Blue Ribbon Panel

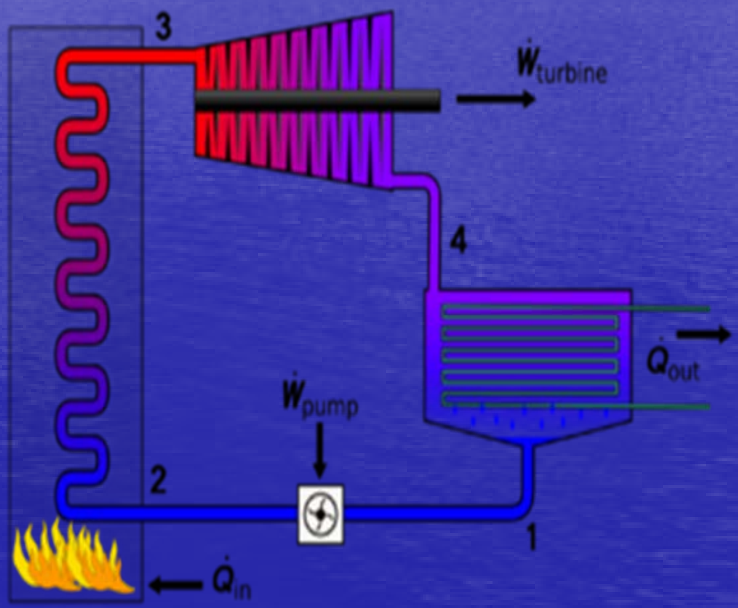
Cooling Water For Electric Generating Stations

Arizona Public Service, Salt River Project, Tucson Electric Power

March 5, 2010

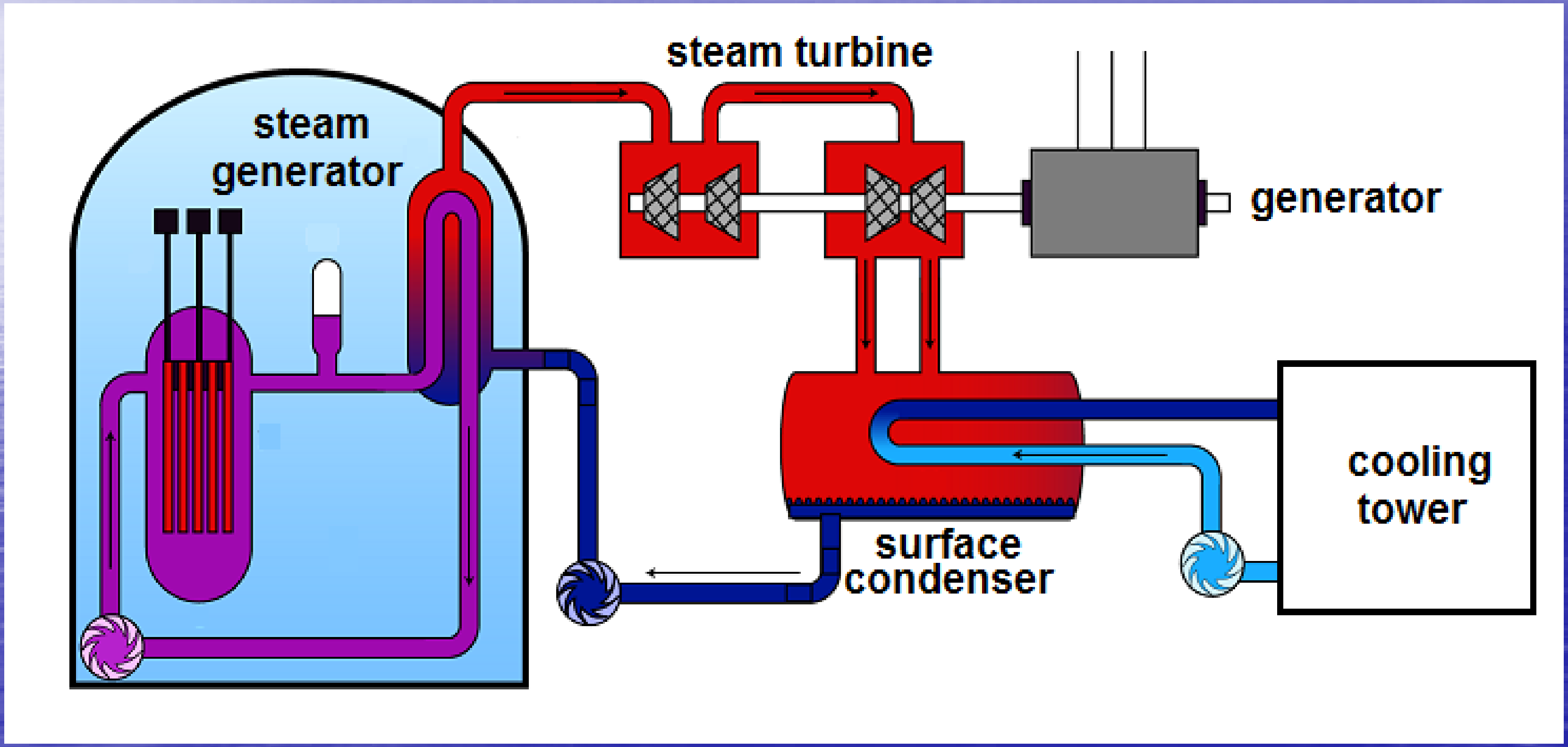
Rankine Steam Cycle

1. Liquid is pumped to a heat source
2. Liquid is heated by external heat source to become steam
3. Steam expands through turbine turning a generator and produces power
4. Steam is re-condensed returning to liquid state



Nuclear Plant Water Use

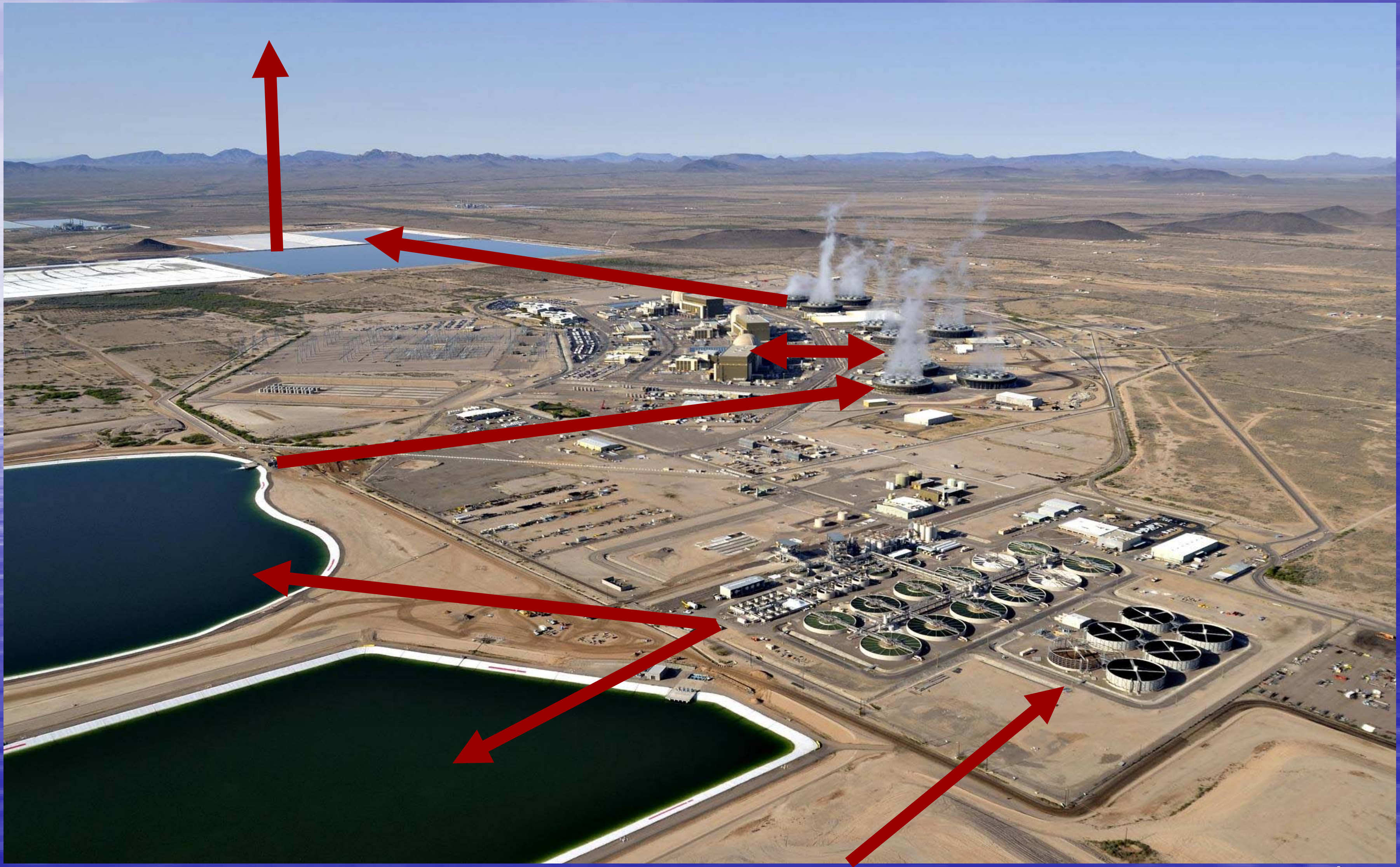
Secondary Loop



Primary Loop

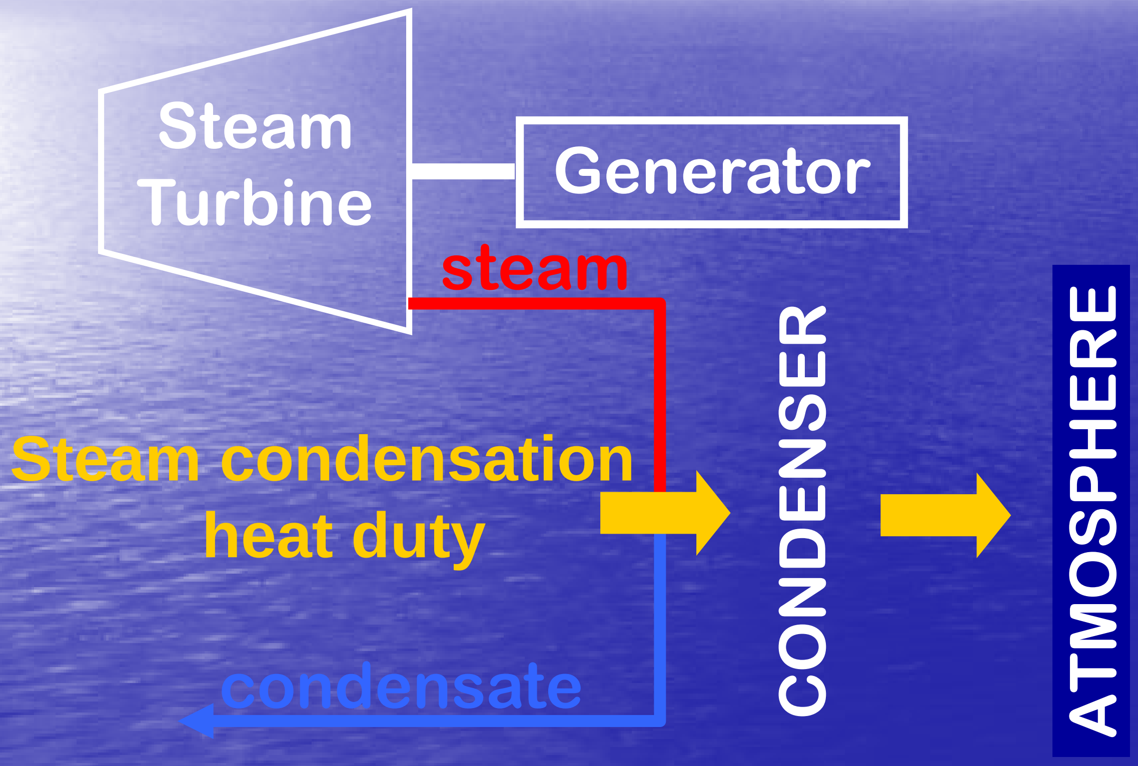
Tertiary Cooling Loop

Water Reclamation Facility – Provides Cooling Water to Palo Verde NGS



Purpose of the cooling system

Major purpose of cooling system = reject heat duty (from steam condensation) to the atmosphere



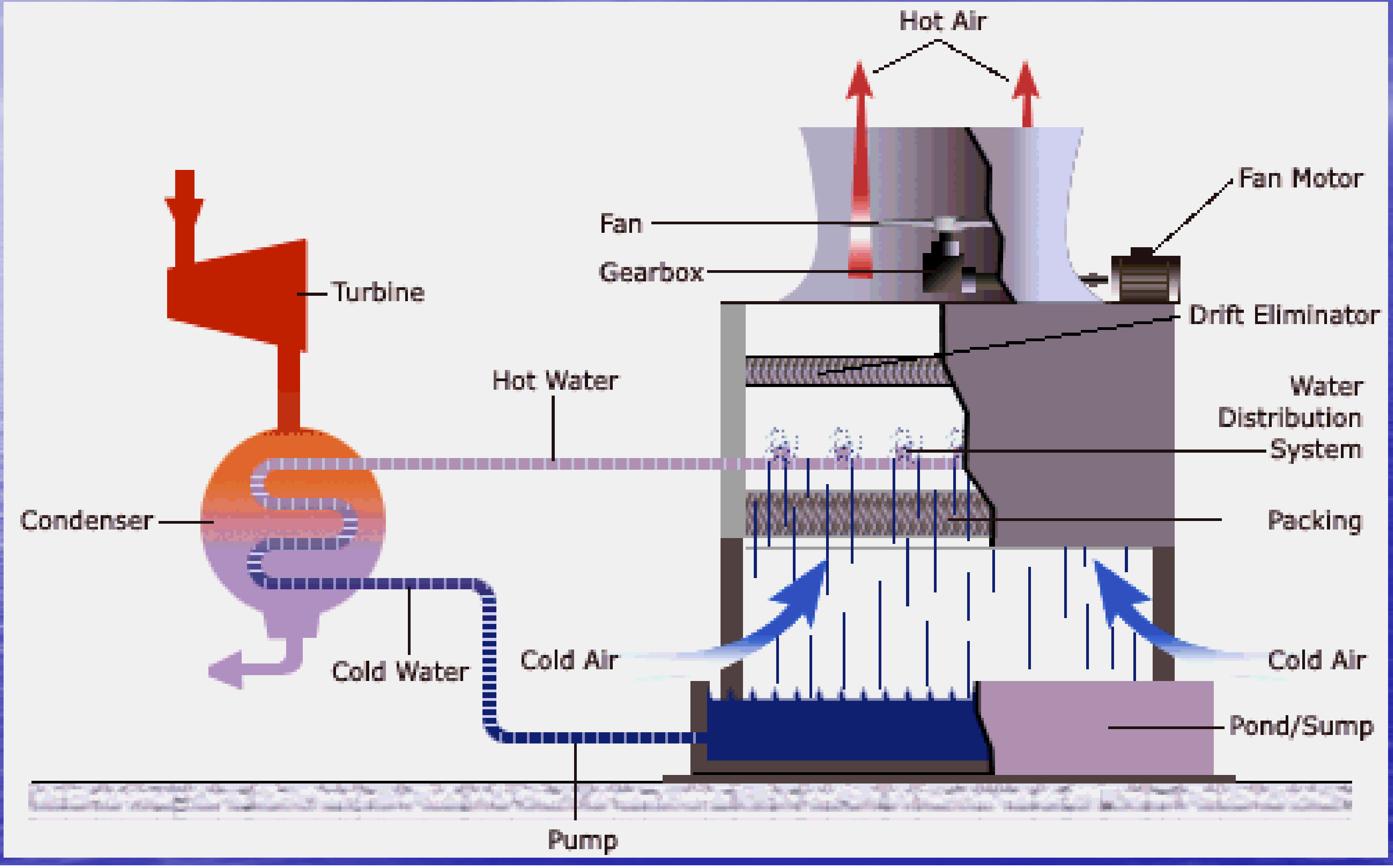
<u>Direct Cooling Systems</u>:

→ Heat Duty of Condensation is **directly** rejected to the atmosphere by the cooling system.

<u>Indirect Cooling Systems</u>:

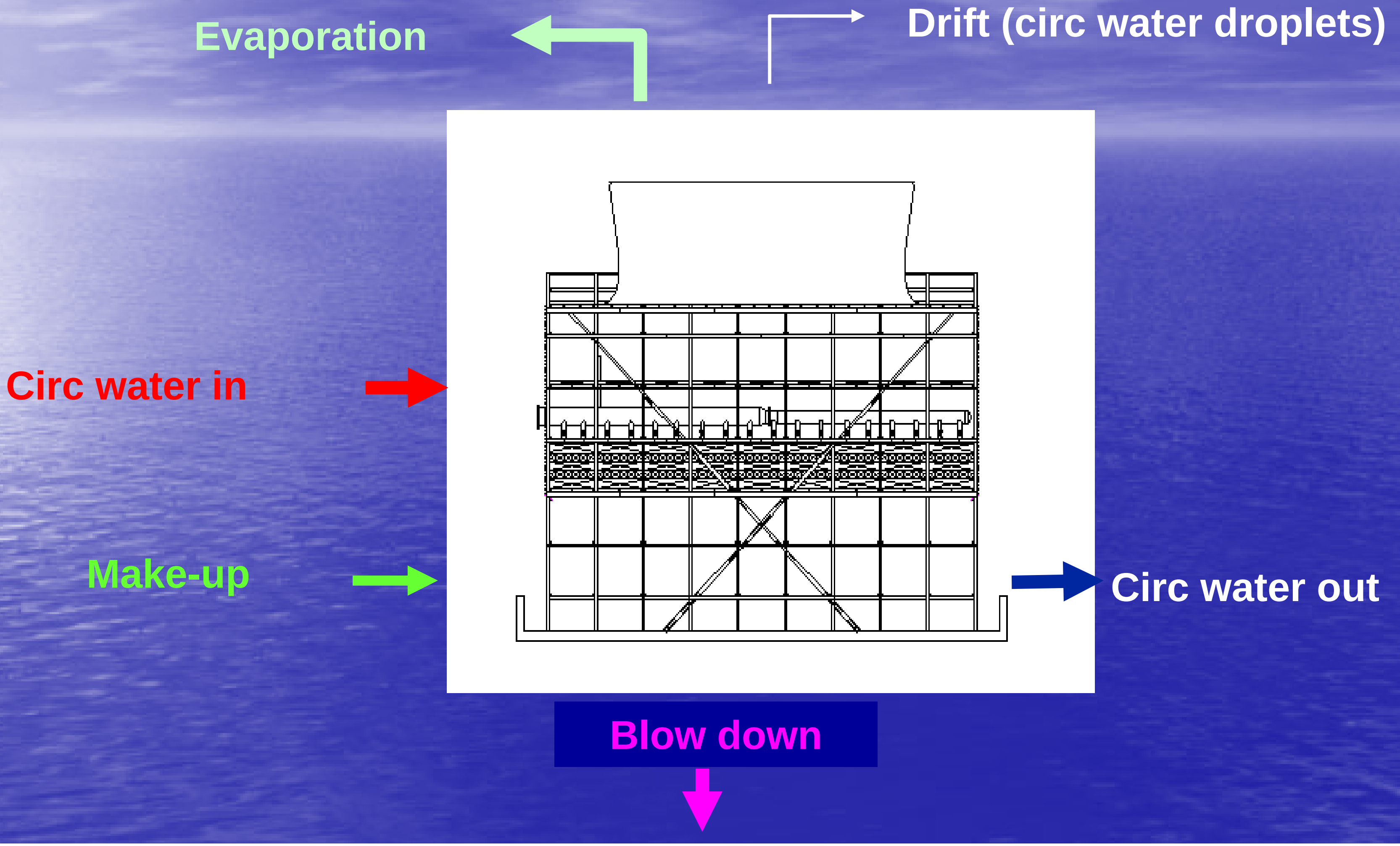
→ Heat Duty of Condensation is first rejected to a condenser, then to the atmosphere by the cooling system.

Mechanical Draft Cooling Tower



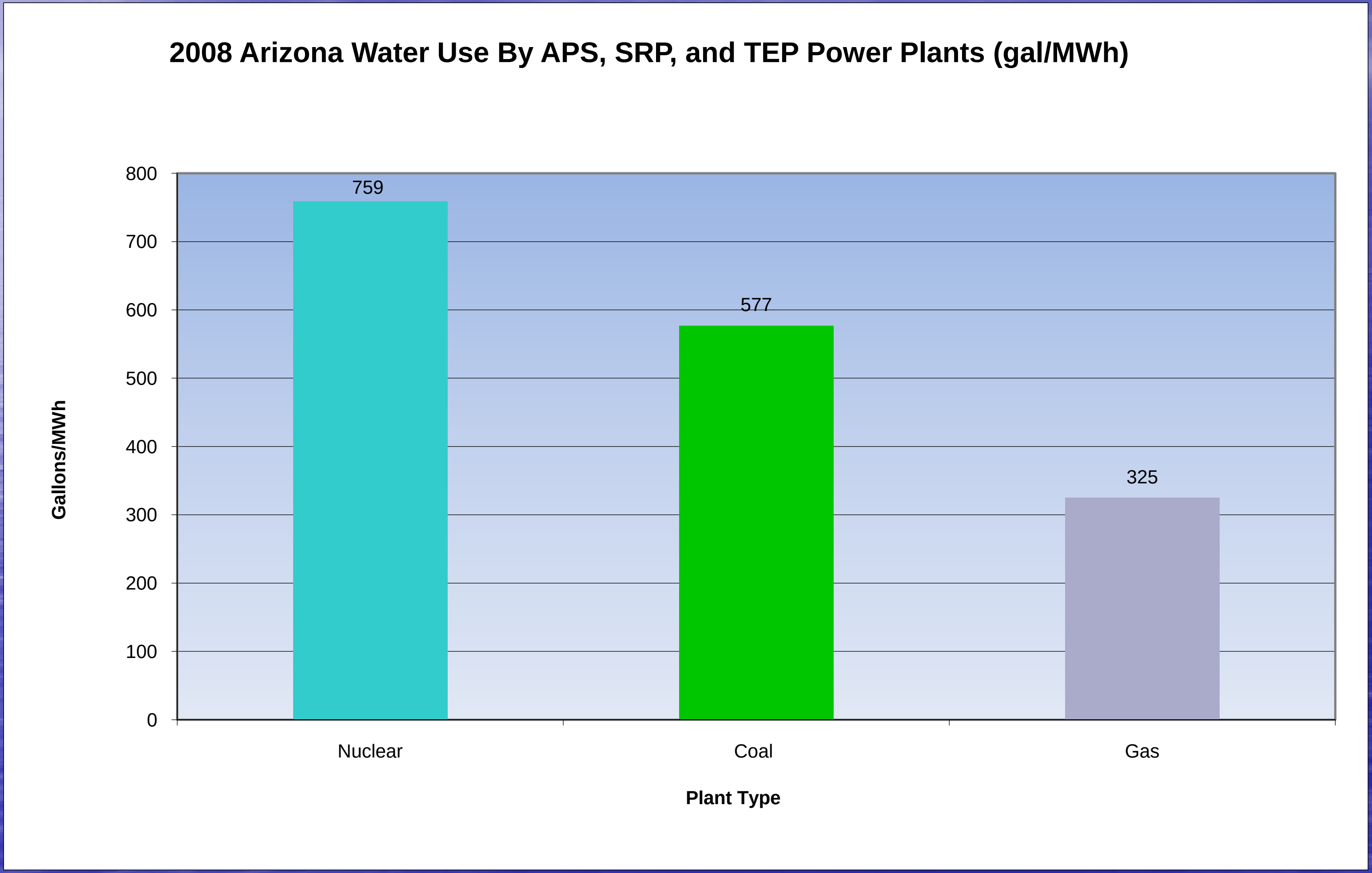
Mechanical Draft Towers → wet cooling standard for power plants

Make-up water requirements for wet cooling



Make-up flow rate = Evaporation + Drift + Blow-down

Power Plant Water Usage

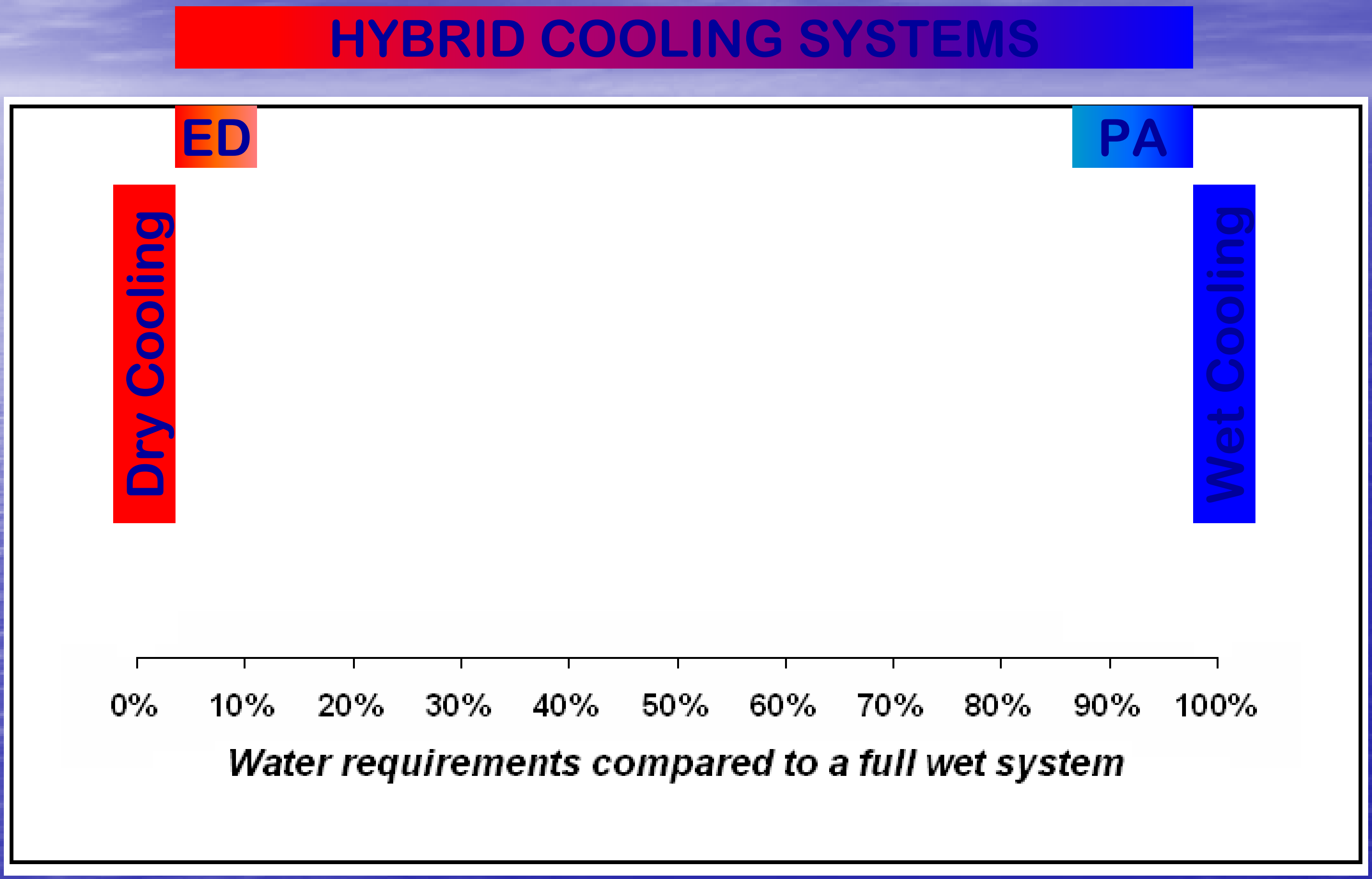


Electricity Industry Value Chain – Water Consumption

RAW MATERIALS	TRANSFORMATION	DELIVERY TO CUSTOMER
Thermoelectric Fuels Coal: 5-70 gallons per MWh **Oil:** wide variance **Natural Gas:** wide variance **Uranium** (nuclear): 45-150 gallons per MWh	**Thermoelectric Generation with closed-loop cooling:** 190-720 gallons/MWh	**Delivery to Customer Through Electric Grid Involves Minimal Water Consumption**
Hydroelectric	**Evaporative Loss:** 4500 gallons per MWh	
Geothermal	1400 gallons per MWh	
Solar	**Concentrating Solar:** 750-820 gallons per MWh	
	Photovoltaic: minimal	
Wind	**Wind:** minimal	

Source WEF 2008

Classification of cooling systems



Cooling Tower Alternatives

100% WET COOLING:

- Lowest cost solution
- Highest net generation
- Lowest parasitic power consumption
- Smallest footprint
- Highest annual water use

Cooling Tower Alternatives

100% DRY COOLING

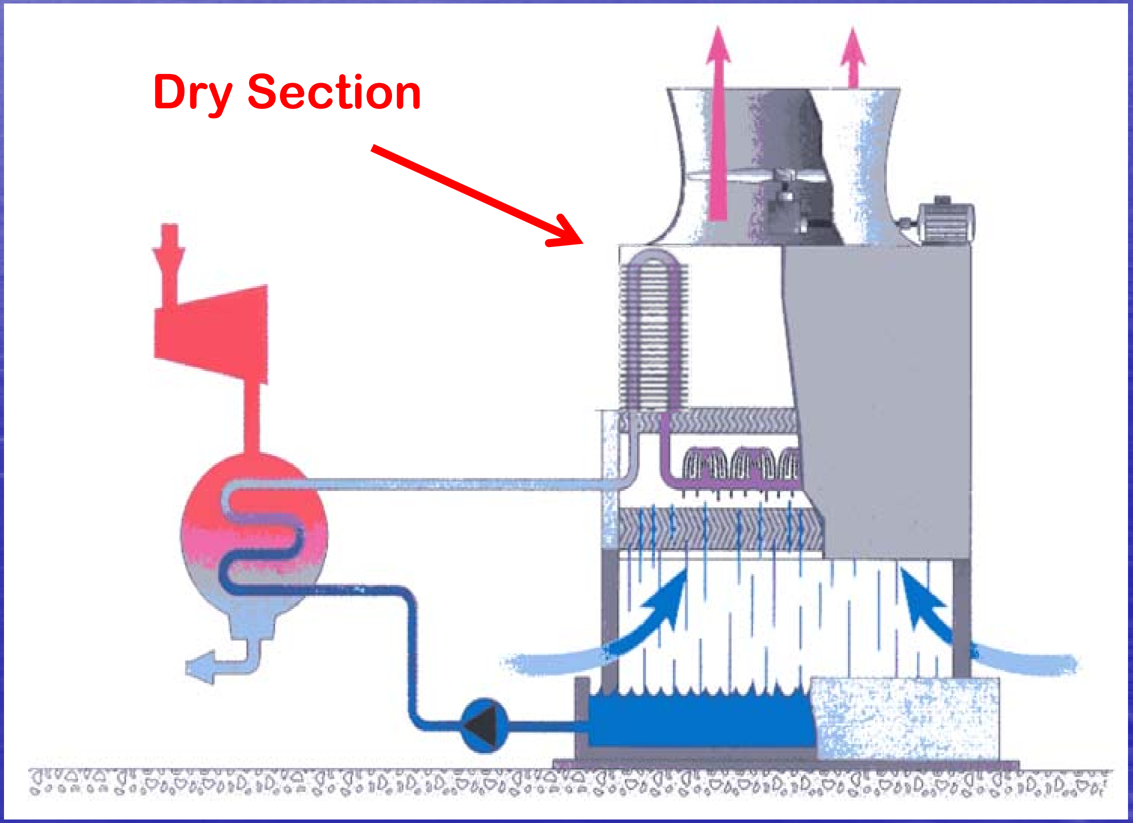
- Performs best in cool, humid climate
- Increased turbine back pressure is required
  – makes retrofits difficult
- Highest life cycle cost – highest parasitic load
- Highest new construction capital cost
- Lowest net generation - particularly impacted during summer when generation is most needed
- Major advantage: 0% water usage is possible

Plume Abatement Cooling Tower

Wet Section identical to wet cooling tower

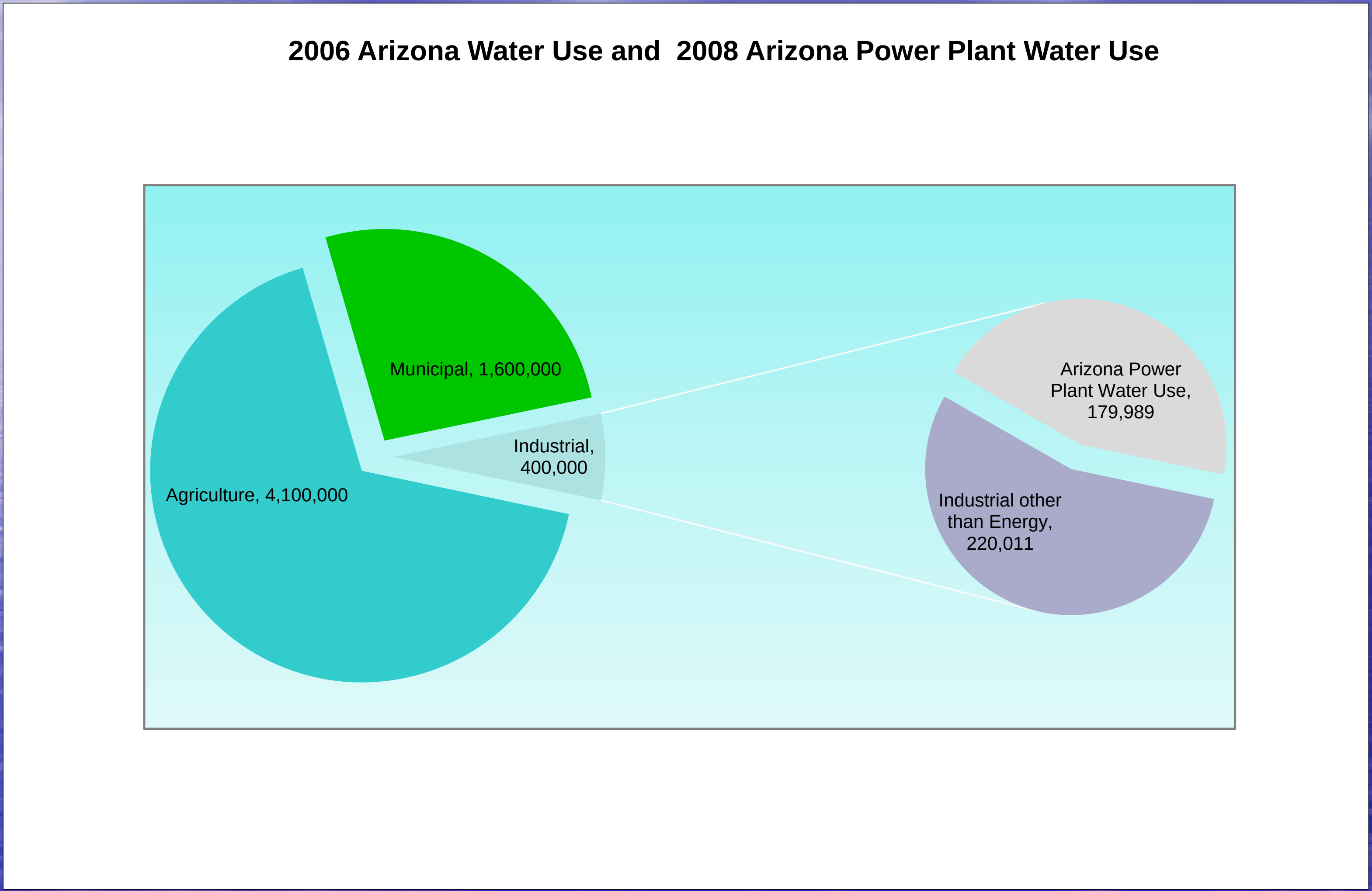
Hot water heats ambient air in dry section:

- Possible water savings: 10% - 15% (dry section at full capacity all year).
- Significantly higher new construction capital cost .
- Higher parasitic load → yearly net generation ≈ 99.8%.
- Higher life cycle cost compared to mechanical draft cooling tower.



Wet and Dry Combination (hybrid)

Water Use


2006 Arizona Water Use and 2008 Arizona Power Plant Water Use
Municipal, 1,600,000
Industrial, 400,000
Agriculture, 4,100,000
Arizona Power Plant Water Use, 179,989
Industrial other than Energy, 220,011

Looking Forward

- **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**