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Exciting Times for EPRI's Water Use and Availability Technology Innovation Program

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Red Rock Resort & Spa
Summerlin, NV

Outline

- EPRI and EPRI Water Use and Availability Technology Innovation Program Overview
- Highlights of our Current Projects in
  - Dry Cooling
  - Other Cooling
  - Water Treatment Projects
- 2013 Joint 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

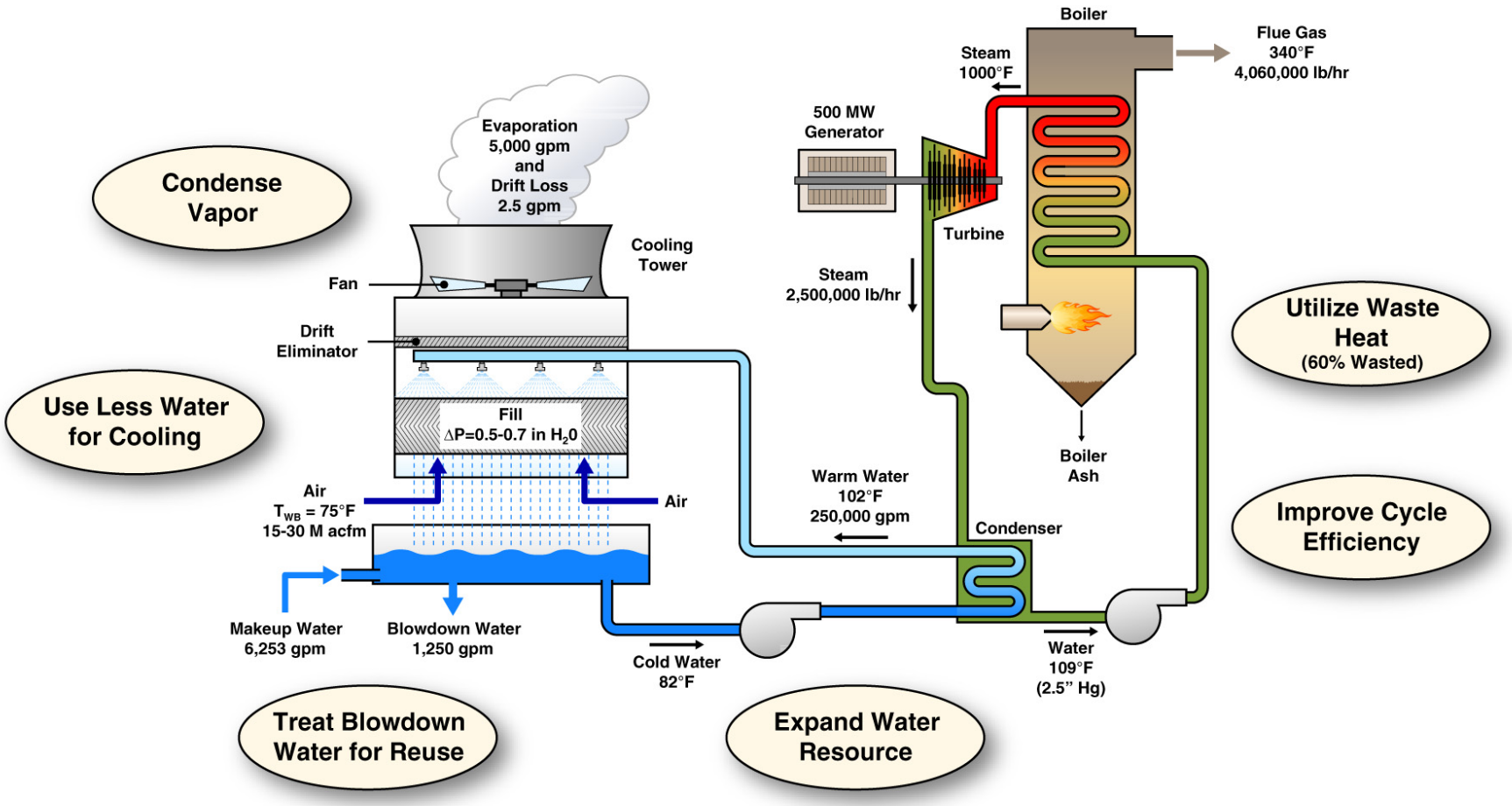
Water Use and Availability Technology Innovation Program Overview and Objective

- Initiated in early 2011
- Cross-sector program
- Collected 168 proposals/white papers from 3 solicitations
  - ✓ Feb., 2011
  - ✓ June, 2012
  - ✓ May, 2013 (jointly with NSF).
- Started 12 projects

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 water consumption reduction.

Opportunities for Power Plant Water Use Reduction



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

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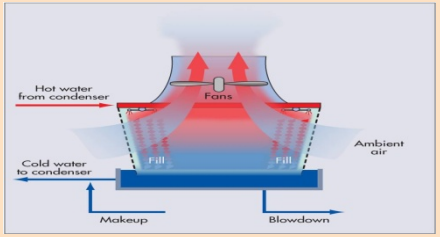
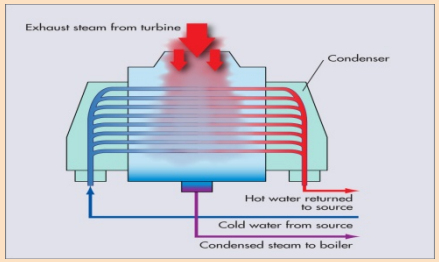
What Cooling System Options are Currently Deployed in the Industry?

Water Cooling

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



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

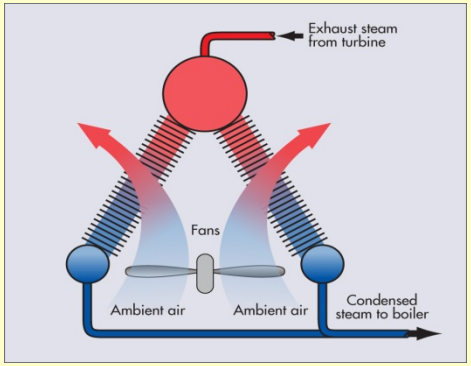


Cooling Pond (14% in US)[2]

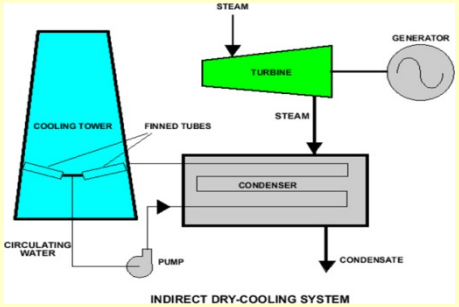
Dry Cooling[1]

Direct Dry Cooling:

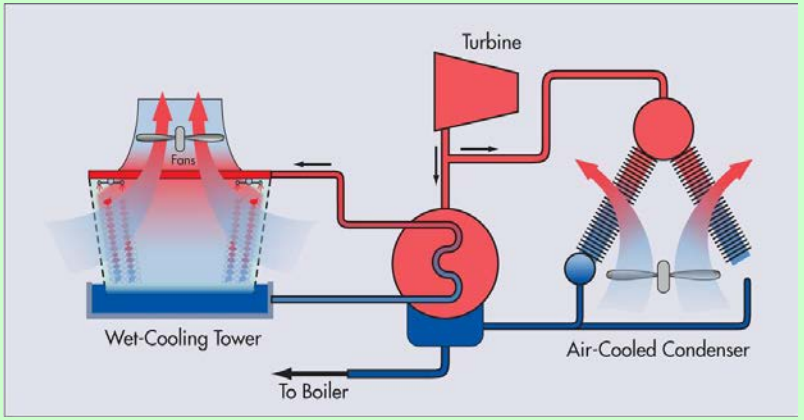
Air Cooled Condenser (1%Usage in US)[2]



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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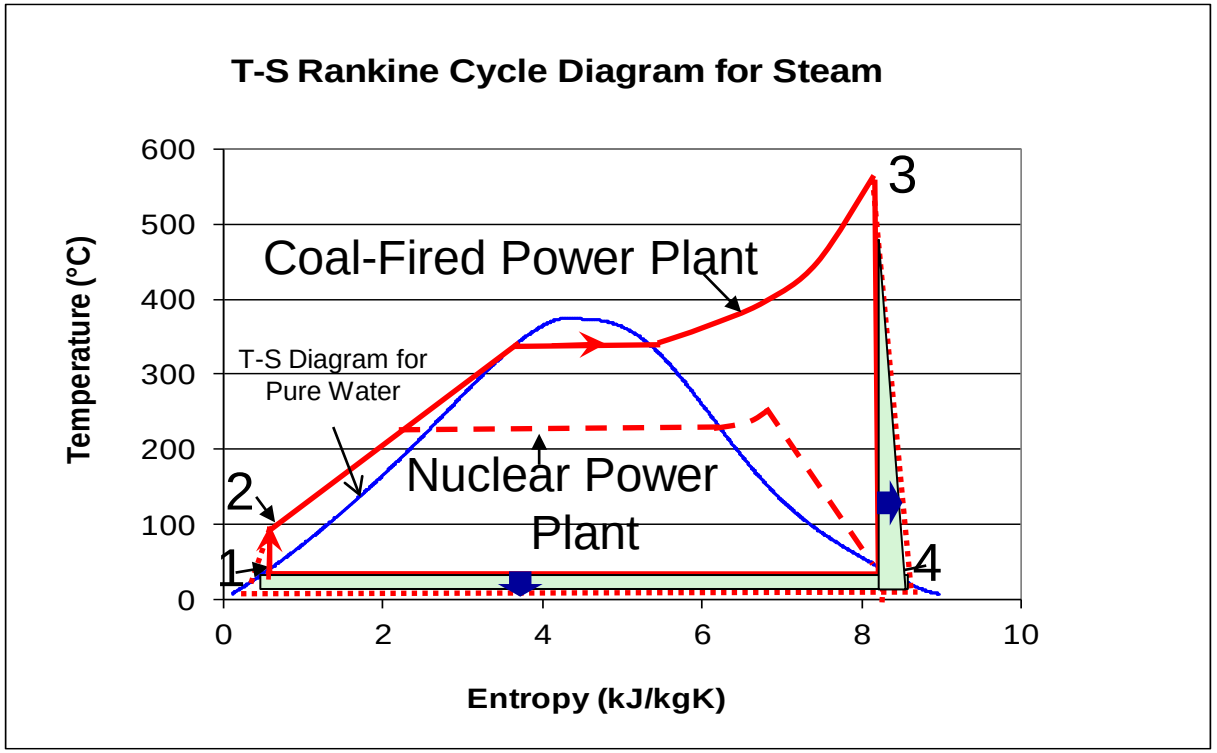
Effect of Reducing Condensing Temperature on Steam Turbine Rankine Cycle Efficiency



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.

Examples of On-Going Advanced Dry Cooling Technology Projects

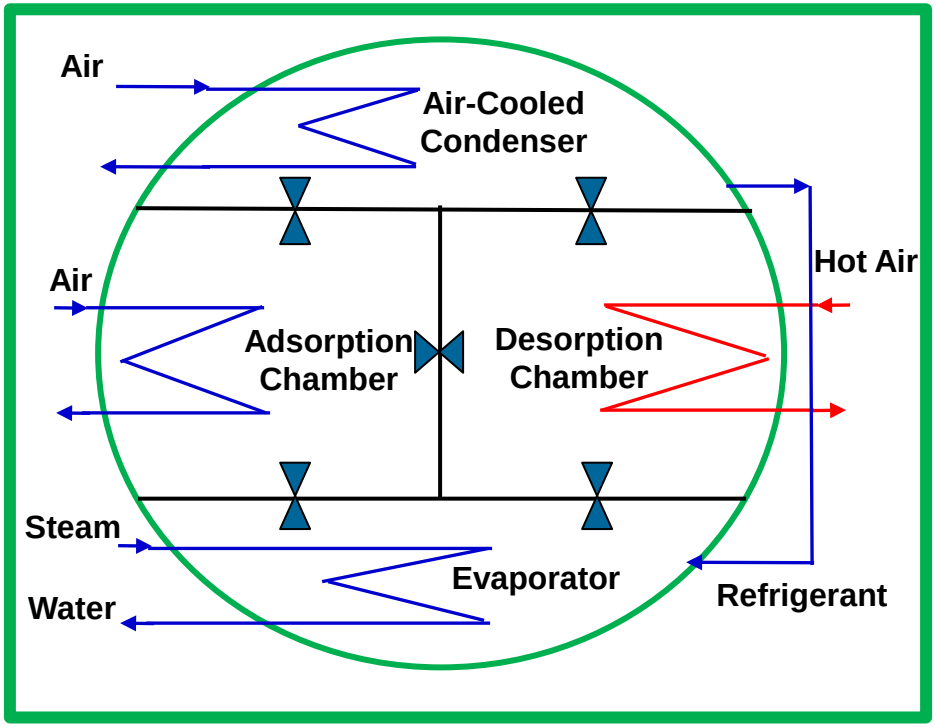
1. **Waste Heat/Solar Driven Green Adsorption Chillers for Steam Condensation (Collaboration with Allcomp)**
2. Thermoelectric Cooling and Waste Heat Recovery Technology (Collaboration with Purdue)
3. **Nearly 100% Vapor Capturing Technology (UMD)**
4. **Hybrid dry/wet Cooling to Enhance Air Cooled Condensers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

More info. available at:

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

Project 1: Waste Heat/Solar Driven Green Adsorption Chillers for Steam Condensation (Collaboration with Allcomp)

Schematic Illustration of a Typical Adsorption Chiller



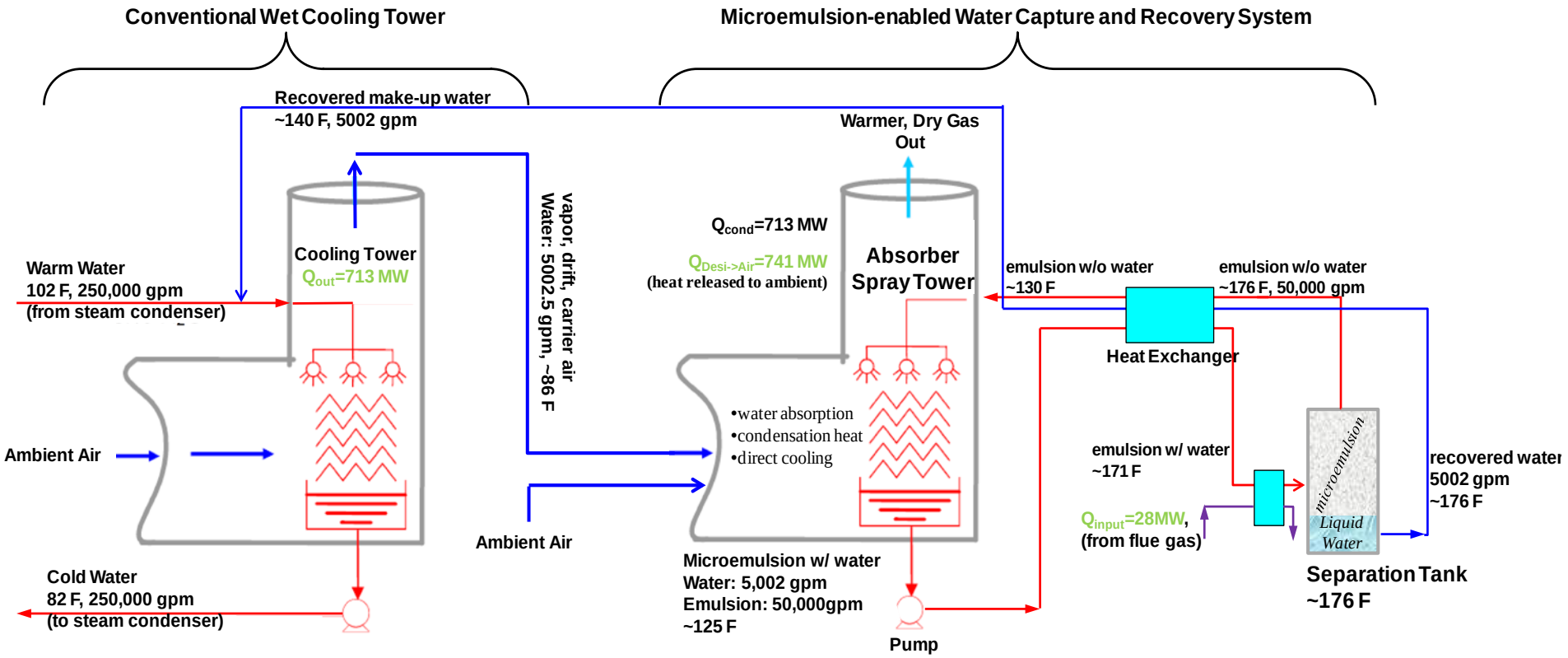
(EPRI Patent Pending)

Key Potential Benefits

- Dry cooling system
  - **Near Zero** water use and consumption
- Reduced condensation temperature
  - As low as **35 ℃**
  - Potential for annual power production increase by up to 5%
- Full power production even on the hottest days compared to air cooled condensers.

Project 3: 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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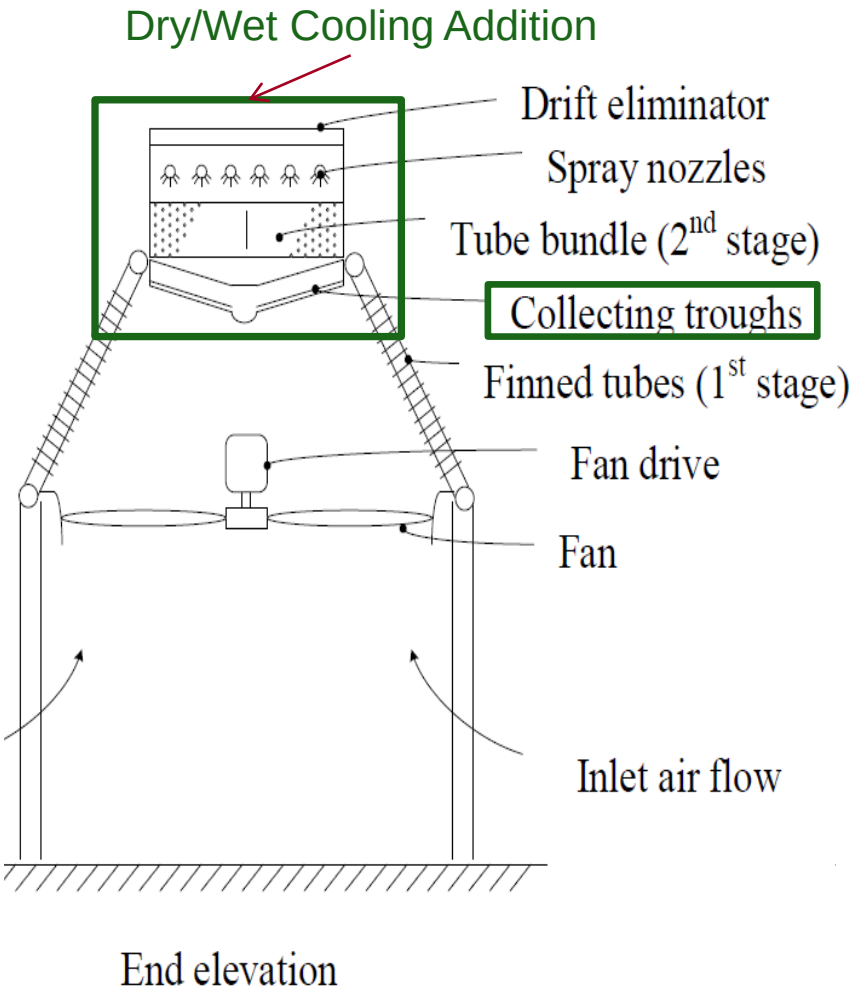
Project 4: Hybrid dry/wet cooling to enhance air cooled condensers (Collaboration with University of Stellenbosch in S. Africa)



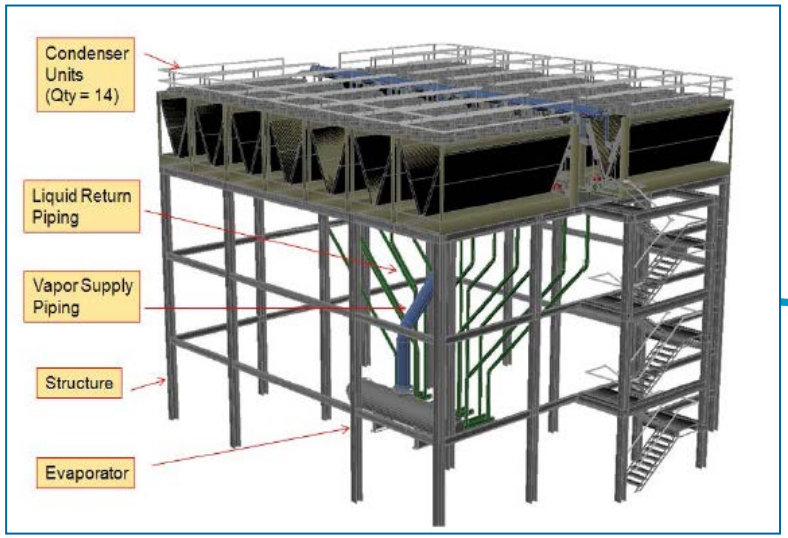
Key Potential Significant Benefits

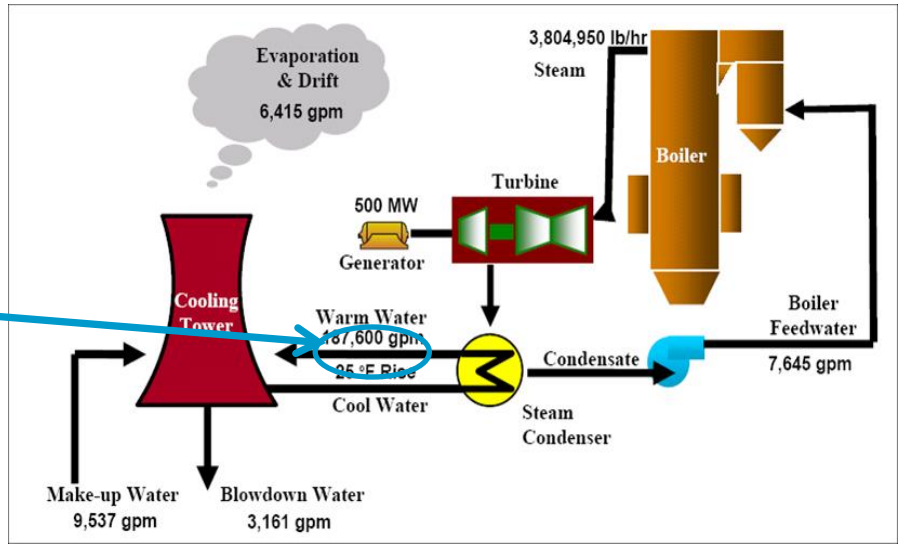
- More power production on the hottest days than air cooled condensers
- Less makeup water use than wet cooling tower systems
- Less water use than currently used dry cooling augmented with water spray precooling for incoming air

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)

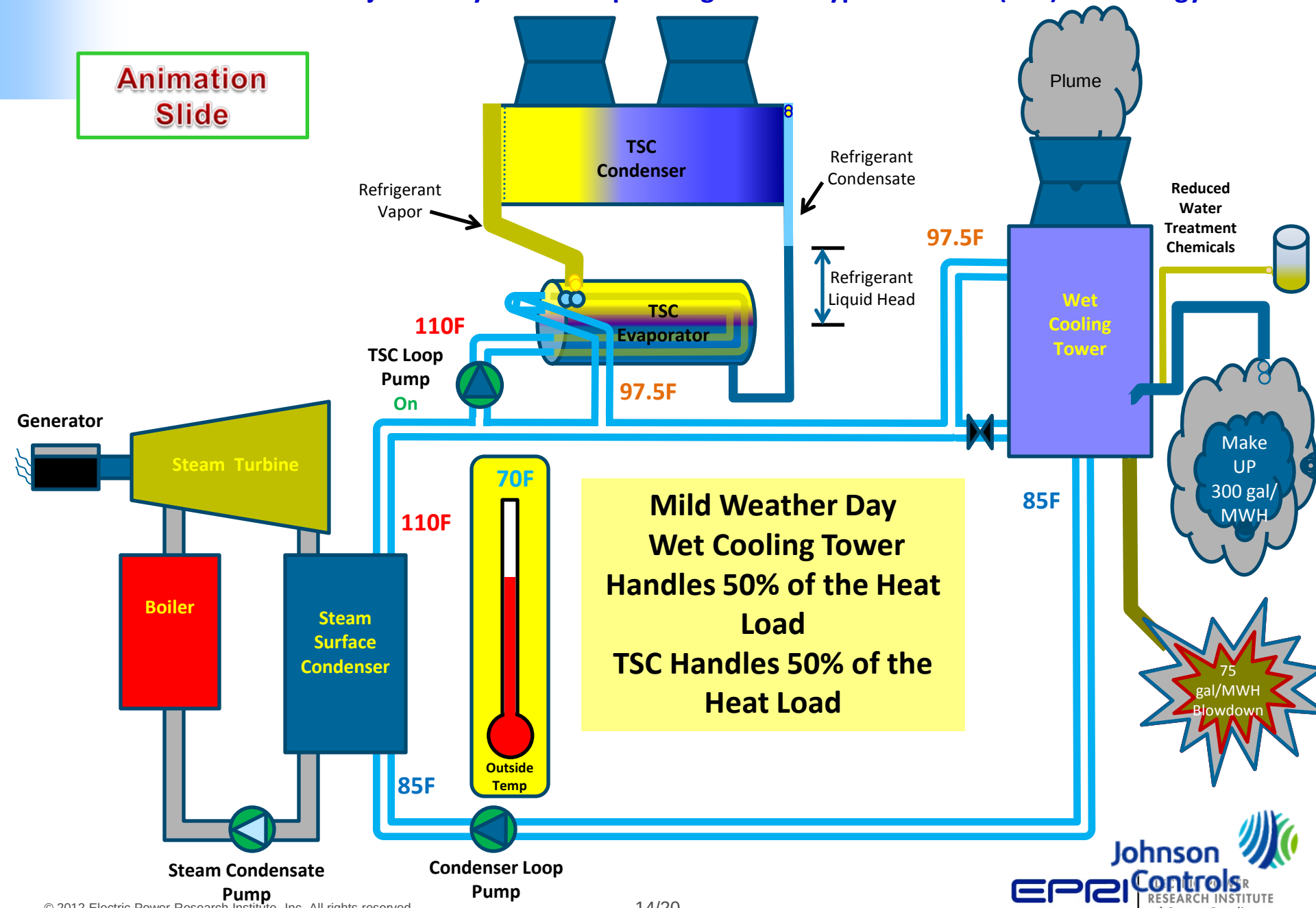




Key Potential Benefits

- 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 sub freezing weather
- Broad application for both new and existing cooling systems for fossil and nuclear plants)

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



Johnson Controls

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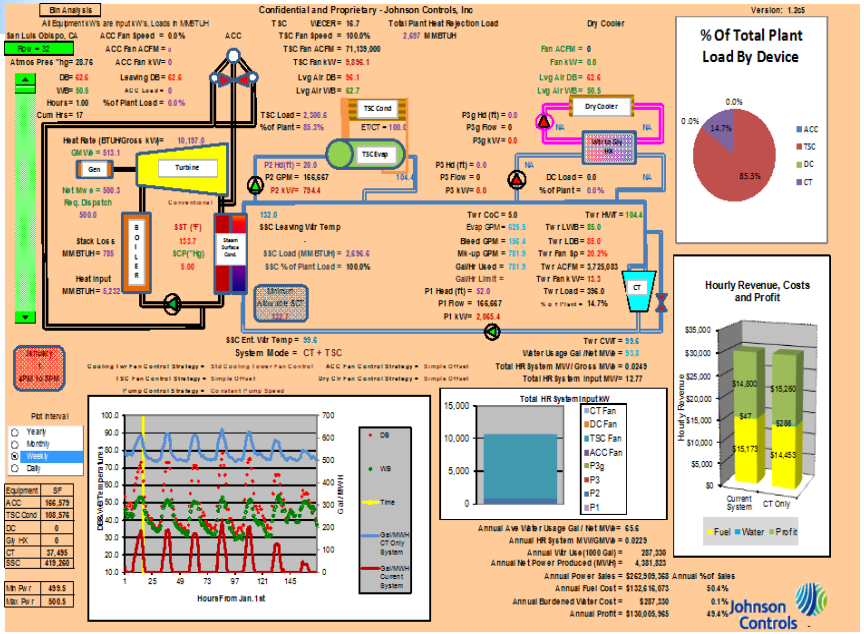
* Patent Pending

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 in Dec., 2013

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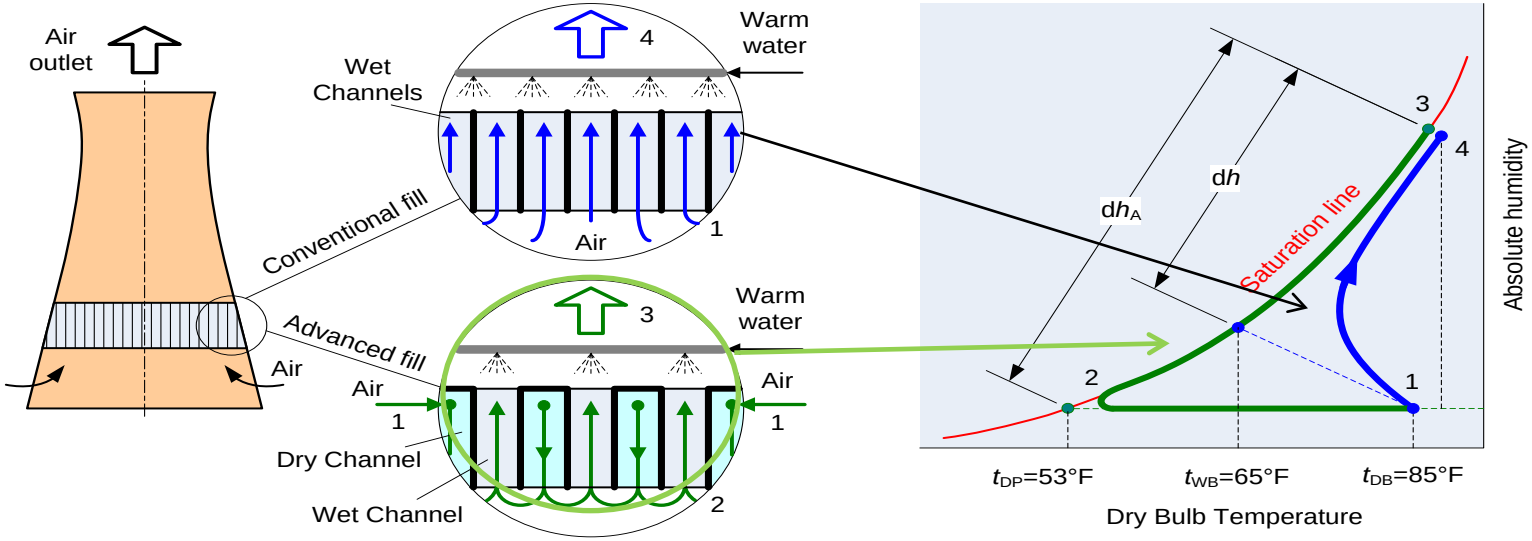
Project 6: Advanced Dew Point Cooling Tower Fill (Collaboration with Gas Technology Institute)

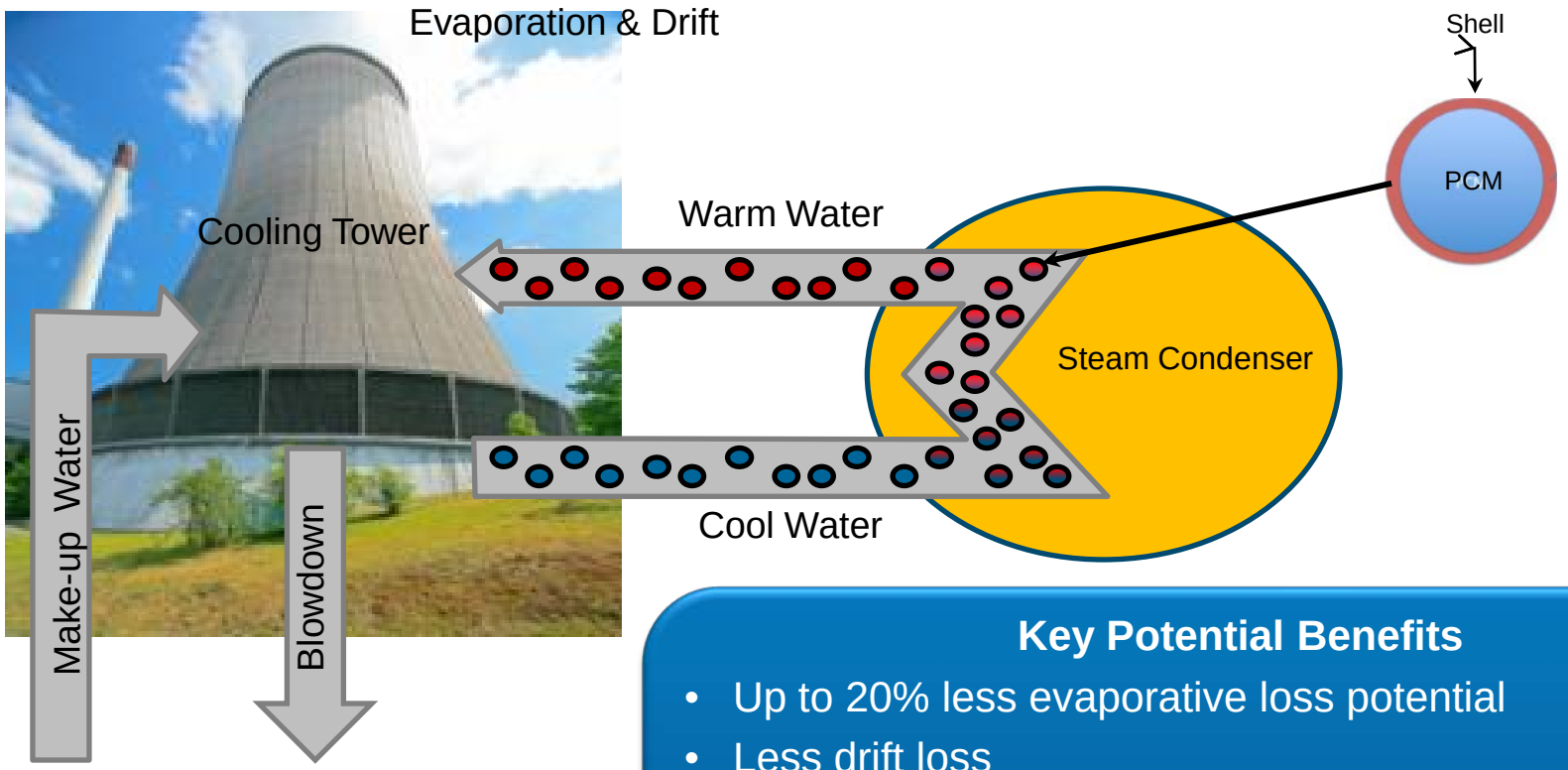


Key Potential Benefits

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

Project 7: Heat Absorption Nanoparticles in Coolant (Collaboration with Argonne National Laboratory)

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)

Examples of Water Treatment Technology Projects for Water Use Reduction

1. Reverse Osmosis Membrane Self Cleaning by Adaptive Flow Reversal (Collaboration with UCLA)
2. Integration of Cooling System with Membrane Distillation Aided by Degraded Water Source (Collaboration with WEN and Sandia National Lab)
3. Carbon Nanotube Immobilized Membrane Distillation (Collaboration with NJIT)

Publications

- Published five EPRI reports, five technology briefs, and several conference papers on cooling
  - 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)
  - Many proposals collected as of August 19, 2013
  - 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.

Thank you so much!

Contacts

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Together…Shaping the Future of Electricity