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Developing Potential Game Changing Technical Solutions for Power Plant Water Consumption Reduction

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Outline

- EPRI Overview
- Research Directions and Gaps for Water Conserving Technologies
- EPRI's Approach
- Highlights of Current EPRI Projects in
  - Dry Cooling
  - Other Cooling
  - Water Treatment Projects
- EPRI-NSF $6M Collaboration

Three Key Aspects of EPRI

Independent

Objective, scientifically based results address reliability, efficiency, affordability, health, safety and the environment

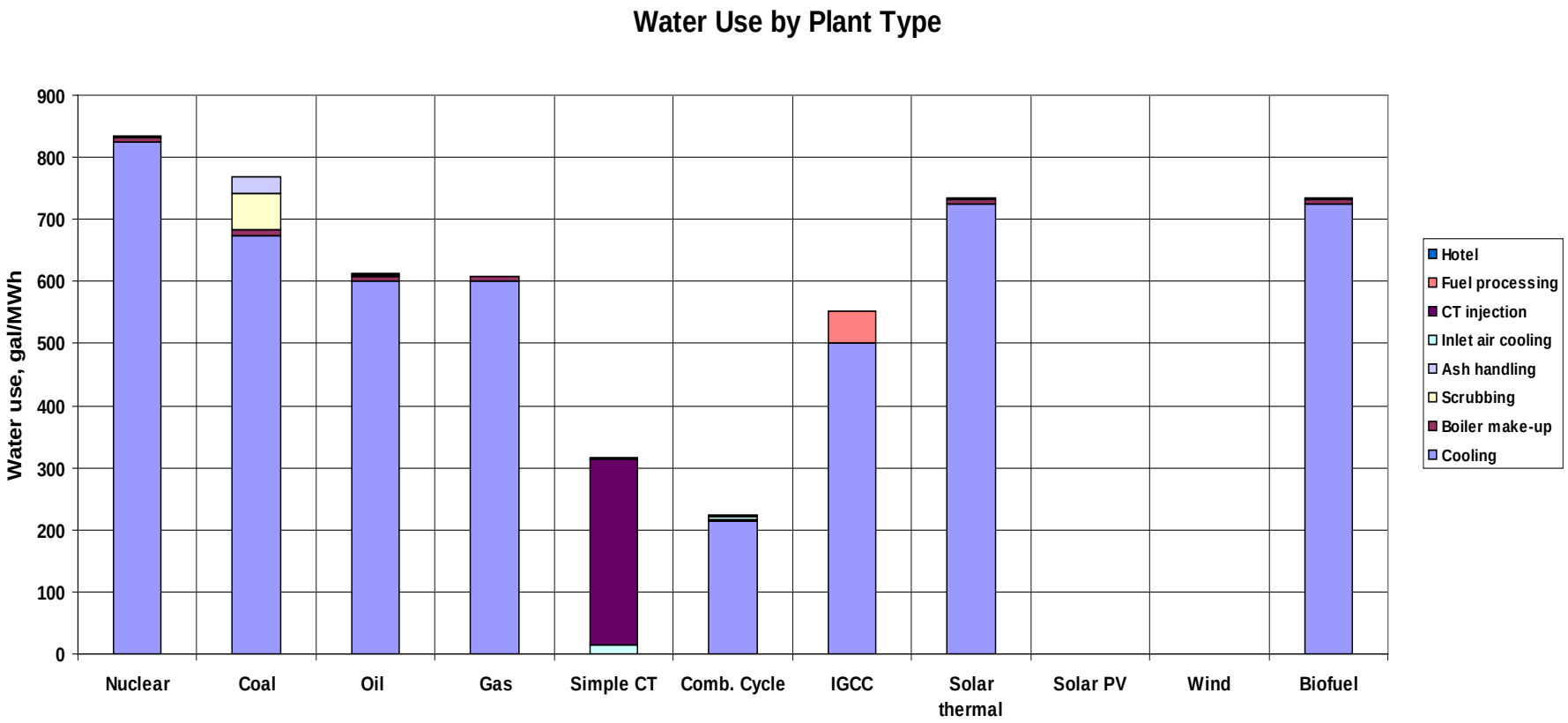
Nonprofit

Chartered to serve the public benefit

Collaborative

Bring together scientists, engineers, academic researchers, industry experts

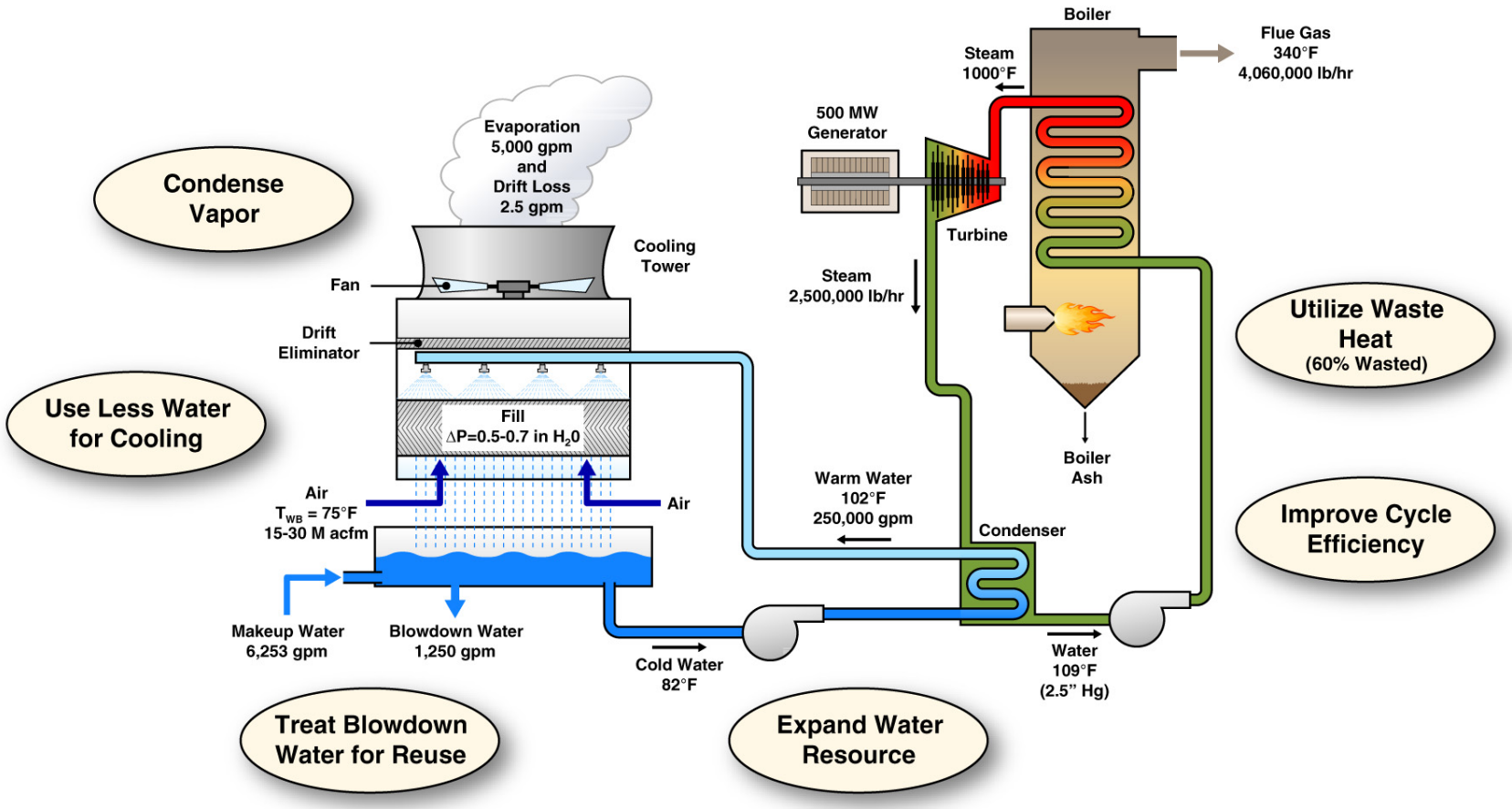
Root Cause of Thermal Power Plant Water Use



Source: EPRI Report, "Water Use for Electric Power generation", No. 1014026, 2008

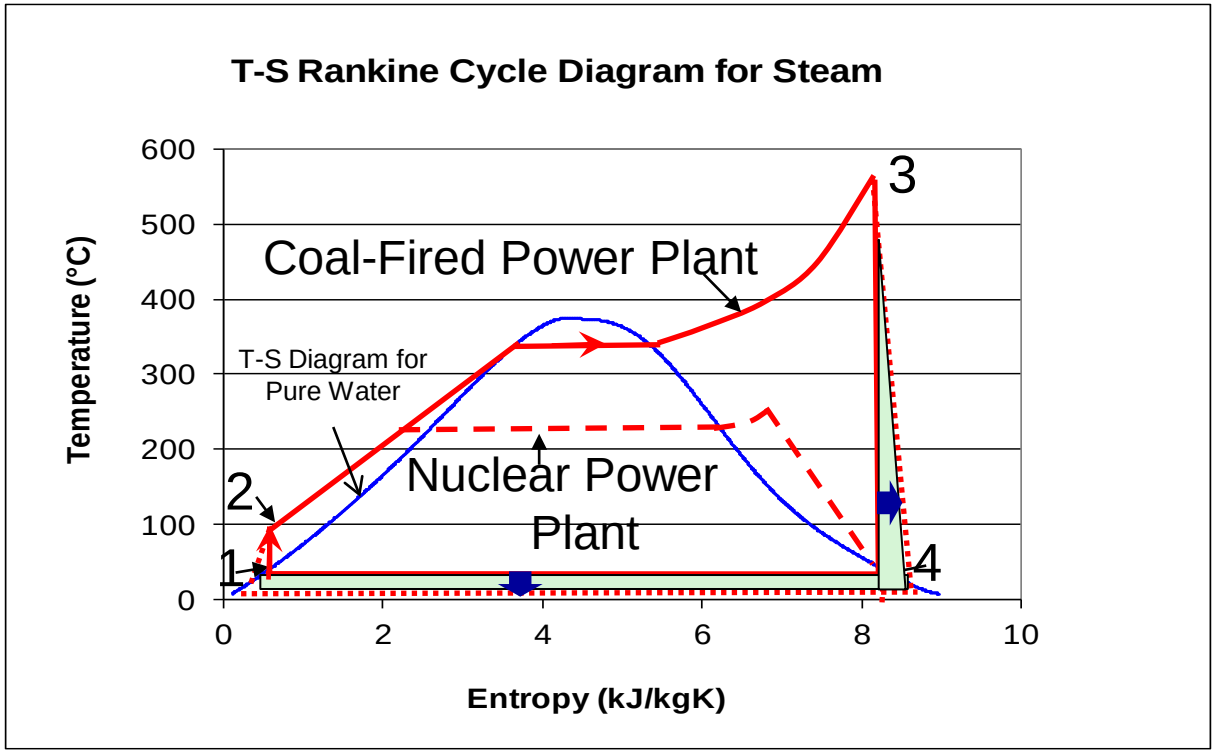
90% of thermal power plant water demand is due to cooling.

Most Rewarding Opportunities for Thermal Power Plant Water Use and Consumption Reduction



<u>Innovation Priorities</u>: Advancing cooling technologies, and applying novel water treatment and waste heat concepts to improve efficiency and reduce water use

Effect of Reducing Condensing Temperature on Steam Turbine Rankine Cycle Efficiency

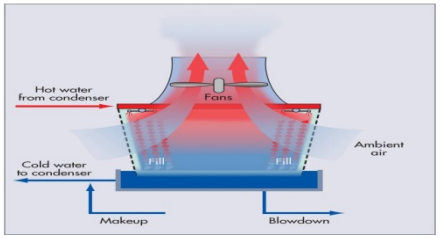


Potential for 5% (1st Order Estimate) more power production or $11M more annual income ($0.05/kWh) for a 500 MW power plant due to reduced steam condensing temperature from 50 °C to 35 °C.

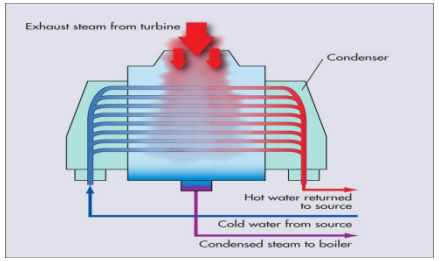
What Cooling System Options are Currently Deployed in the Industry?

Water Cooling

Cooling Tower[1] (42% in US)[2]



Once Through Cooling[1] (43% in US)[2]

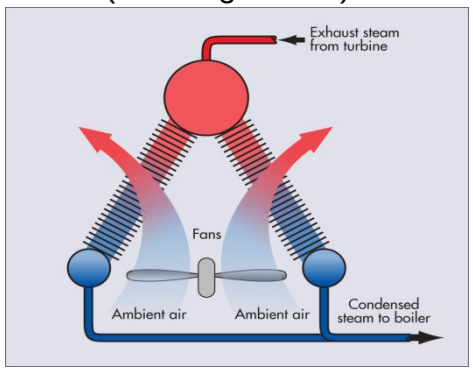


Cooling Pond (14% in US)[2]

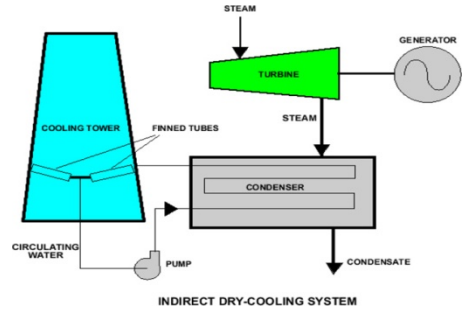
Dry Cooling

Direct Dry Cooling[1]:

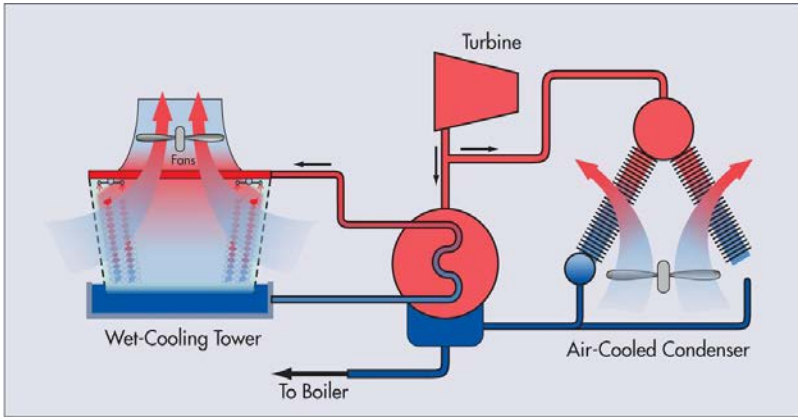
Air Cooled Condenser (1%Usage in US)[2]



Indirect Dry Cooling[3]



Hybrid Cooling[1]



Increasing demand for dry cooling in water scarcity regions.

1. *EPRI Report, "Water Use for Electric Power generation", No. 1014026, 2008.*
2. *Report of Department of Energy, National Energy Technology Laboratory, "Estimating Freshwater Needs to Meet Future Thermoelectric Generation Requirements",* DOE/NETL-400/2008/1339, *2008*
3. *http://www.globalccsinstitute.com/publications/evaluation-and-analysis-water-usage-power-plants-co2-capture/online/101181*

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Technology Gaps and Challenges

Dry Cooling

- Minimize
  - ✓ **Steam condensation temperature** or power production penalty from 10-15% in summer
  - ✓ Cost from 3-5 times cost of wet cooling tower systems
  - ✓ Foot print
- Improve efficiency, and operational and maintenance issues
- Develop alternative dry cooling solutions for diverse generation types (e.g., Nuclear)

Hybrid Cooling

- Precool hot water
- Maximize use of dry cooling

Water Cooling

- Reduce vapor loss by up to 100%
  - ✓ Vapor capturing technologies
- Use degraded water sources
  - ✓ Develop cost effective water treatment technologies

Opportunity: Alternative Water Sources for Cooling Water Use

Agricultural drainage

Municipal effluent

Oil and gas produced water

Saline groundwater

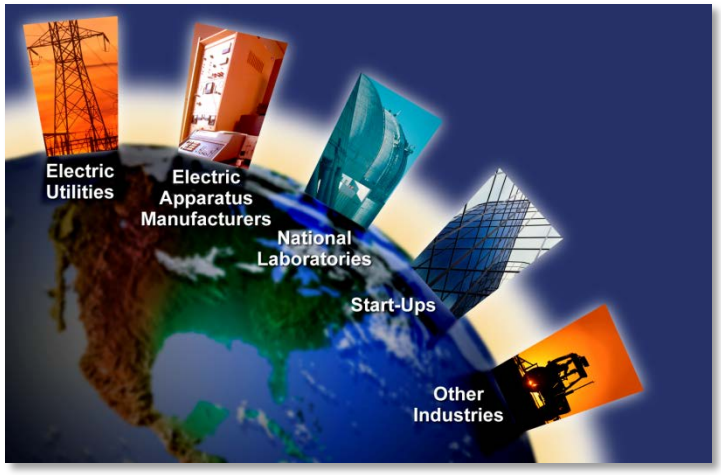
Sea water

Storm water

- Integrated and distributed water source infrastructure is our future.
- **Cost effective water treatment technologies will enable the use of degraded water sources.**

EPRI's Approach

- Initiated water conservation technology innovation research in early 2011
- Collected 168 proposals/white papers from 3 solicitations
  - Feb., 2011
  - June, 2012
  - May, 2013 **($6 M Collaboration with The National Science Foundation).**
- Funded 12 projects
- Plan to fund 5 or more projects in 2014



Objective

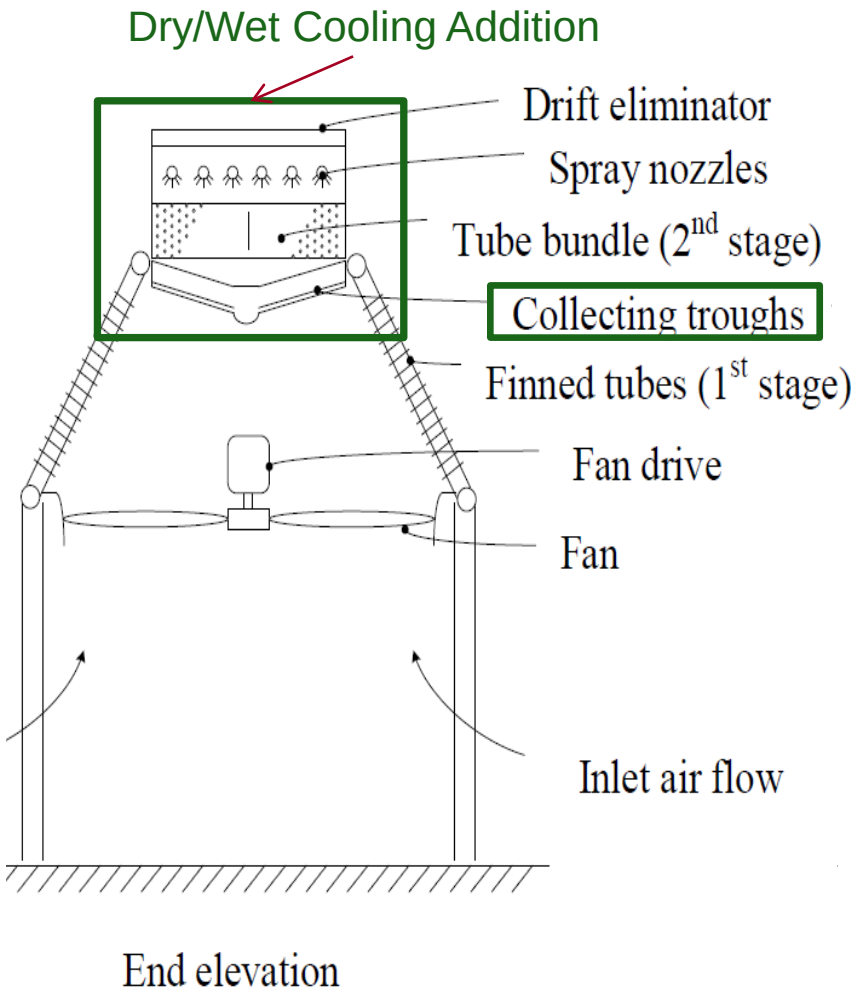
Seek and develop "out of the box", game changing, early stage, and high risk cooling and water treatment ideas and technologies with high potential for significant water consumption reduction.

Examples of On-Going Advanced Dry Cooling Technology Projects

1. **Water Spray to Enhance Air Cooled Condensers (Collaboration with University of Stellenbosch in S. Africa)**
2. **Nearly 100% Vapor Capturing Technology (Collaboration with UMD)**
3. Waste Heat/Solar Driven Green Adsorption Chillers for Steam Condensation (Collaboration with Allcomp)
4. Thermoelectric Cooling and Waste Heat Recovery Technology (Collaboration with Purdue)

More info. available at:
http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000000001025771&Mode=download&Mode=download

Project 1: Water Spray to Enhance Air Cooled Condensers (Collaboration with University of Stellenbosch in S. Africa)

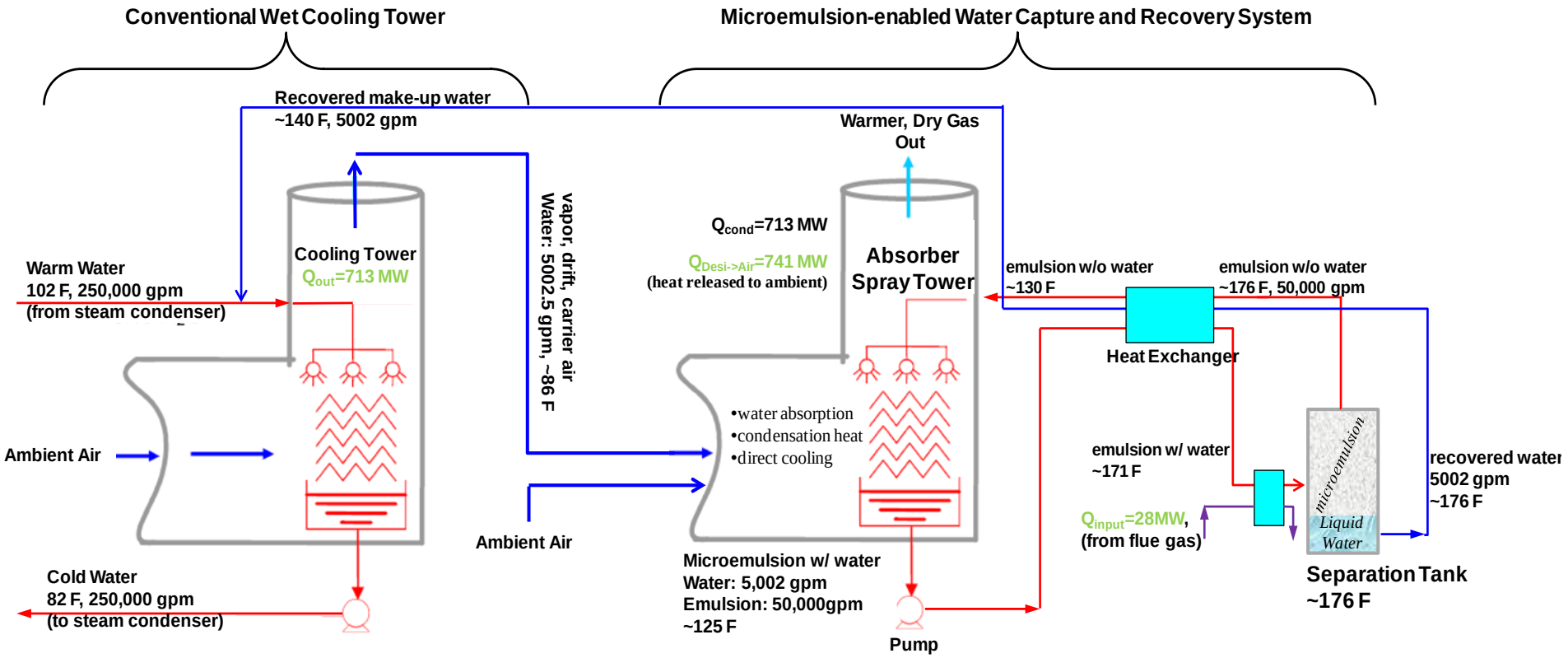


Key Potential Benefits

- More power production on hottest days
- Less makeup water use than wet cooling tower systems
- Less water use than currently used dry cooling augmented with water spray precooling for incoming air

Project 2: Micro-emulsion Vapor Capturing Technology

(Collaboration with UMD) – Joint Patent Pending



Key Potential Benefits

- Nearly 100% vapor capturing system driven by waste heat
- Much lower steam condensation temperature, up to 50% less costly and much smaller footprint than a dry cooling system

- 500 MWe Power Plant
- Amount of heat required: 28 MW (from flue gas)
- Total amount of heat released to ambient: 713 MW + 28 MW

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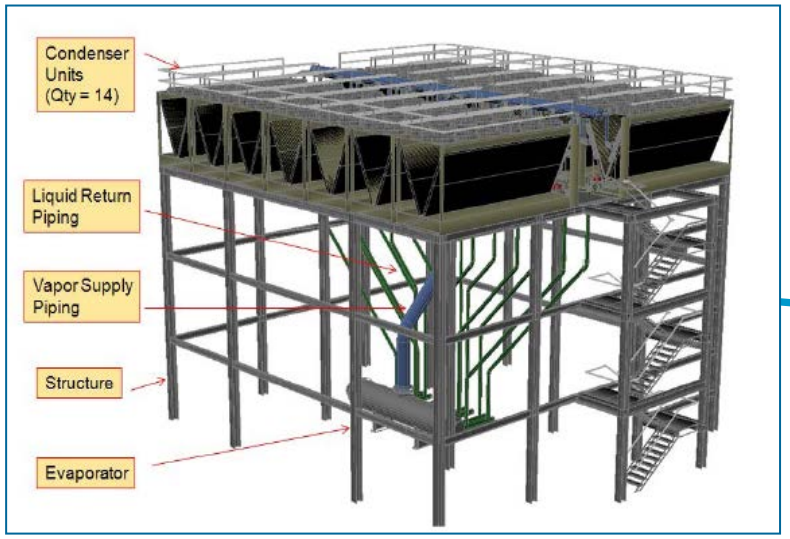
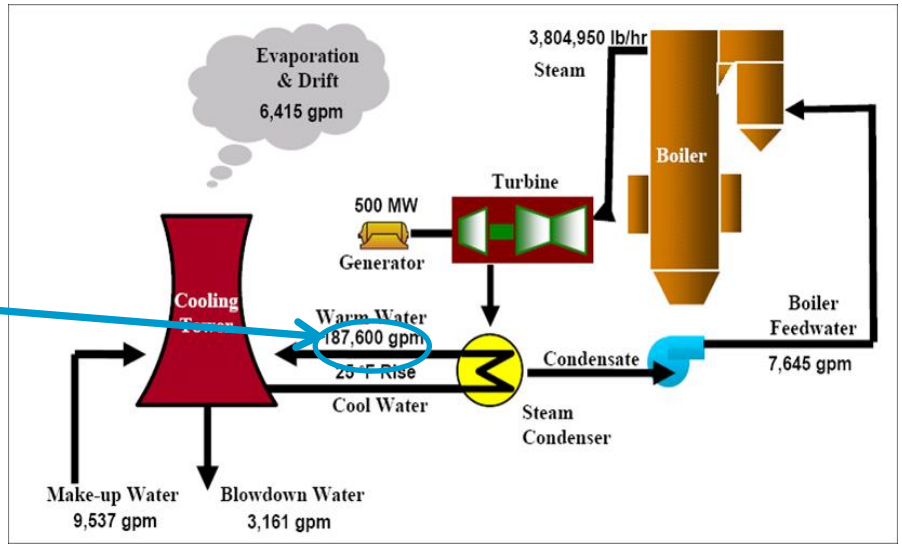
Other Cooling Projects

5. **Thermosyphon Cooler Technology (Collaboration with Johnson Controls)**
6. Advanced M-Cycle Dew Point Cooling Tower Fill (Collaboration with Gas Technology Institute)
7. Heat Absorption Nanoparticles in Coolant (Collaboration with Argonne National Laboratory)
8. Parametric Evaluation of Effects of Nanofluid on Cooling Tower Evaporation Loss Reduction (Collaboration with GTI)
9. Emerging Heat Transfer Enhancement Technology Evaluation (Collaboration with UIUC)

Project 5: Thermosyphon Cooler Technology
(Collaboration with Johnson Controls)

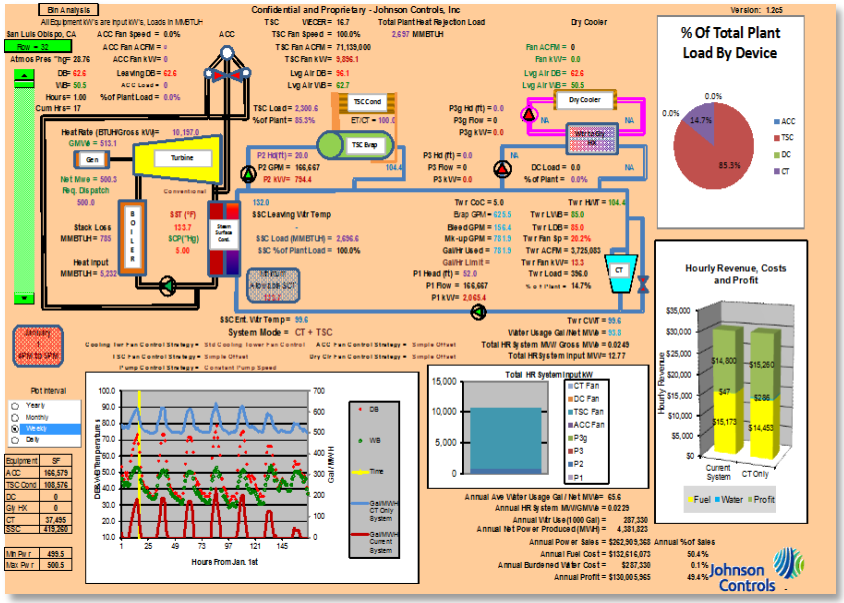




Key Potential Benefits

- Potential annual water savings up to 75%
- Compared to ACC, full plant output is available on the hottest days
- Ease of retrofitting
- No increase in surface area exposed to primary steam
- Reduced operating concerns in subfreezing weather
- Broad application for both new and existing cooling systems for fossil and nuclear plants)

More About Project 5: Thermosyphon Cooler Technology



Project Outputs

- Detailed, interactive 8760 hour, cooling system model simulations for five climatic locations
- Thermosyphon Cooler (TSC) conceptual module design
- Thermosyphon Cooler Hybrid System (TCHS) concept for a 500 MW Coal-Fired Plant
- Final project report to be released soon

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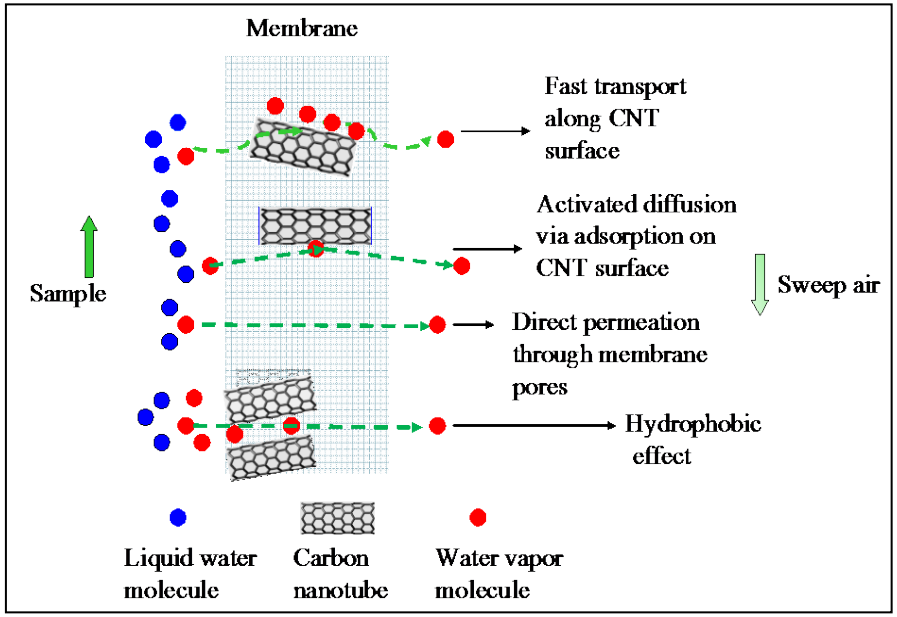
Examples of Water Treatment Technology Projects for Water Use Reduction

1. **Carbon Nanotube Immobilized Membrane Distillation (Collaboration with NJIT)**
2. Integration of cooling system with membrane distillation aided by degraded water source (Collaboration with WEN and Sandia National Lab)
3. Reverse Osmosis Membrane Self Cleaning by Adaptive Flow Reversal (Collaboration with UCLA)

Project 1: 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 MD technologies
  - Up to 10 times more vapor flux due to CNTs
  - Reduced cost of utilizing alternative water sources
- Enabling technology for A3E concept to eliminate the cooling tower and turn the cooling system into a water treatment plant for other use

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

Partial List of Publications on Cooling

- Published five EPRI reports, five technology briefs, and several conference papers
  - **1025642**, Program on Technology Innovation: New Concepts of Water Conservation Cooling and Water Treatment Technologies
  - **1025643**, Program on Technology Innovation: Feasibility Study of Using a Thermosyphon Cooler Hybrid System to Reduce Cooling Tower Water Consumption
  - **1026878**, Program on Technology Innovation: Review of Advanced Cooling Tower Technologies with Reduced Cooled Water Temperature and Evaporation Losses
  - **1025006**, Program on Technology Innovation: Tradeoffs Between Once-Through Cooling and Closed-Cycle Cooling for Nuclear Power Plants
  - **1023780**, Program on Technology Innovation: Biotechnological Approaches to Removing Boron from Electric Utility Wastewater
  - **1026763**, Brief: Multifunctional Nanoparticles for Reducing Cooling Tower Water Consumption
  - **1026527**, Technology Insights Brief: Power Industry Working to Adapt Revolutionary M-Cycle Technology for Power Plant Cooling Towers to Lower Energy Consumption, Water Use
  - **1024910**, Technology Insights Brief: Green Adsorption Chiller for Power Plant Cooling
  - **3002000337**, Technology Pipeline Brief: Dew-Point Cooling for Increased Water Use Efficiency and Power Plant Productivity
  - **1026766**, Technology Pipeline Brief: Thermosyphon Cooler System for Lower-Cost Hybrid Plant Cooling and Drought Resiliency

NSF-EPRI Collaboration
on Advancing Dry Cooling Technologies

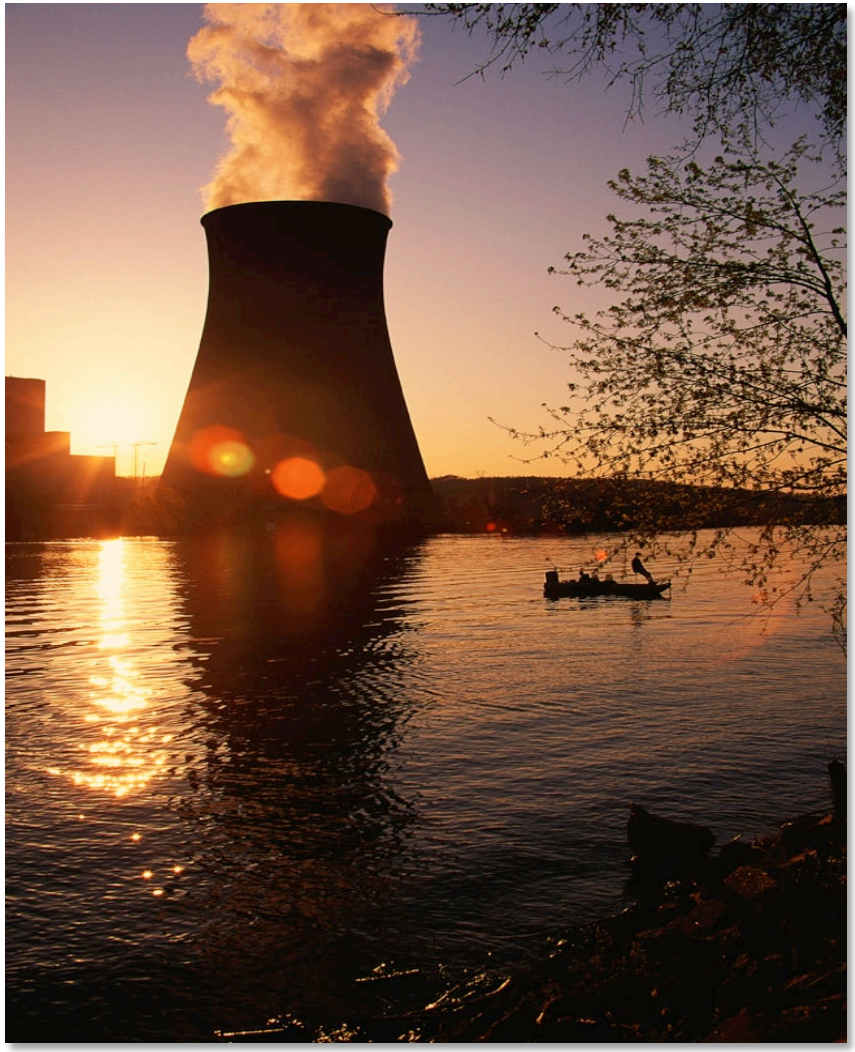
- **Funding Size**
  - **$6 M Collaboration ($3 M commitment from each of EPRI TI and NSF)**
  - $600 K to $2.1 M for a 3 year project
  - 5 to 10 projects
- **Timing**
  - Solicitation released on May 22, 2013
  - Informational Webcast on 7/24/13 (Slides, Recording)
  - Award Notification in Dec., 2013
- **Funding Approach**
  - Coordinated but independent funding
    - NSF awards grants.
    - EPRI contracts.
  - Joint funding for most proposals
  - Independent funding for a few proposals if needed

Value

- Leveraged $3M from NSF
- Attracted top talents to power plant cooling innovation.

Concluding Thoughts

- Power plant cooling systems are the major cause of power plant water withdrawal and consumption and represent the most rewarding opportunity for innovation.
- Results indicate high potential to dramatically reduce water use in power plant cooling.
- Results support significant value of increasing power plant cooling research and collaboration.



Thank you so much!

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