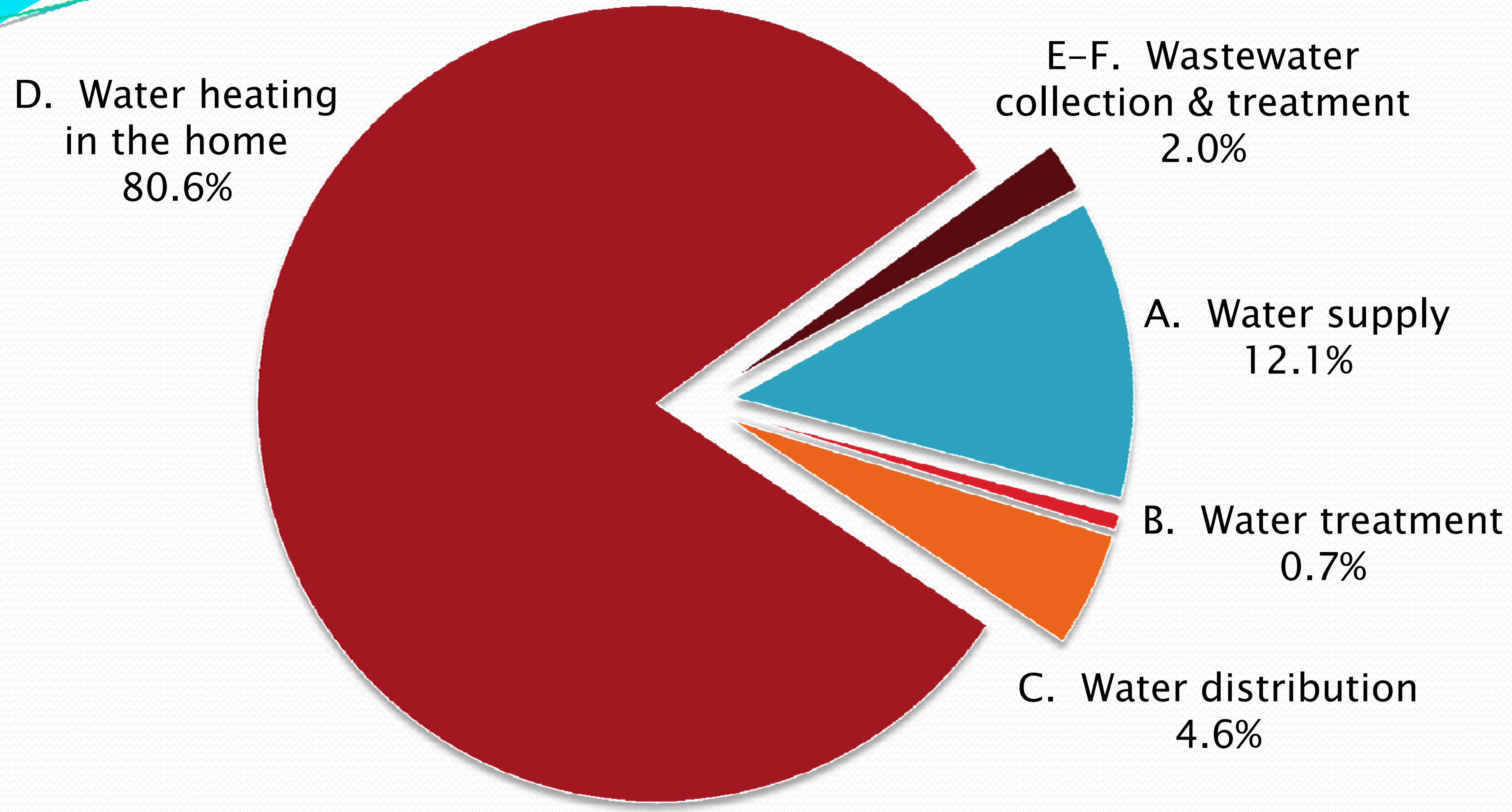
Home

Component	Intensity
Home water use (heated and unheated)	22.8 kWh / 1000 gal
	22.8 kWh / 1000 gal

Overall cycle intensity * = 24.5 kWh / 1000 gal

* "Overall" intensities take into account the relative "weight" of each contributing component.

Electricity Embedded in the Water Use Cycle



***Over 80%** of the electricity use and carbon emissions for the **entire** residential (potable) water use cycle can be attributed to **water heating** in the home.*

What this Means…for a Home

- **Monthly** water use of ~10,000 gallons translates to
  - ✓ About **300 kWh** embedded electricity
  - ✓ About **430 pounds** of CO_2e

*300 kWh is the equivalent of leaving four (4) 100-watt light bulbs burning non-stop **all month long**!*

What This Means…for a Community

So, if all 410,000 Single Family homes in the City of Phoenix were like the households we modeled:

- ✓ Nearly **1.5 million MWh** of embedded electricity
- ✓ Nearly **950,000 metric tons** of CO_2e

*This is roughly the equivalent of annual GHG emissions from **175,000** passenger vehicles.*

Impacts of Water Conservation

The savings compound if a community works together to conserve.

- 10% reduction in water use (~12,000 gallons/yr) saves:
  - ✓ 150,000 MWh of embedded electricity

This is enough energy to power nearly 7,000 homes for a year – through water conservation alone!

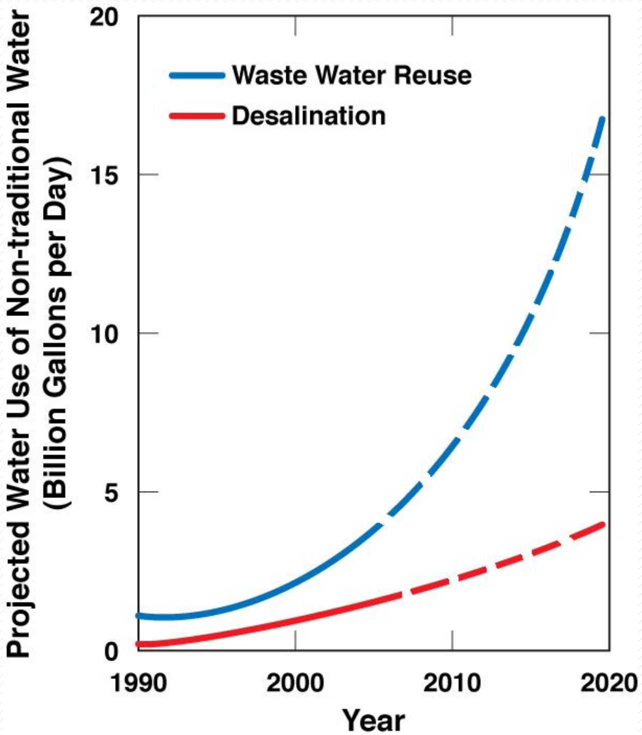
95,000 metric tons of CO_2e avoided

Saving water saves energy, which results in additional water savings at the power plant…this could amount to <u>nearly 80 million gallons saved at the power plant each year</u>.

Future Considerations for Cities

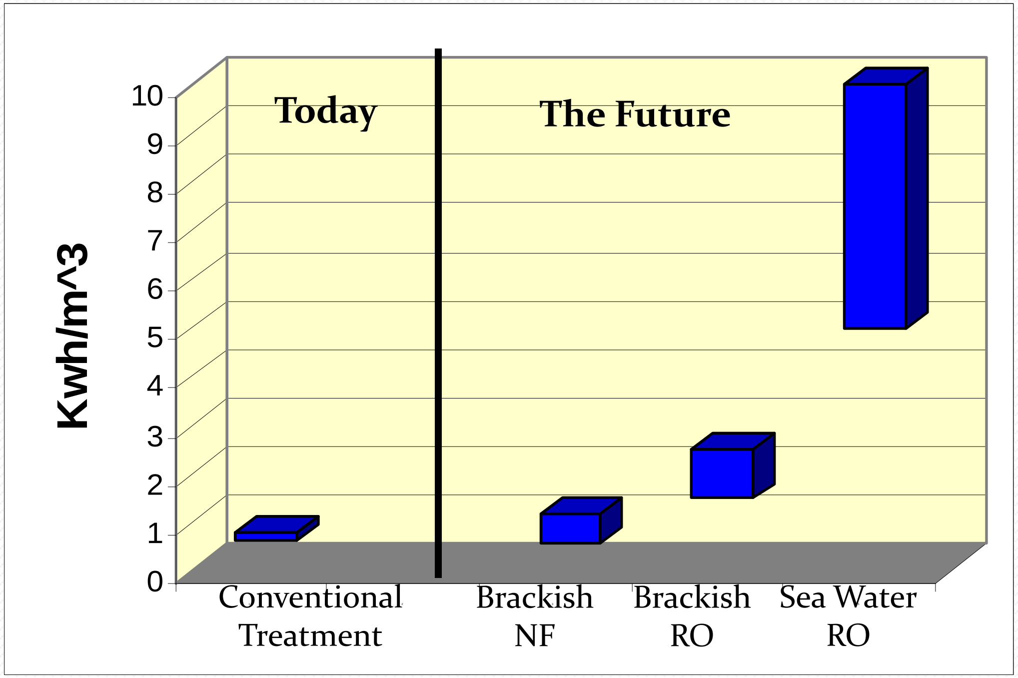
- New water regulations take effect in 2012….
  - US EPA Safe Drinking Water Act - Stage 2 Disinfectants and Disinfection Byproducts (DBPs) Rule
    - ✓ Purpose: enhance monitoring for & reduce concentrations of two classes of DBPs - Trihalomethanes (THMs) & haloacetic acids (HAAs)
    - ✓ Impact: more stringent limits at more locations
  - Water & wastewater facilities are considering alternative / advanced treatment technologies
    - ✓ Examples: Granular Activated Carbon (GAC) or membrane filtration for organic removal, and UV or ozone for disinfection
    - ✓ Impact: increased energy, chemical, infrastructure costs

Growing Use of Non-traditional Water Resources



(From EPA 2004, Water Reuse 2007, Mickley 2003)

Power Requirements For Treating



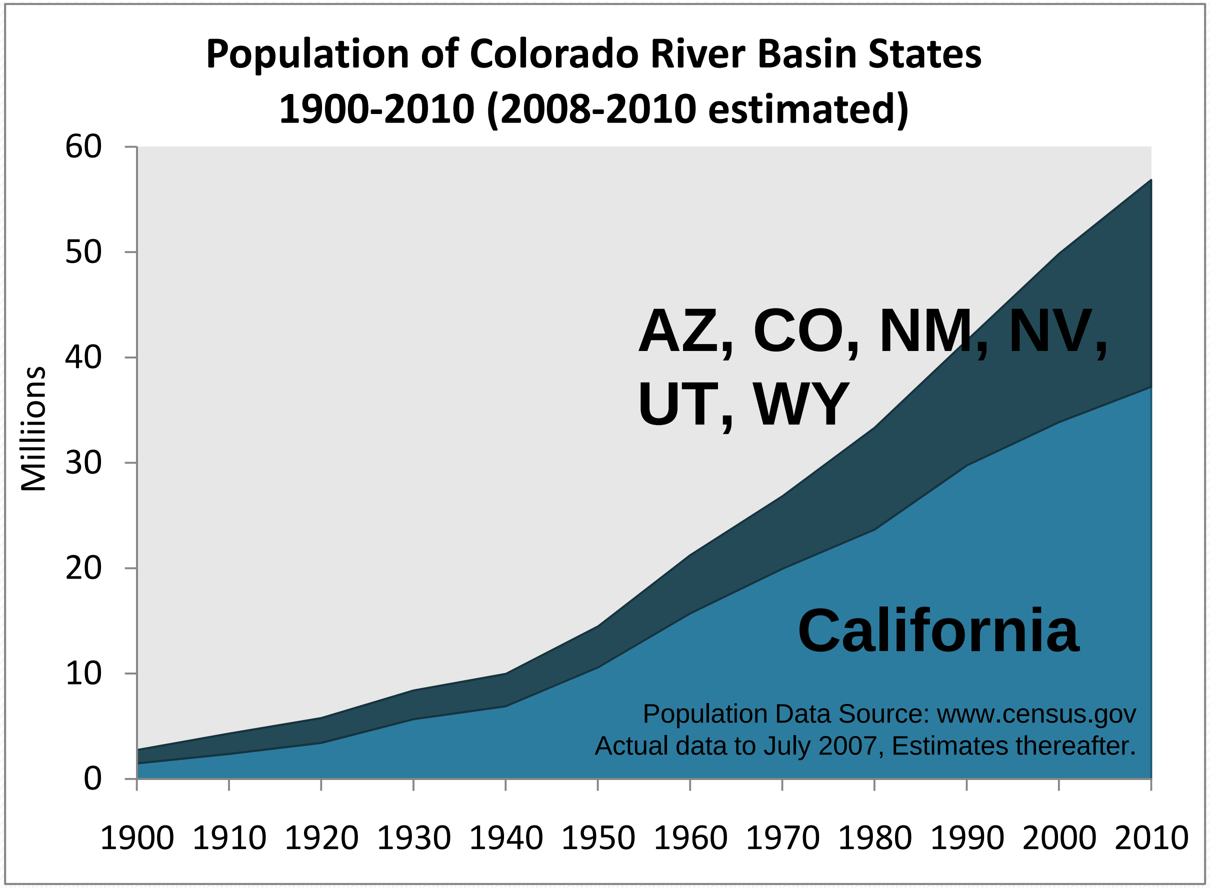
(Einfeld 2007)

- Desal growing at 10% per year, waste water reuse at 15% per year
- Reuse not accounted for in USGS assessments
- Non-traditional water use is energy intensive

Work Performed in Other States

Regional Challenges

- **Rapidly growing population**
- Social & environmental stresses
- Highly variable and complex climate

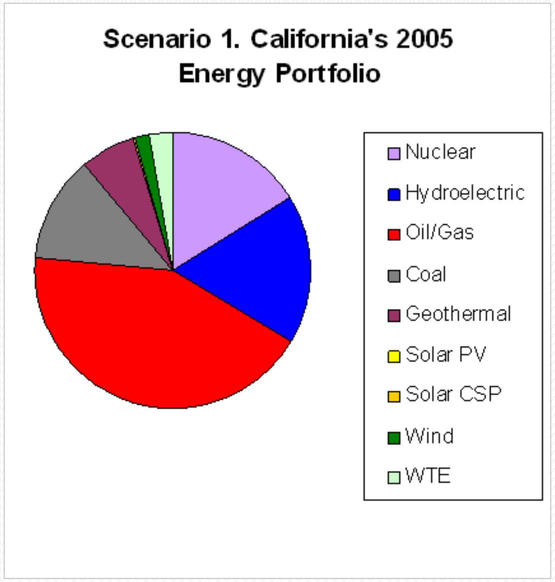


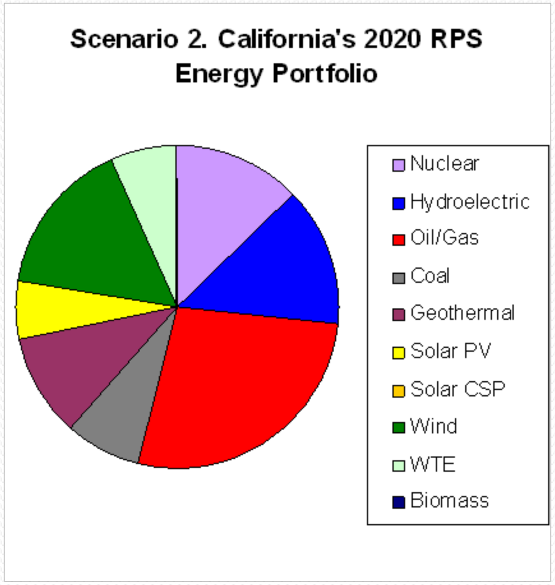
Energy Embedded in Water

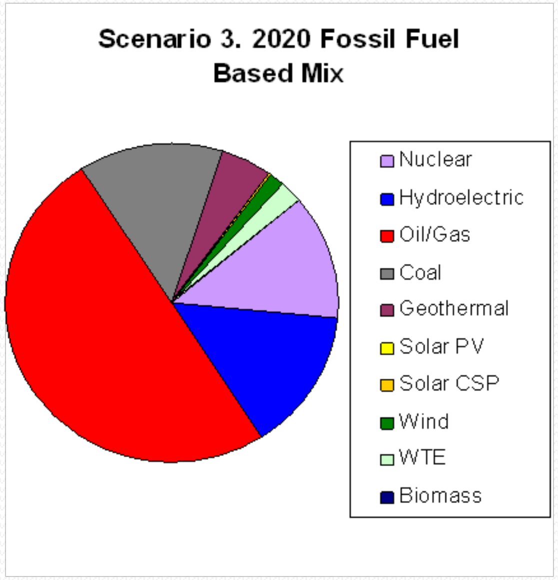
California Energy Use:

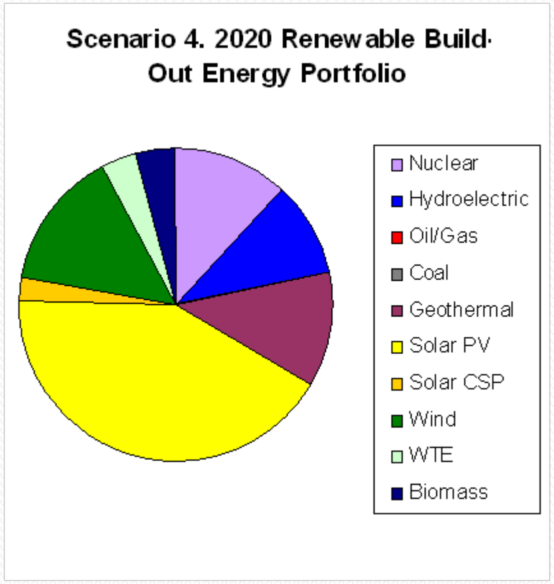
19% of electricity is used to acquire, treat, and deliver water

Water for Electricity

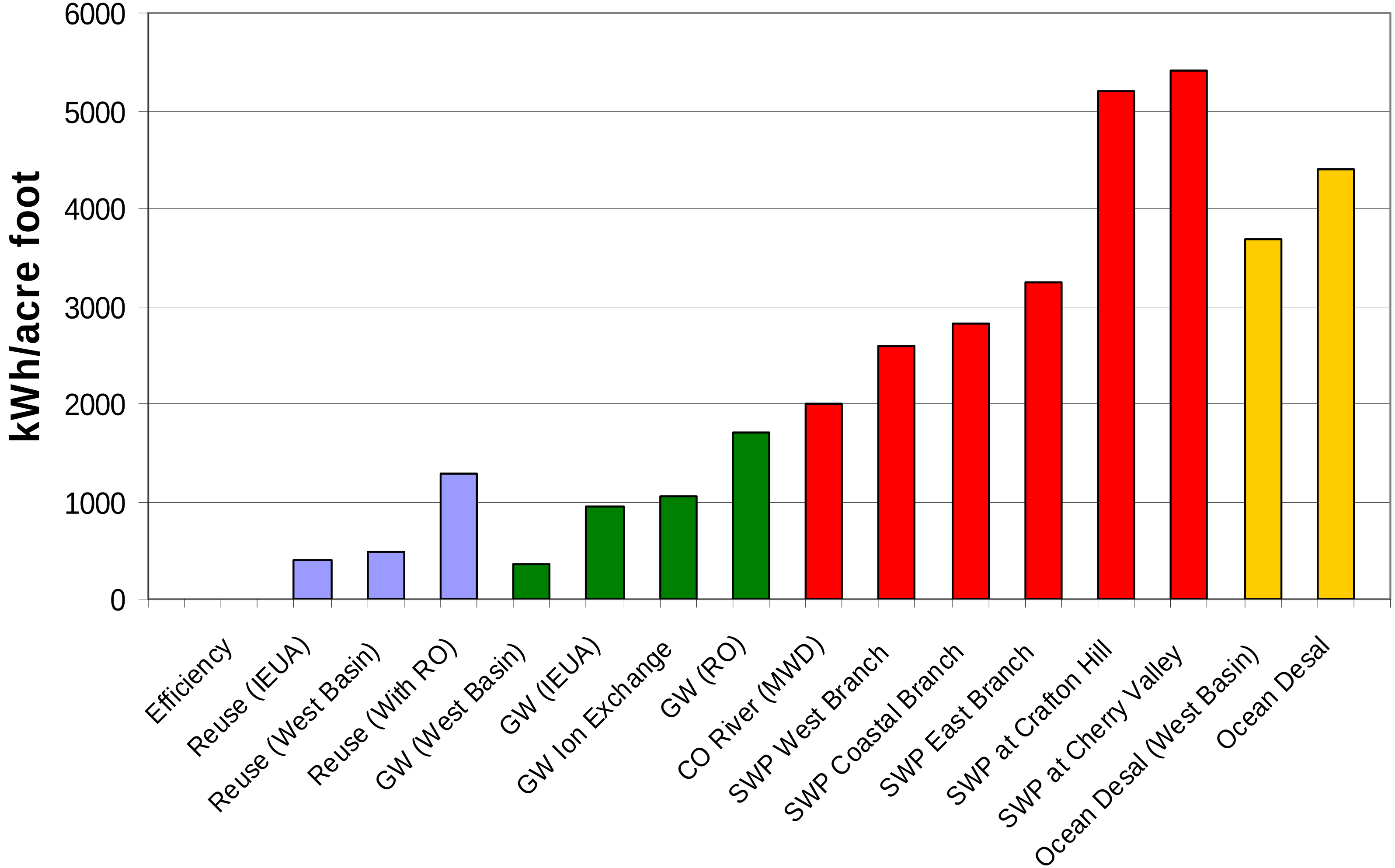








Energy Intensity of Selected Water Supply Sources in Southern California



Key Points (California)

- Coordinated planning between energy & water resource managers will be critical
- Energy & water conservation are key and there are some useful linked opportunities
- Source of energy & water have huge impacts
- Climate change will add another dimension to the energy-water nexus

Key points - Arizona

- Water and Energy are Interrelated - Conservation of one conserves the other
  - Promote water/energy conservation
  - Identify alternative cooling strategies
    - Investigate practical application of wet, dry, or hybrid cooling towers
  - Identify alternative cooling water sources
    - Right Water For "The Right Use"
      - Utilize impaired waters, where practical, and treat those waters to a quality suitable for use as cooling water
      - Conserve higher quality waters for use as potable water
  - Water and energy providers work collaboratively planning for the future

Discussion