



Water Use and Conservation in the Electric Power Industry

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Presentation Overview

- New and emerging regulations that will affect water use in power plants
- Overview on freshwater withdrawal and consumption,
- Water use and management (how power plants use water, how much do they use, how can we reduce total use and increase the water use efficiency)
- EPRI Research – the next generation of technologies and management tools
- Reducing energy use for water transport and treatment, including end use efficiency
- Hydropower generation and expected impacts of climate change

New and Emerging Water Regulations and Challenges for Electric Generation

WATER SUSTAINABILITY

Droughts Over Allocation

Raw Water Quality

Watershed Protection

New TMDLs (Regional, Air Deposition)

Arsenic Cancer Slope Factor

Nutrient Criteria

WATERPOWER

CO2 Emissions

Fish Passage

Environmental Flows

FISH PROTECTION

Fine Mesh Screens Thermal Discharge

Cooling Tower Retrofits (Fed and States)

Impingement/Entrainment Reductions

EFFLUENT GUIDELINES

Bottom Ash Handling FGD WW Treatment

Classification and Handling of Fly Ash

Se & Hg Limits

ZLD

Plenty of new water related challenges and risks to address

Water Risk Areas for Electric Power Generators

Physical

- Too little water
- Poor water quality (e.g., temperature, TDS, metals)

Regulatory

- Water withdrawal permits denied
- CWA 316(a) / 316(b), TMDLs, NPDES permit compliance, endangered species, effluent guidelines

Reputational

- Labeled as “biggest water user” compared with other sectors
- Public pressure / lawsuits (new power plants, conversion of cooling technologies)

Financial

- Curtailment / shut down under limited water resources
- Water efficient technologies are expensive

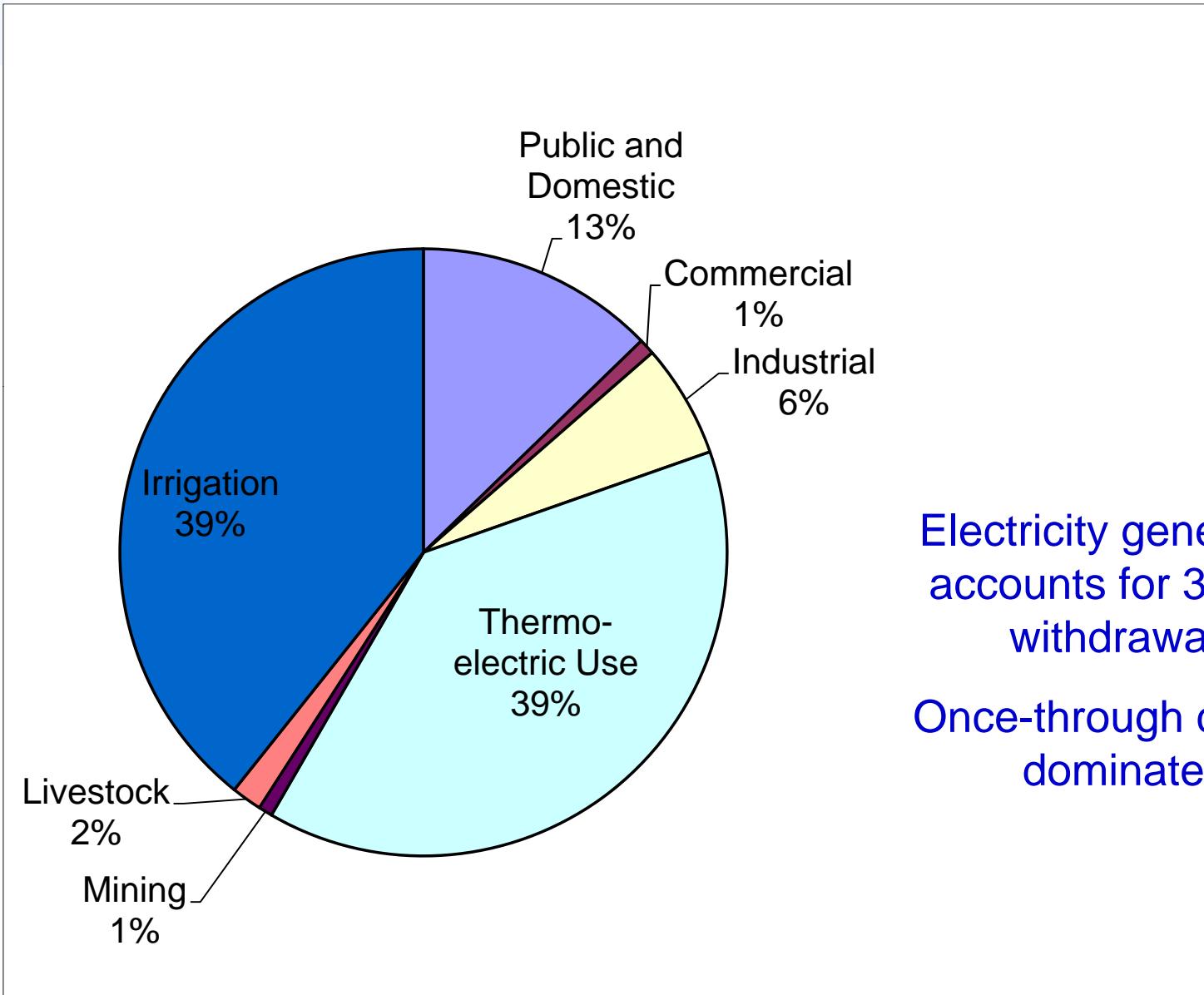
Risks will grow as competition for water increases

Source: *Pacific Institute, 2009 (Water Scarcity and Climate Change); World Business Council, 2009 (Why Water is Everyone's Business)*

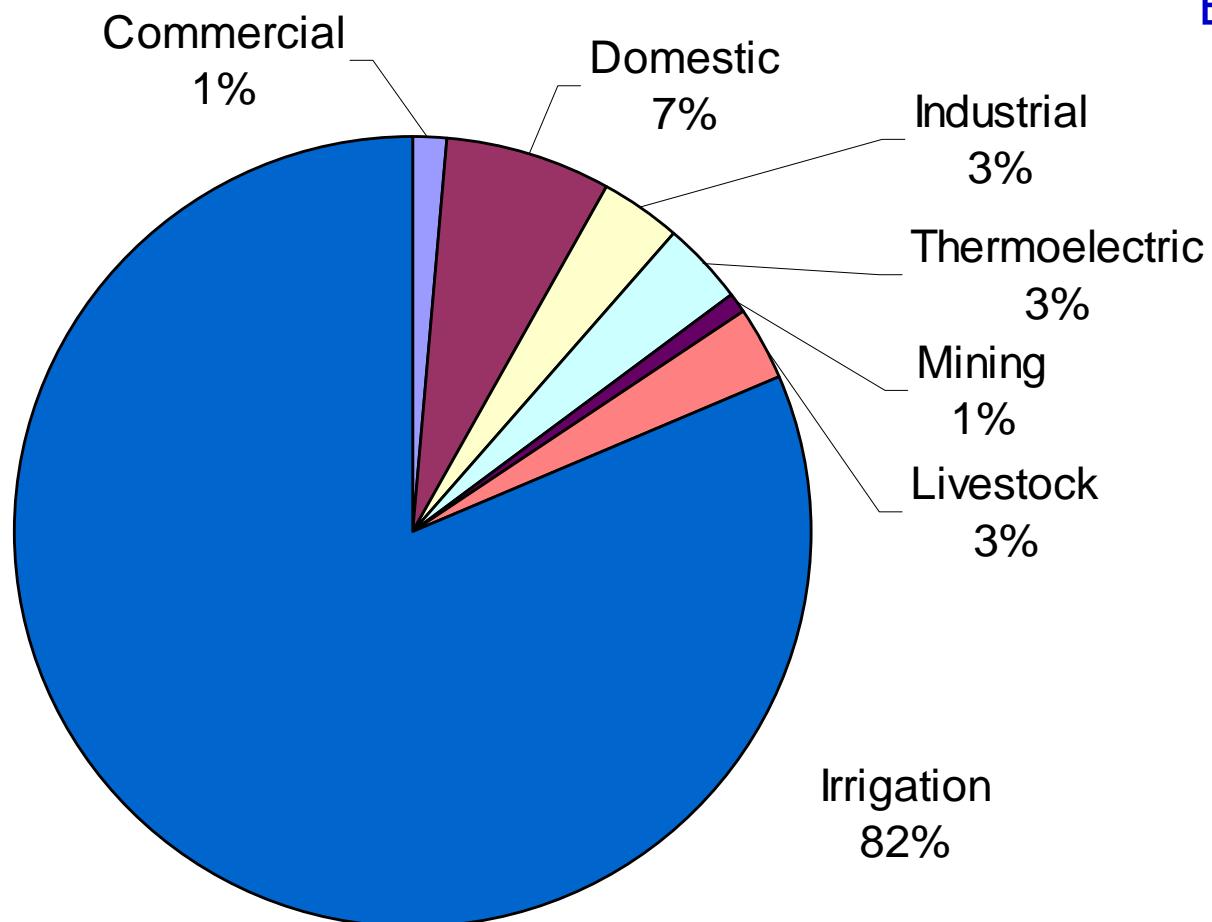
Overview of Freshwater Withdrawal and Consumption for Power Generation



1995 Fresh Water Withdrawal (USGS)



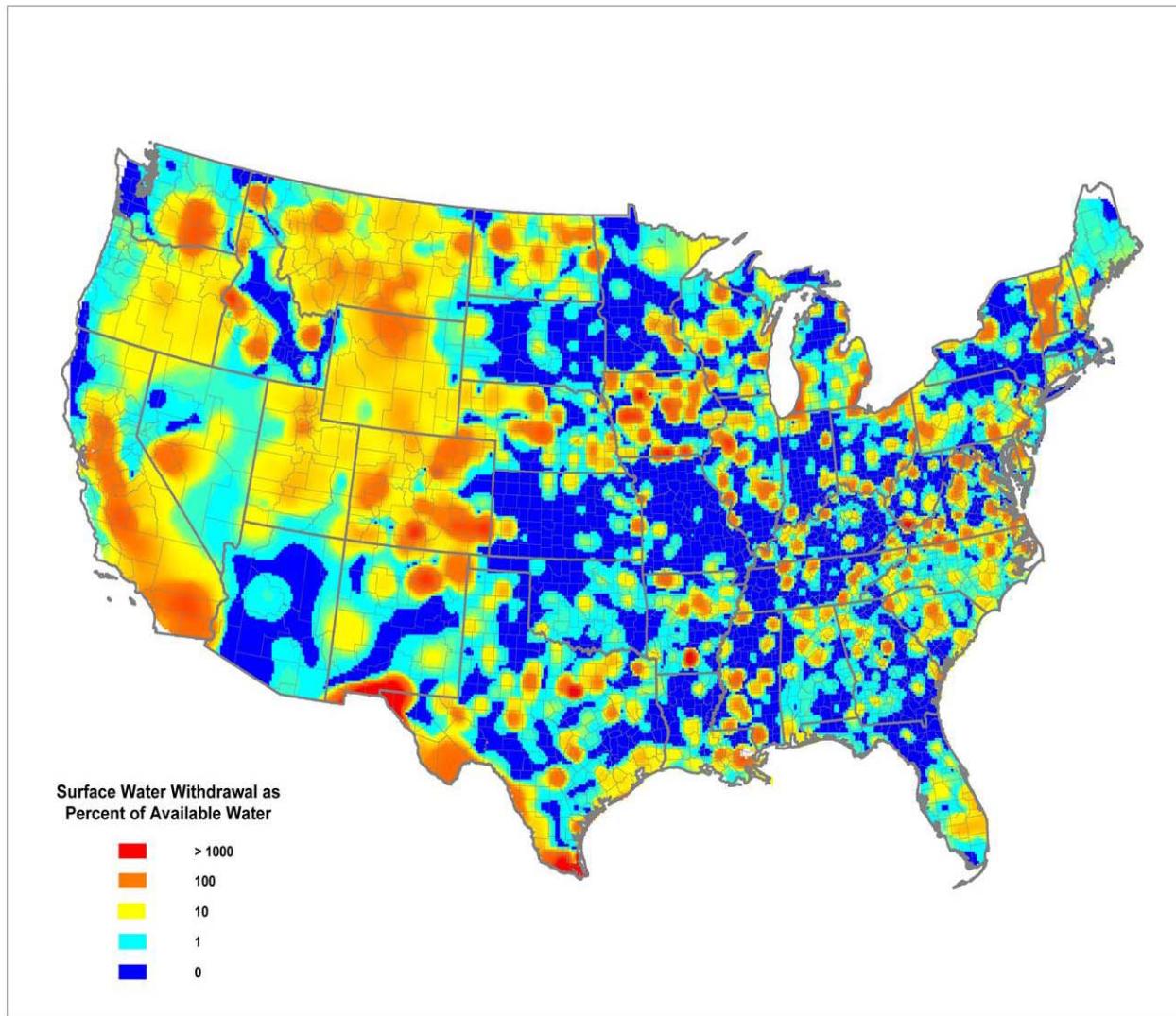
1995 Fresh Water Consumption (USGS)



Electricity generation accounts for 3% of consumption

An important distinction:
Withdrawal vs. consumption

Annual Surface Water Withdrawal

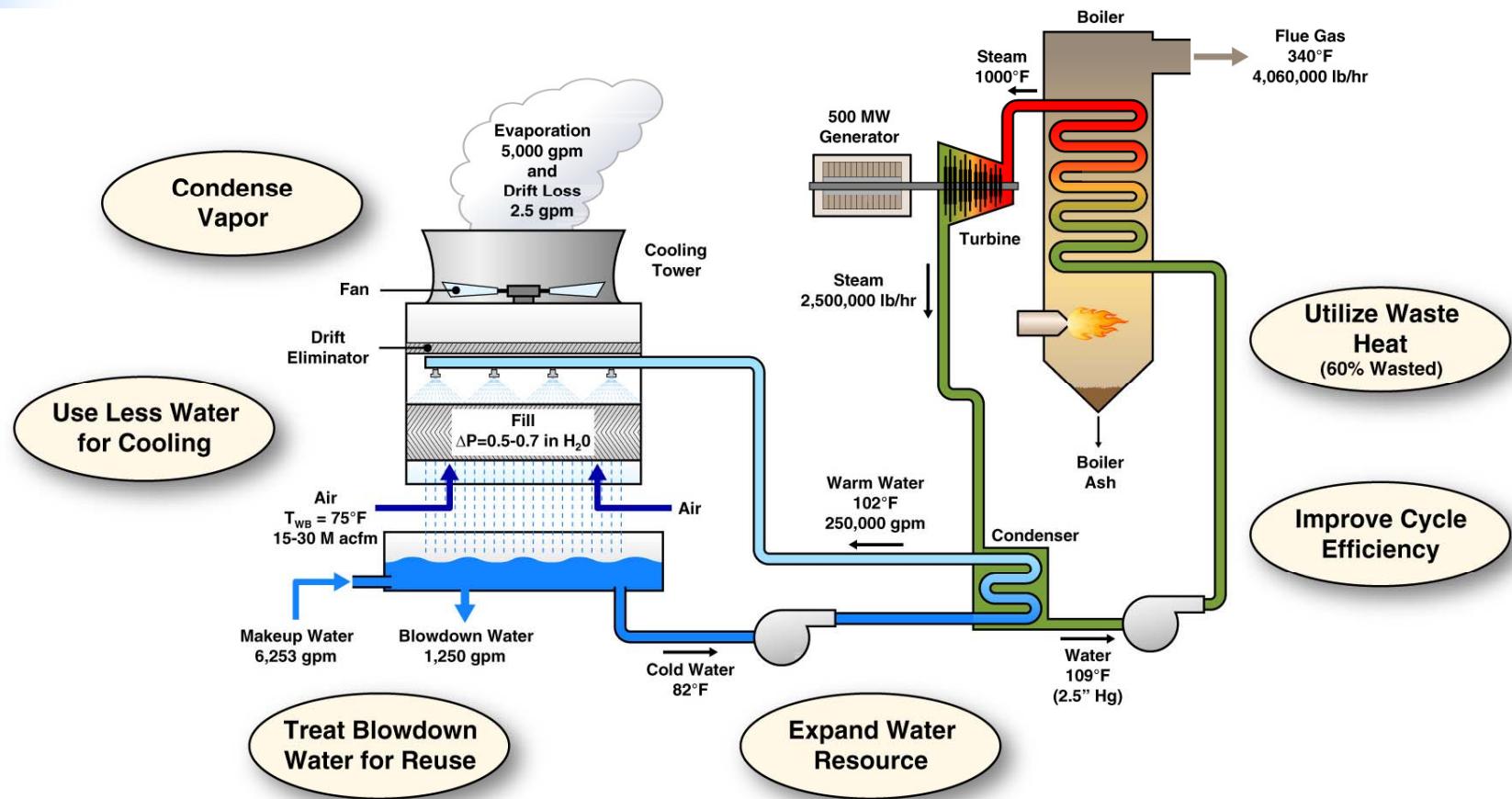


Percentage of precipitation minus evapotranspiration, by county, across the US (Withdrawal data from 1995)

Water Use and Management in Power Plants



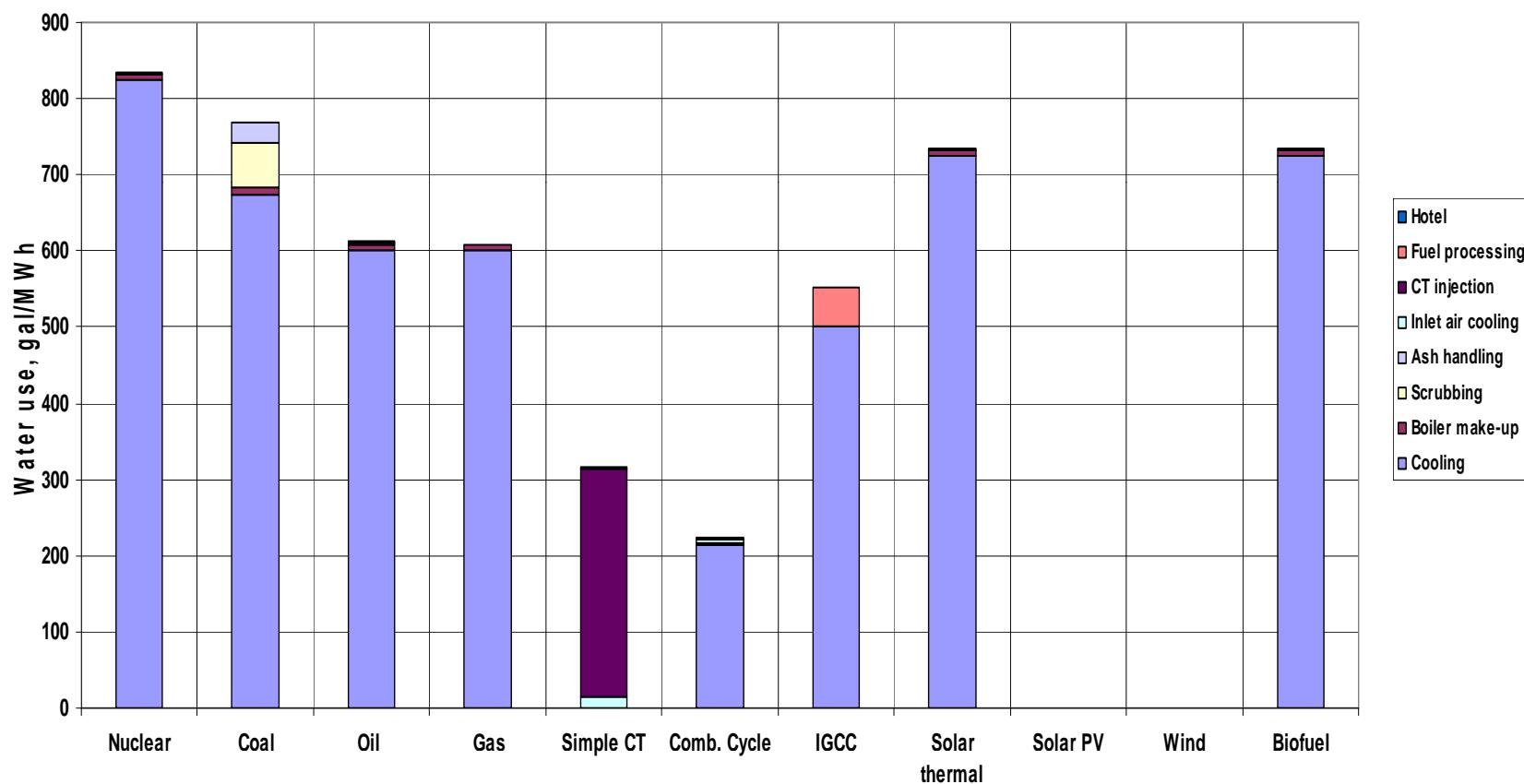
Opportunities for Power Plant Water Use Reduction



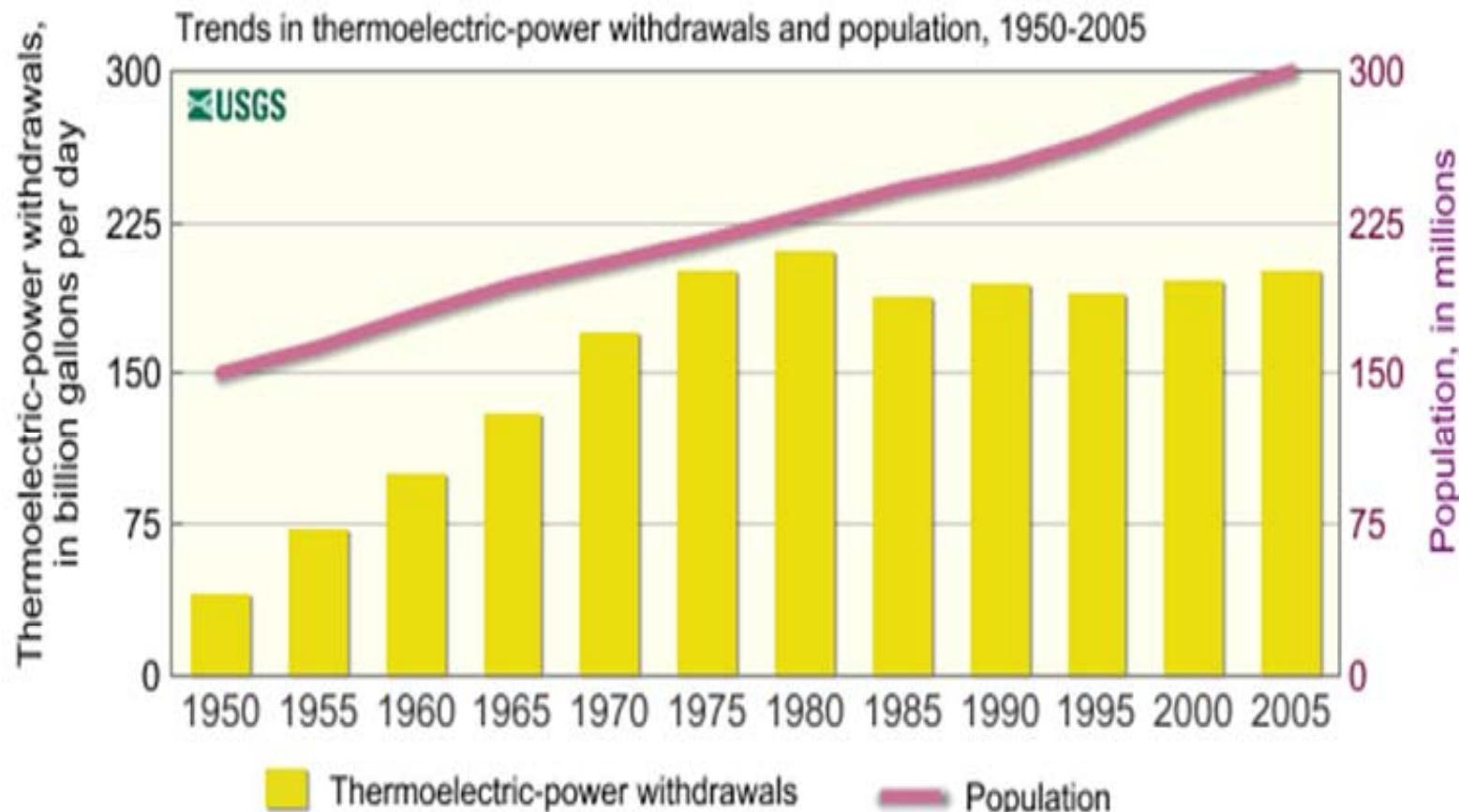
Research Priorities: Advancing cooling technologies, novel water treatment and waste heat recovery concepts to improve efficiency and water use

Water Use Efficiency (Steam Cycle Plants Using Wet Cooling Towers)

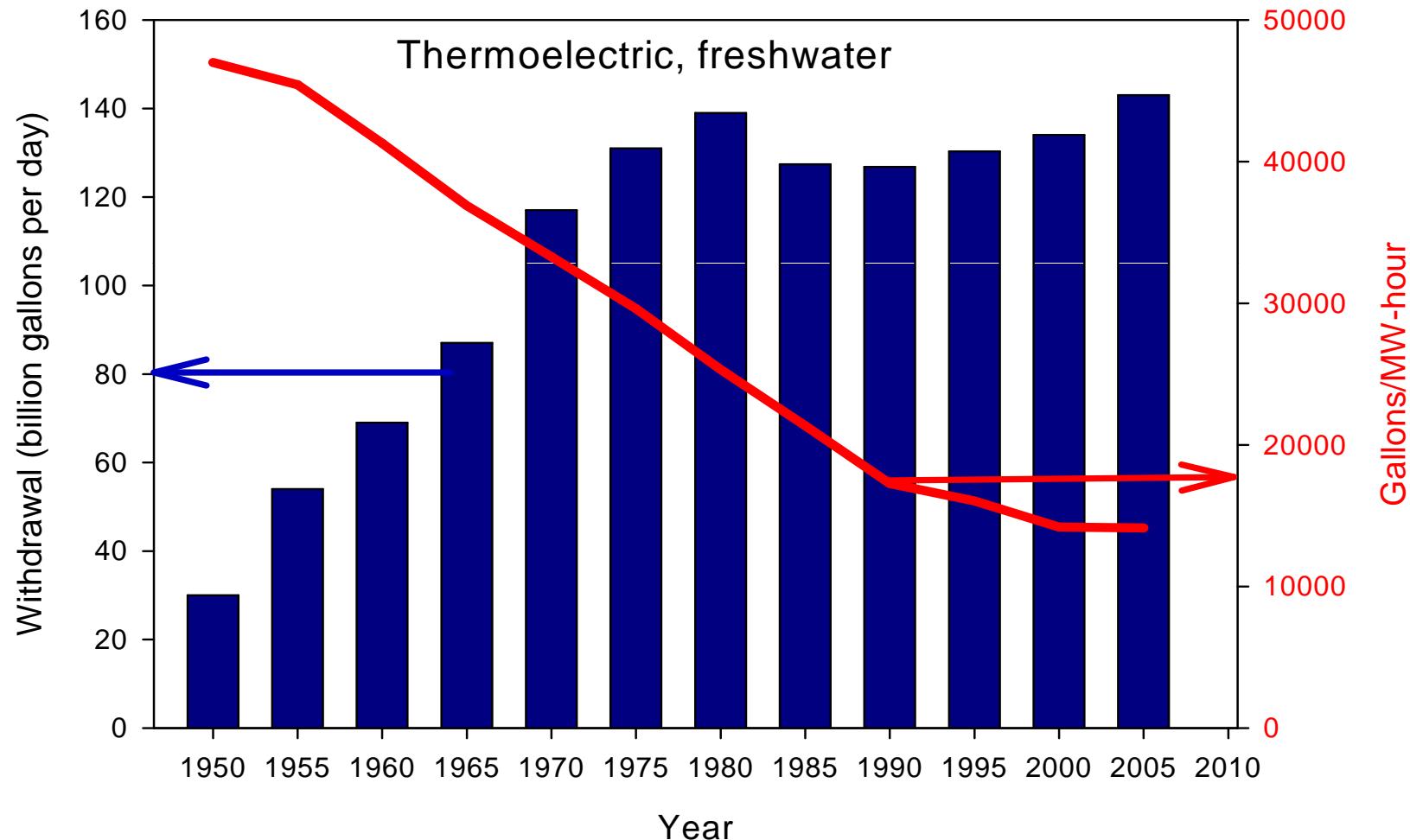
Water Use by Plant Type



Electric Power Water Withdrawal and Population Trends



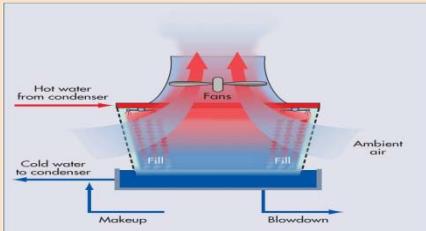
Trend for Water Consumption per Unit Energy



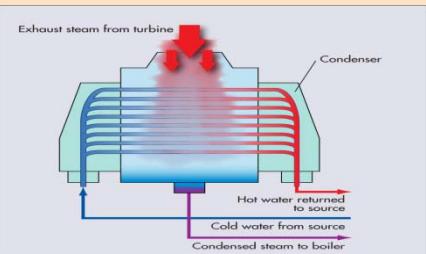
What Cooling System Options are Currently Deployed in the Industry?

Water Cooling

Cooling Tower (42% in US)



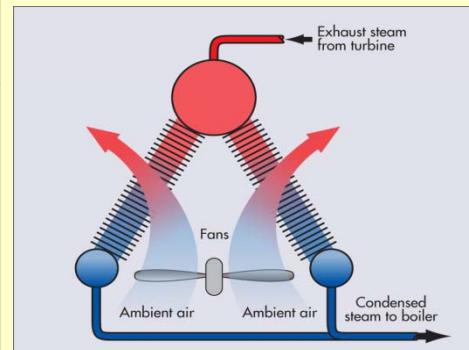
Once Through Cooling (43% in US)



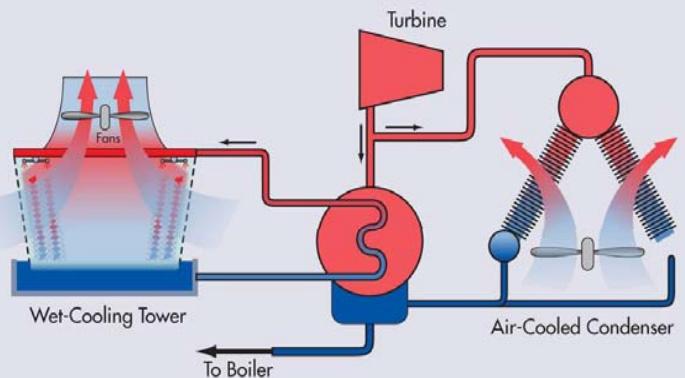
Air Cooling

Air Cooled Condenser

1% Usage in US



Hybrid Cooling



Trend Continues Towards Increased Cooling Tower Use

Commercial Alternative Cooling Options

- Degraded Water Use
- Air Cooled Condensers
- Hybrid Towers
- Wet Surface Air Cooling

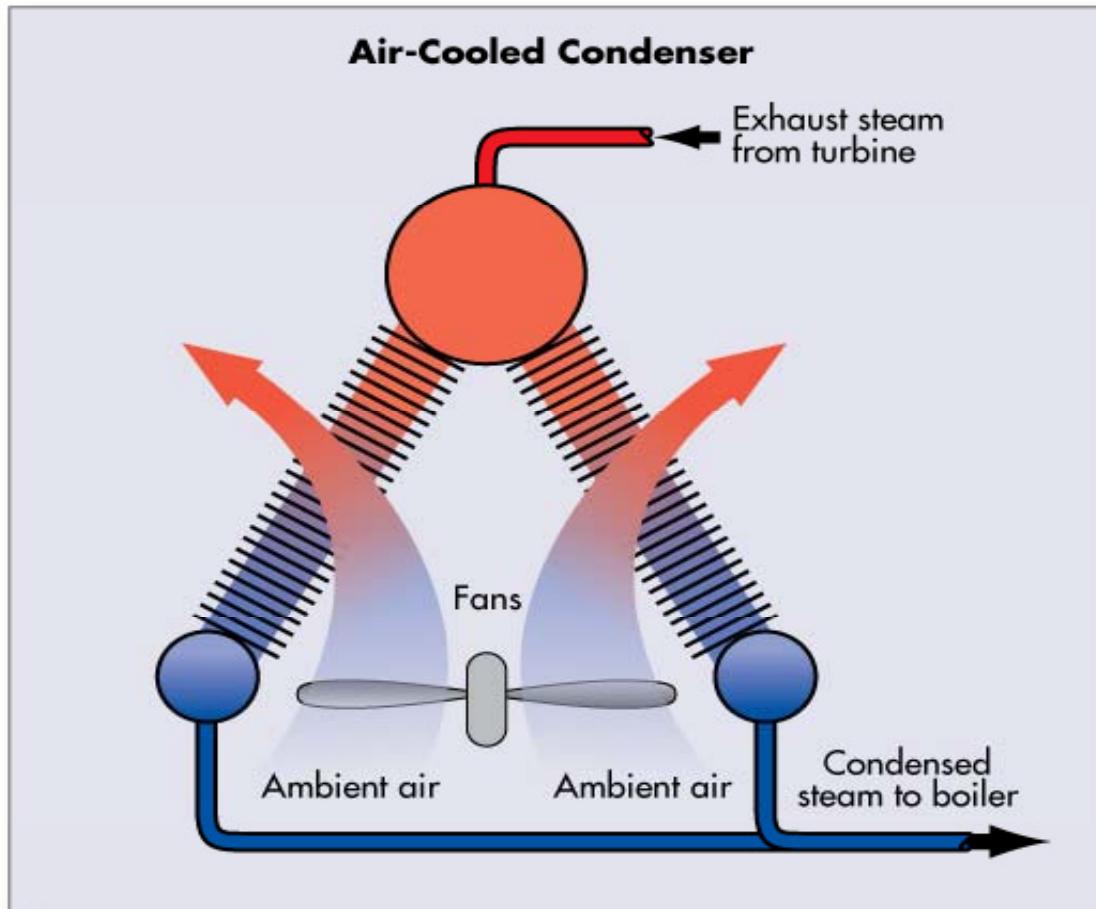
Degraded Water Use

Photos courtesy of
St. John's River Power Park

- Potential Sources
 - Waste water treatment plant discharge (effluent)
 - Produced waters from oil/gas extraction
 - Storm water flow
 - Mine drainage
 - Agricultural runoff
 - Saline aquifers
- Challenges
 - Consistent water availability and quality
 - Proximity (transport costs and feasibility)
 - Treatment costs
 - Operational impacts (scaling, fouling and corrosion)
 - Blowdown disposal
 - Drift issues
 - Exposure to employees and public



Dry Cooling



Matimba 6x665MW Coal

Courtesy of Eskom



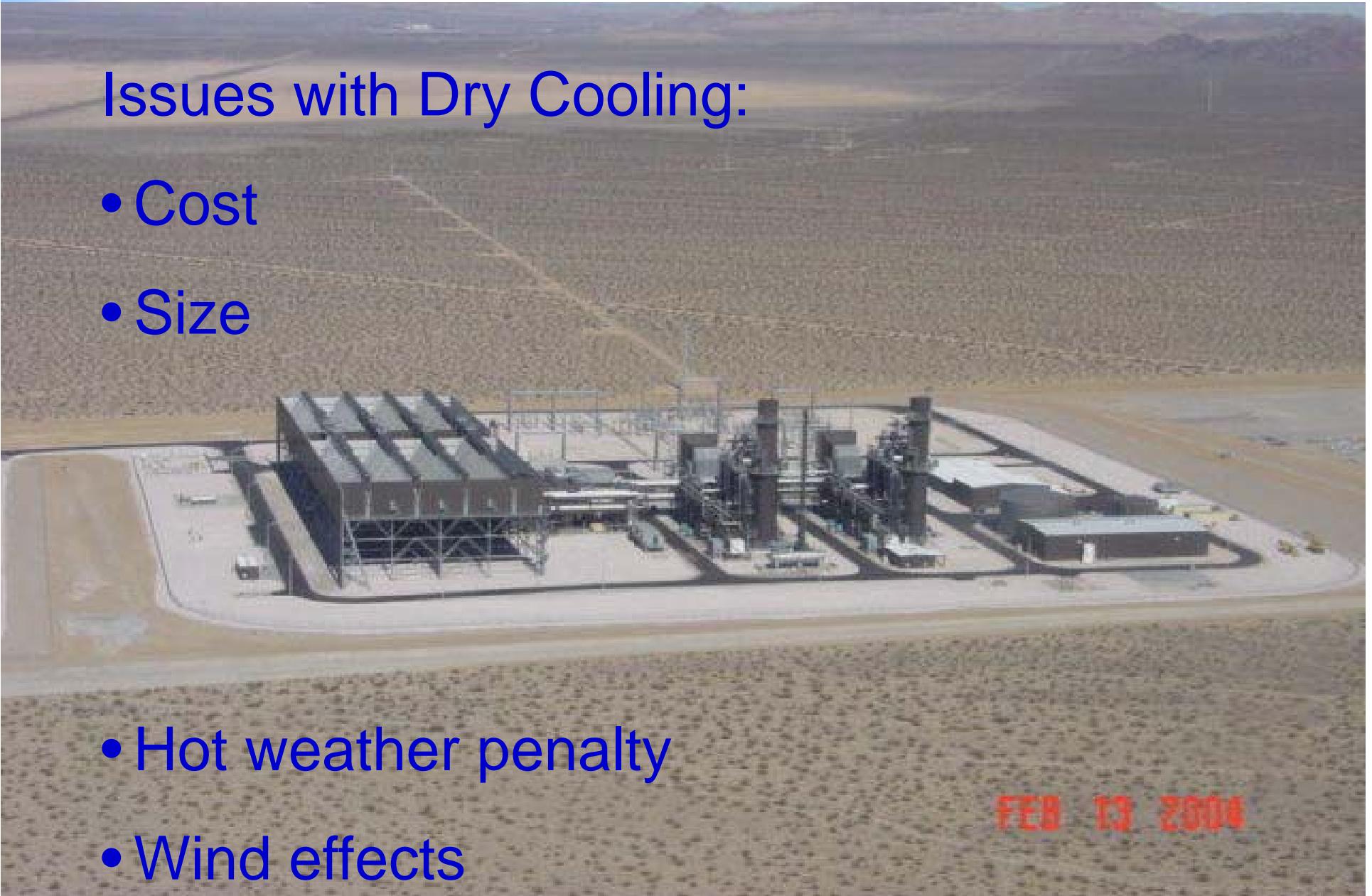
Bighorn---530 MW Combined-Cycle with ACC

Issues with Dry Cooling:

- Cost
- Size

- Hot weather penalty
- Wind effects

Feb 13 2006



Indirect Dry



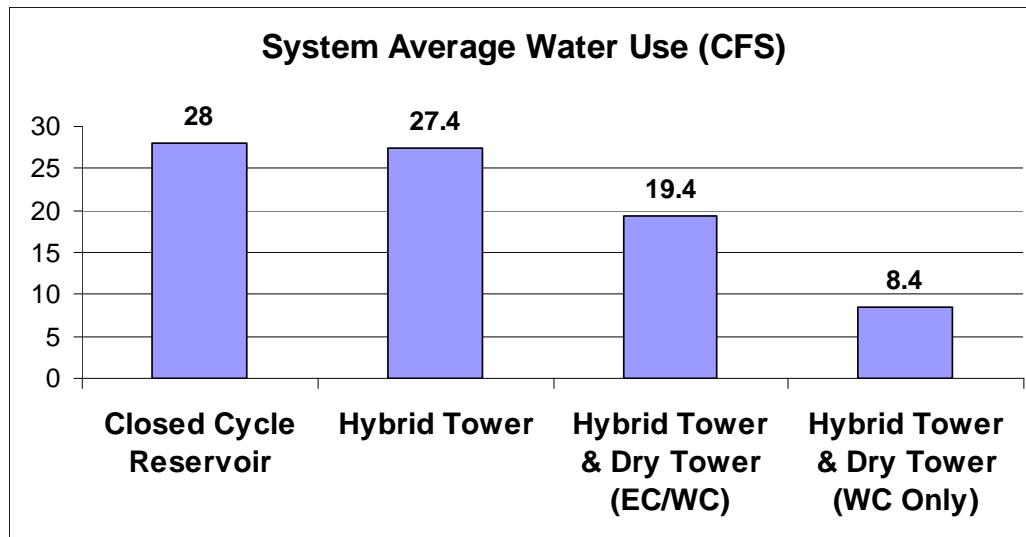
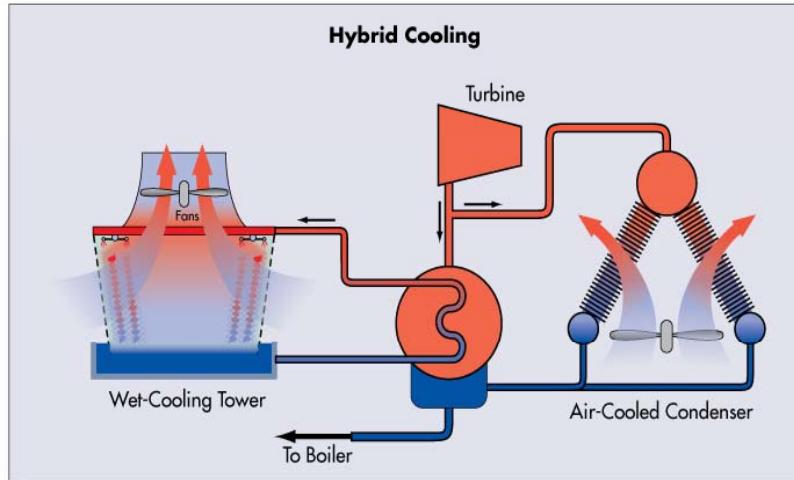
Kendal Station Six 686MW Coal Units

Photos Courtesy of Eskom

Hybrid Cooling Towers

- Plume Abatement
 - Small amount of dry cooling to remove visible plumes for aesthetics
- Water Reduction
 - Larger percentage of dry cooling for water conservation purposes

Parallel Hybrid Cooling System



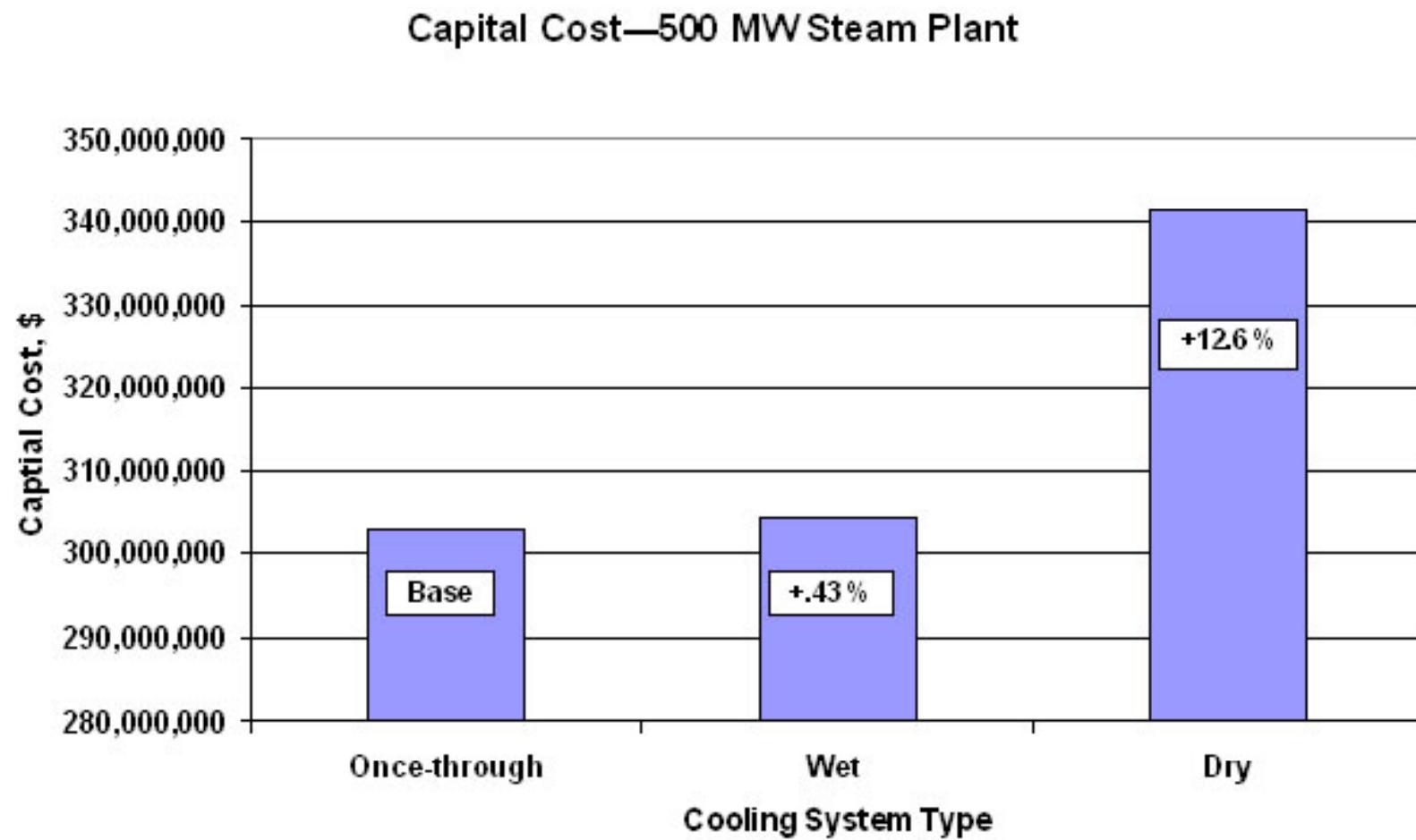
Issues with Hybrid Systems:

- Large capital costs
- Same issues as wet and dry cooling systems
- Additional issues related to controls, freeze protection



Dominion North Anna Unit 3
Hybrid Cooling

Capital Costs of Cooling Systems



Potential Drought Impacts to Power Generation

- Decreased water supply
 - Insufficient water for full load operation
 - Insufficient suction head for pump operation
- Lower water quality
 - Can cause issues with increased treatment requirements, siltation, corrosion and fouling, etc.
 - Potential to exceed permit limits for wastewater discharge
- Thermal impacts – exceed permitted discharge temperature
- Higher ambient air and water temperatures decrease cooling and plant efficiency

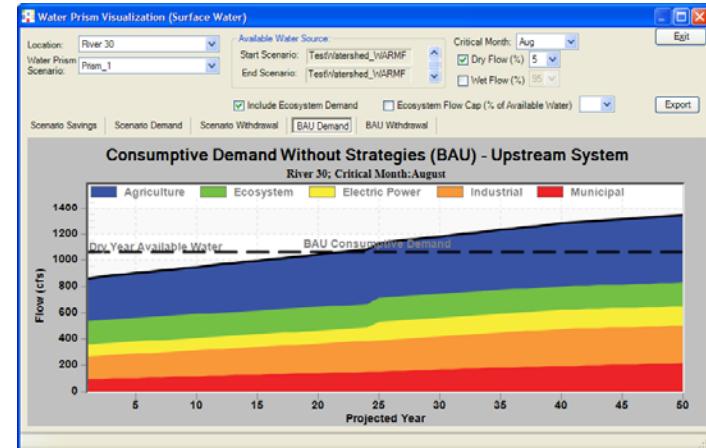
All of the above can negatively impact generation capacity, coincidental with higher power loads associated with droughts

EPRI Research – Water Management and Water Conservation



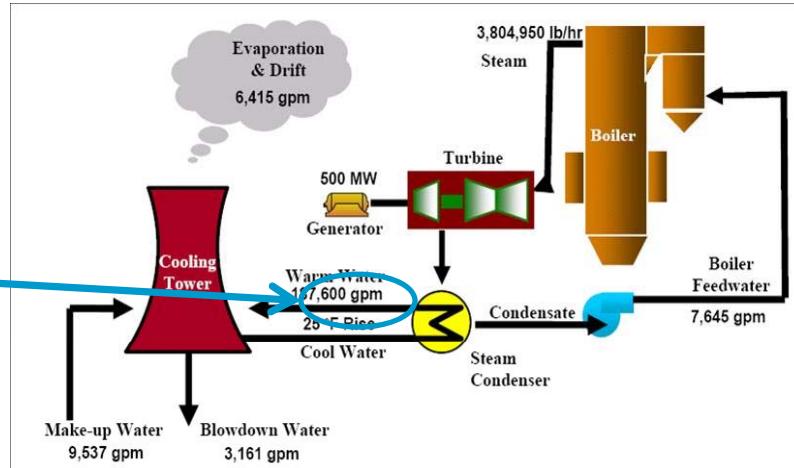
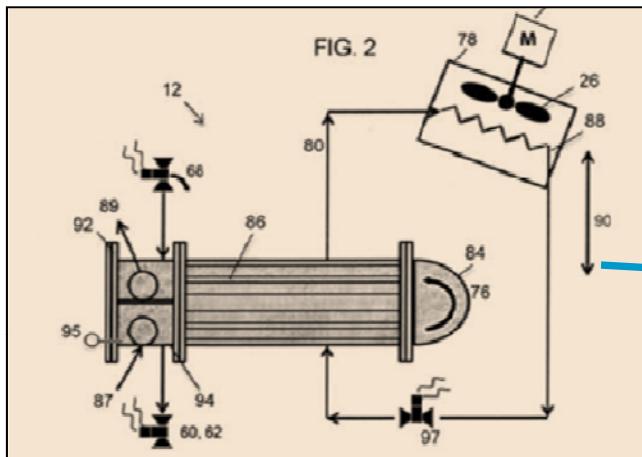
Water Prism Analysis Tool

Example Water Prism for a River



- Water Prism - decision support system for siting/retrofitting power plants; understand/verify water risks; explore water saving benefits across sectors; encourage collaboration
- Computes system water balance on regional scale
 - Surface water watershed model
 - Groundwater sources & uses
- Projects consumptive & withdrawal demands for 40 to 50 year horizon
- Comparative analysis of water saving strategies through scenarios, stakeholder engagement

Thermosyphon Cooler Technology (Collaboration with Johnson Controls)



Project Scope

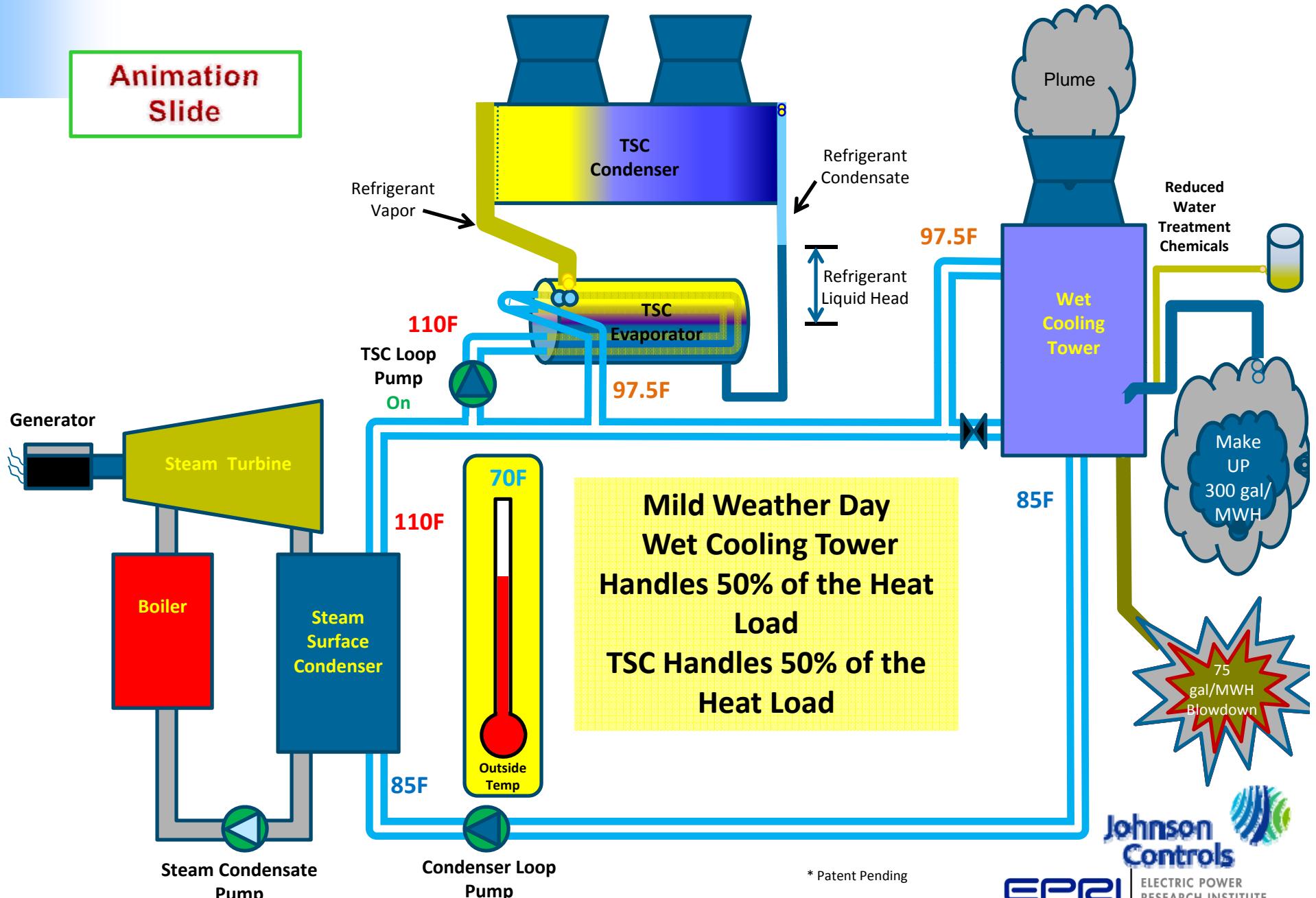
- Feasibility evaluation of a hybrid, wet/dry heat rejection system using Thermosyphon coolers
- Compare in multiple climates to standard cooling tower systems, all dry systems using ACC's, and hybrid systems using parallel ACC's
- Determine most effective means to configure and apply the thermosyphon coolers

Key Potential Benefits

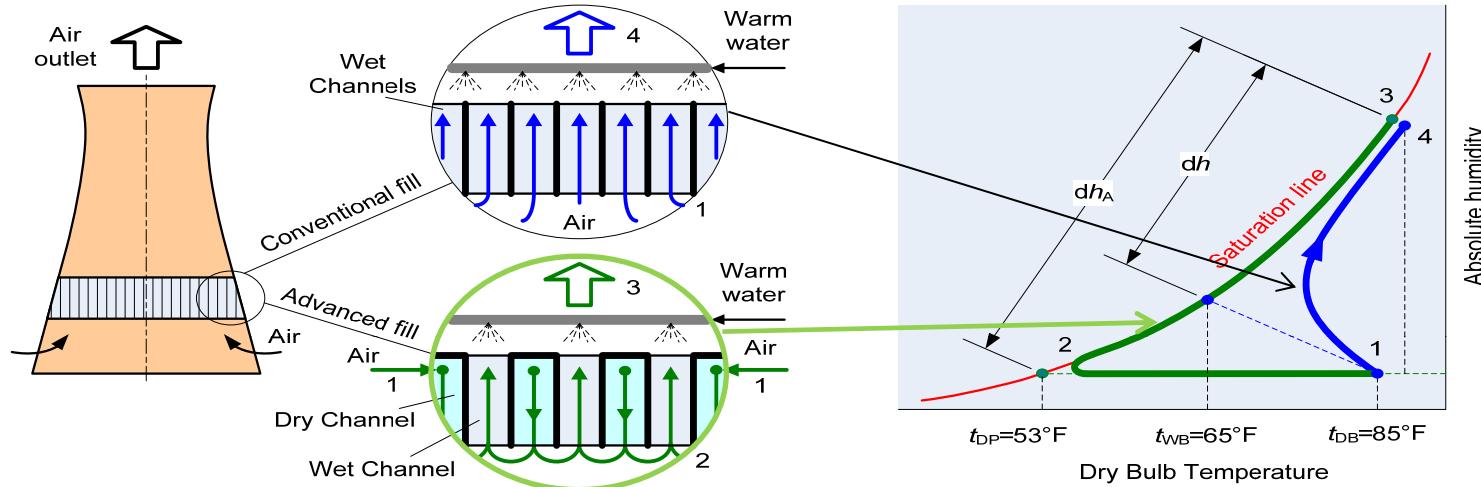
- Potential annual water savings > 50%
- Compared to ACC, full plant output is available on the hottest days
- Ease of retrofitting
- Reduced operating concerns in sub freezing weather
- Broad application (hybrid, new, and existing cooling systems)

Power Plant Heat Rejection System Incorporating Thermosyphon Cooler (TSC) Technology*

Animation
Slide



Advanced Dew Point Cooling Tower (Collaboration with Gas Technology Institute)



Project Scope

- Develop an advanced fill
- Perform energy, mass, and momentum balance modeling
- Evaluate performance and annual water savings for several typical climates using simulation models
- Perform prototype testing in scaled down cooling towers
- Perform technical and economic feasibility evaluation

Key Potential Benefits

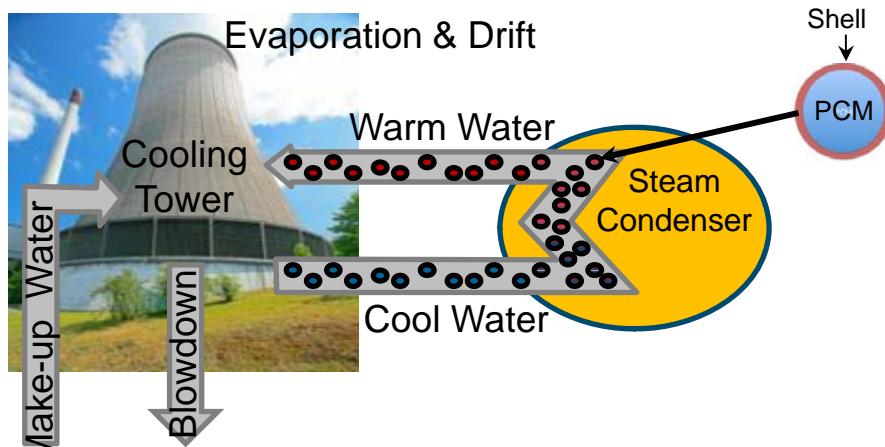
- Potential for less cooling water consumption by up to 20%
- Lower cooling tower exit water temperature resulting in increased power production
- Ease of retrofitting
- Potential to enhance hybrid cooling

Heat Absorption Nanoparticles in Coolant (Collaboration with Argonne National Laboratory)

Project Scope

- Develop multi-functional nanoparticles with ceramic shells and phase change material cores
- Measure nano-fluid thermo-physical properties
- Perform prototype testing in scaled down water cooled condenser and cooling tower systems
- Assess potential environmental impacts due to nanoparticle loss to ambient air and water source.
- Perform technical and economic feasibility evaluation

Phase Change Material (PCM) Core/Ceramic Shell
Nano-particles added into the coolant.

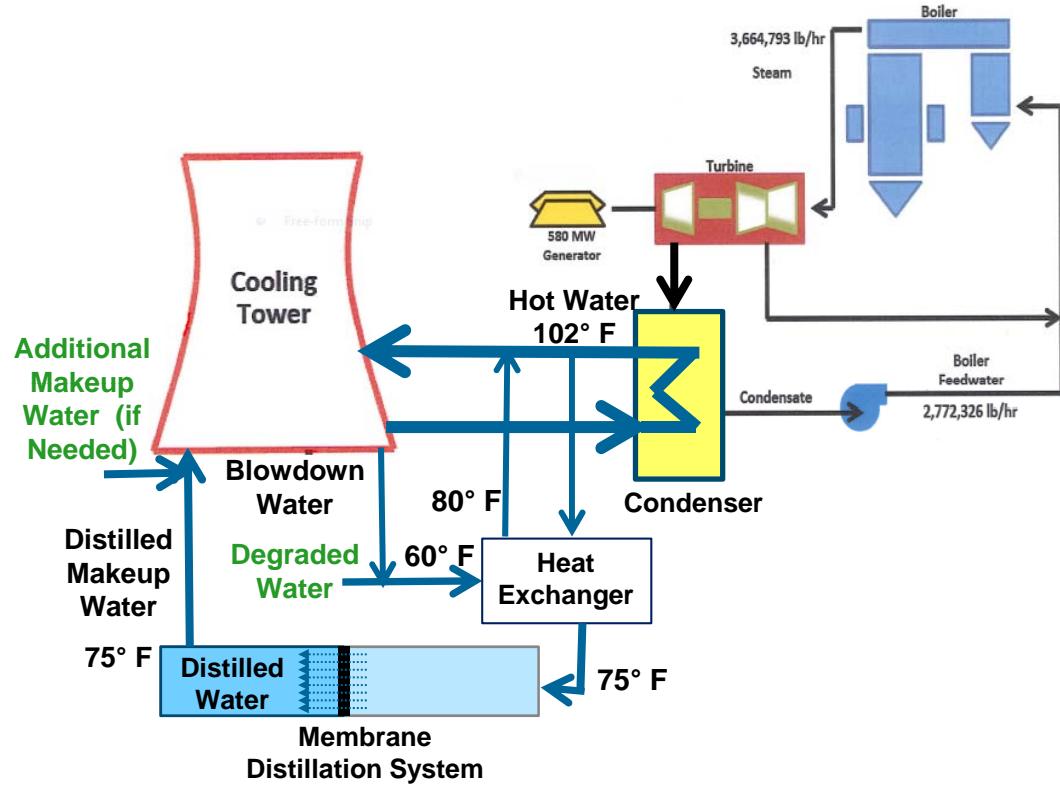


Key Potential Benefits

- Up to 20% less evaporative loss potential
- Less drift loss
- Enhanced thermo-physical properties of coolant
- Inexpensive materials
- Ease of retrofitting
- Broad applications (hybrid/new/existing cooling systems)

Membrane Distillation Integration with Cooling System

(Collaboration with A3E and Sandia National Lab)



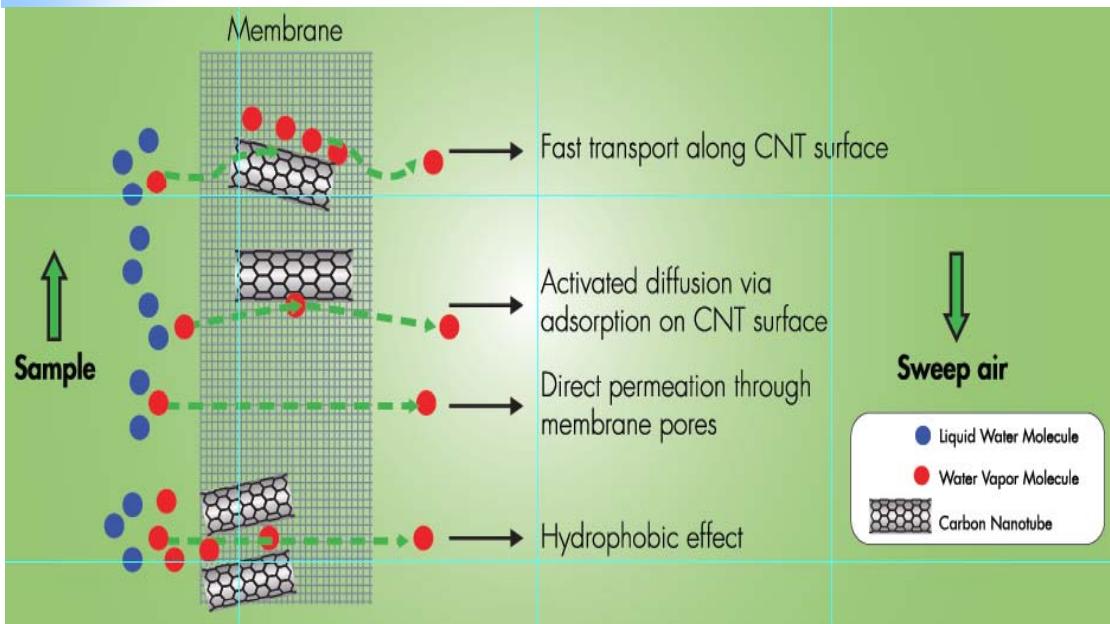
Key Potential Benefits

- Membrane distillation technology utilizes
 - Waste heat from condenser hot coolant
 - Cooling system as a water treatment plant
- Reduced fresh water makeup by up to 50% - 100%
- Potential to eliminate cooling tower for dry cooling

Project Scope

- Further develop and assess system integration strategy
- Perform technical and economic feasibility study

Carbon Nanotube Immobilized Membrane (CNIM) Distillation (Collaboration with New Jersey Institute of Technology)



Mechanisms of MD in the presence of CNTs

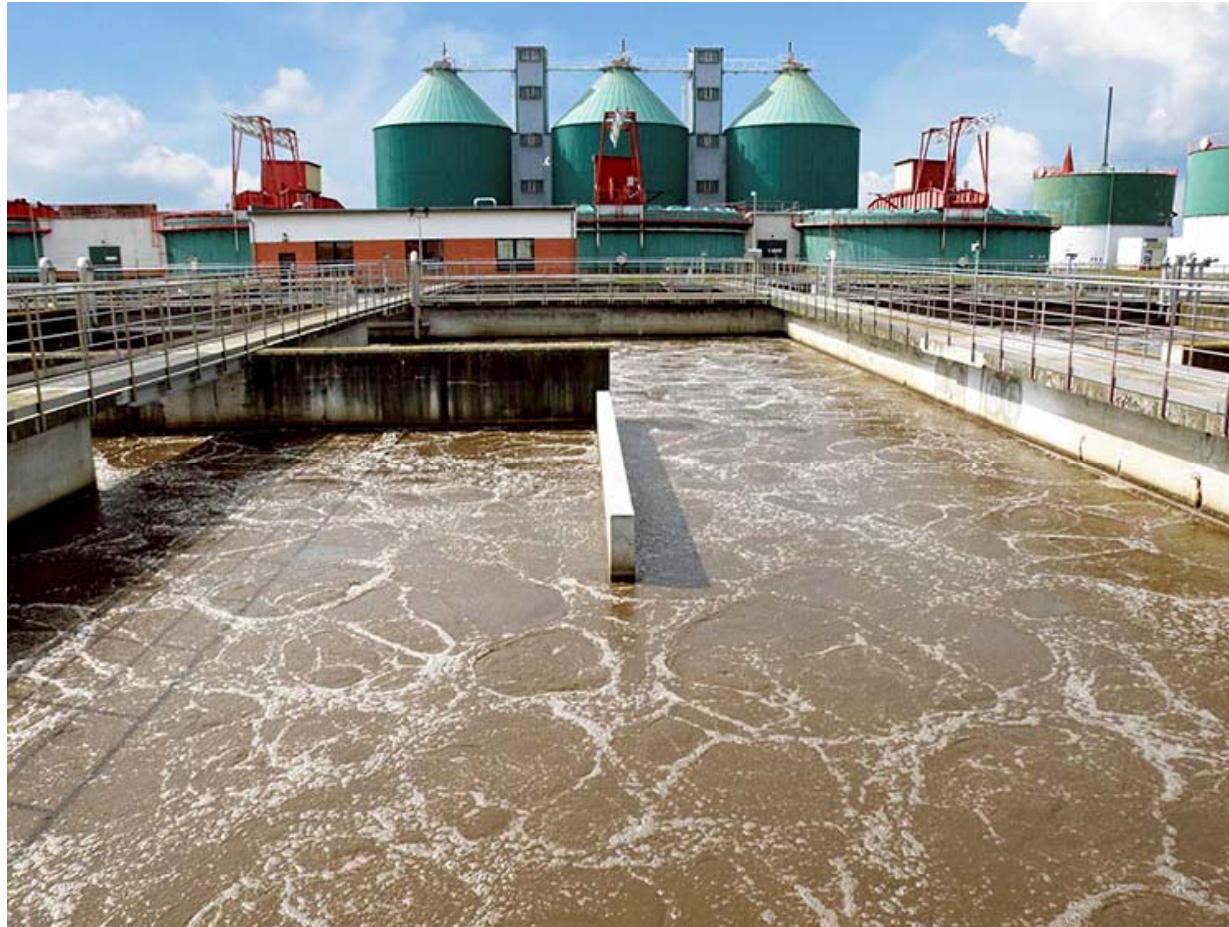
Key Potential Benefits

- Compared to top commercial MD technologies
 - Up to 10 times more vapor flux due to CNTs
 - Reduced cost of utilizing alternative water sources
- Enabling technology to:
 - Eliminate cooling tower
 - Utilize the cooling system as a water treatment plant

Project Scope

- Develop carbon nanotube (CNT) technology for membrane fabrication
- Further develop and test CNIMs for membrane distillation (MD)
- Develop and optimize MD integration strategies/process for water recovering
- Perform technical and economic feasibility of the process

Electricity Use and Management in the Municipal Water Supply and Wastewater Industries



Electricity Use and Management in the Municipal Water Supply and Wastewater industries: *Past EPRI research*

“Water and Wastewater Industries: Characteristics and Energy Management Opportunities” (EPRI report, 1996)

- Around 3.3% of the electricity consumed in the US annually is used for water and wastewater conveyance and treatment
- Most wastewater plants are 30 to 50 years old
- When these plants were constructed, energy efficiency was not an issue
- This report details how energy is used and describes opportunities for energy efficiency and load management



Popular Product – Being Used by Utility Managers

Electricity Use and Management in the Municipal Water Supply and Wastewater industries: *Current EPRI research*

- Construct a complete picture of energy use in the water and wastewater sectors from the bottom up by assessing unit level operations
- Provide electric utility staff with a practical tool to better understand the water and wastewater industries and the challenges they face.
- Provide information about the state-of-the-art technologies that can optimize the processes
- Provide examples and discussions of energy efficiency and load management opportunities



Collaborative Project with Water Research Foundation

Wastewater Technologies Investigated

Forced vortex grit removal	Effluent pumping (to reclamation or discharge)	Surface filtration (e.g., cloth filters)	Pyrolysis
Centrifuge thickening and dewatering	Side-stream treatment for ammonia removal	Thermal drying	Incineration
Anaerobic/anoxic basin mixing (biological nutrient removal=BNR)	Non potable water	Electro dewatering	
Conventional Activated Sludge (AS), Sequencing Batch Reactor (SBR), and Membrane Bioreactor (MBR)	High pressure air	Pyrolysis	
Mixed liquor recycle pumping	Channel aeration	Incineration	
Screw presses (could be combined with belt filter presses due to similar energy)	Pasteurization and Hydrolysis	Surface filtration (e.g., cloth filters)	
Odor control	Primary effluent filtration	Thermal drying	
UV disinfection	Depth filtration	Electro dewatering	

Drinking Water Technologies Investigated

Unit Process	Process Description
Ballasted sedimentation	These are high rate settlers involving the fixing of flocs, or suspended solids, onto ballast (sand) with the aid of polymers.
Ozone	Ozone is a proven drinking water treatment disinfectant that improves the taste of the treated water and decreases unwanted disinfection by-products.
UV	UV is a proven and safe alternative for primary disinfection as it is free of the harmful by-products associated with chemical disinfection. UV also has the added benefit of not compromising the taste, color or odor of water.
Air stripping	Air stripping is used mainly to treat VOCs, iron, and manganese in groundwater.
Dissolved air flotation	Dissolved Air Flotation (DAF) technology is the process where suspended solids, oils & greases, and other impurities are separated from water slurries by a process of dissolving air into water. Micro-bubbles interact with the particles to cause them to float to the surface of a vessel where they are skimmed and separated.
Membrane filtration	This will cover membrane filtration across the various pressures including reverse osmosis (RO).
Carbon adsorption	Activated carbon is used to adsorb natural organic compounds, taste and odor compounds, and synthetic organic chemicals in drinking water treatment.

Next Steps

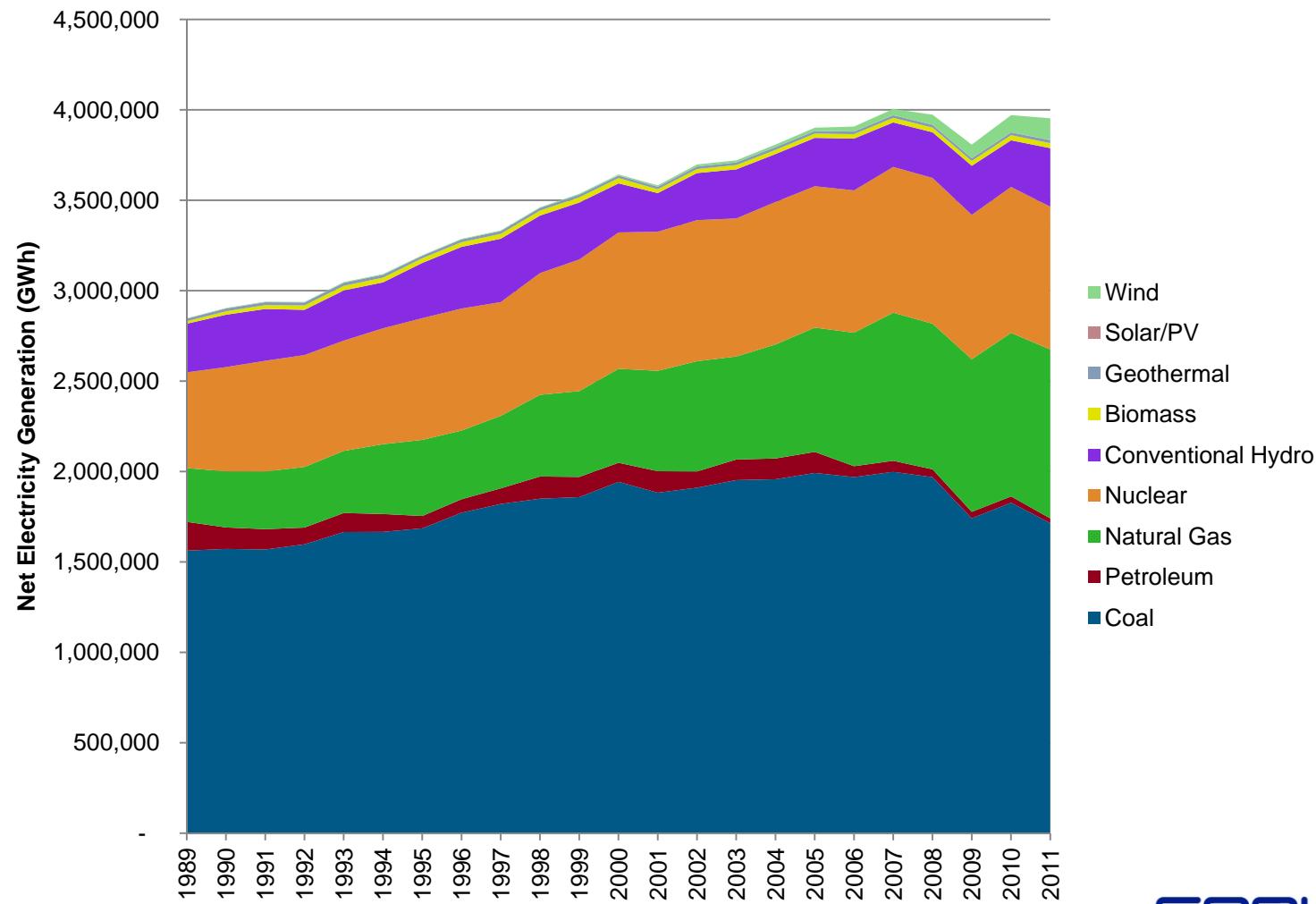
- Based on this work, EPRI plans to form a collaborative with electric utilities and water utilities to demonstrate new and promising energy efficient technologies in the field
- Similar effort in Agricultural Sector expected to launch in 2015

Hydropower Generation and Potential Impacts of Climate Variability



Conventional Hydro

Conventional hydro comprised about 7.8% of total generation in US (about 320,000 MWh) in 2011 (EIA data)



Potential Climate Impacts to Hydro-generation

- Lower storage volume in snow packs
 - Shorter generation periods
- Higher variability in precipitation events
 - Larger swings in run of river
 - Changes in peak generation
 - Predictability is reduced and modeling impaired
- Potential need for additional reservoir capacity
- Aquatic species protection (environmental flows)
 - Maintaining water quantity and quality to maintain survival and reproduction requirements
- Hydropower systems can be managed to mitigate some of the climate variability