Potential Game Changing Cooling Technology Development for Power Plant Water Conservation

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Presentation for 15th IAHR International Cooling Tower and Air-Cooled Heat Exchanger Conference, Beijing, China

Oct. 25, 2011
Outline

- EPRI Overview
- Program Overview
- Technology Scanning Approach
- Proposal Stats and Selection Criteria
- Four Technologies to be Developed
- Summary and 2012 Funding Plan
EPRI is Member Funded & Non-Profit Organization.

- 38 year history
- 450+ funders in more than 40 countries
- About $370 m funding in 2011
- More than 90% of the electricity in the United States generated by EPRI members
- More than 15% of EPRI funding from international members
TI Water Conservation Program
Overview and Objective

• Initiated in early 2011
• Funded by EPRI Office of Technology Innovation
• Collaborated by all EPRI Sectors (Nuclear, Generation, and Environment)
• Broadly distributed Request for Information (RFI) to solicit top technologies for development in Feb., 2011

Objective

Seek and develop “out of the box”, game changing, early stage, and high risk cooling ideas and technologies with high potential for water conservation, performance, and financial improvements to members.
EPRI Technology Innovation (TI) Strategic Issues

- Smart Grid
- Energy Efficiency
- Long-Term Operations
- Renewable Resources and Integration
- Near Zero Emissions
- Water Conservation

Water Conservation Ranked Top Priority.
Received More Than 70 RFI Responses

<table>
<thead>
<tr>
<th>Organization Type</th>
<th>Number of Proposals</th>
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<tr>
<td>Universities</td>
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<td>National Labs</td>
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<td>Company</td>
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<tr>
<th>Technology Type</th>
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<td>Cooling/Thermal Technologies</td>
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<td>Green Chillers</td>
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<td>Thermal-Electric Cooling</td>
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<td>Scrubber Water</td>
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- Many respondents never worked with power industry.
- Second round of RFI will start early next year.
Selection Criteria for TI Funded Projects

• Innovation ("out of the box", game changer, cutting edge)
• Potential Impacts
  – Significant reduction of water (especially fresh water) consumption and/or withdrawals
  – Improved thermal efficiency
  – Economic potential in terms of water and energy consumption, cost, and space
  – Other
• Respondent’s capabilities and related experience
• Realism of the proposed plan and cost estimates

More than 35 proposals kept for funding considerations
Target All Types of Thermal Power Plants

- Coal
- Oil
- Natural Gas
- Combined Cycle
- Renewable
  - Solar Thermal (Many built in hot desert.)
  - Geothermal (Low steam temperature)
  - Bio-fuel
  - Others

- Most thermoelectric power plants use a lot fresh water.
- About 90% of thermoelectric power plant fresh water use is for cooling.

Drivers

- Majority of freshwater use (~90%) in plants for cooling
- Current water-conserving technologies, such as air-cooled condensers and hybrid cooling with significant capital outlays, lower efficiency, and operational and maintenance issues.

Water Use Reduction Opportunities Identified for Power Plants

Top Priority in 2011

Develop Water Conserving Cooling Technologies
Effect of Reducing Condensing Temperature on Steam Turbine Rankine Cycle Efficiency

Potential for 10% (1st Order Estimate) more power production or $37 m more annual income ($0.085/kWh) for a 500 MW power plant due to reduced steam condensing temperature from 50 °C to 10 °C.
Project 1 (EPRI Patent Pending): Development of Green Adsorption Chillers to Replace Cooling Towers and Water Cooled Steam Condensers by Allcomp

Key Potential Benefits

- **Evaporative cooling**
  - Significantly higher heat removal rate than convective water cooling
- **Closed loop cooling system**
  - Near Zero water use and consumption
- **Reduced condensation temperature**
  - As low as 10 °C
  - Potential for increased power production by 10%
- **Waste Heat Utilization**

Project Scope

- Explore best power plant system level approaches to utilize waste heat for desorption
- Perform system integration energy and mass flow balance analysis for a 500 MW coal-fired power plant
- Develop and build a 5 kW Green Adsorption Chiller Prototype
- Perform prototype testing
- Perform technical and economic feasibility study
Potential Project 2 for 2011 Start
Feasibility Study of Using Thermosyphon Coolers to Reduce Cooling Tower Water Consumption by Johnson Controls Inc.

As ambient conditions permit, the thermosyphon cooler pre-cools the condenser water leaving the steam surface condenser reducing the evaporative load on the cooling tower.

Thermosyphon Cooler

Project Scope

- Perform a thorough feasibility evaluation of a hybrid, wet/dry heat rejection system comprising recently developed, patent pending, thermosyphon coolers (TSC).
- Make comparisons in multiple climatic locations, to standard cooling tower systems, all dry systems using ACC’s, hybrid systems using parallel ACC’s, and air coolers replacing the thermosyphon coolers.
- Determine the most effective means to configure and apply the thermosyphon coolers.

Key Potential Benefits

- Potential for annual savings > 50% in cooling tower evaporation, make-up, chemical use, and blowdown.
- Full plant output is available on the hottest days when the demand for electricity is the greatest.
- Ease of retrofitting
  - Taps into existing condenser water cooling loop
  - Increased layout flexibility – just run water piping
  - Can be added incrementally in stages
- No increase in surface area exposed to primary steam.
- Broad application (hybrid, new, and existing cooling systems)

Water Usage Comparison for Seattle, WA
500 MW Plant with 600 TSCs

Yearly Average Water Usage
- 0.287 Mgal/kWh with TSCs
- 0.267 Mgal/kWh with TSCs
- 0.287 Mgal/kWh with TSCs

Cumulative Hours
- DB
- WB
- Water Usage w/ TSCs
- Water Usage w/ TSCs
Potential Project 3 for 2011 Start
Development of Advanced Cooling Tower Fill to Enable Cooling Near Dew Point Temperature Through Maisotsenko Cycle by Gas Technology Institute

Key Potential Benefits

- Potential for less cooling water consumption by 18%
- Colder water exiting cooling tower
  - 43 °C to 13 °C (slightly higher than DP)
  - Lower steam condensation temperature potential
  - More power production potential
- Ease of retrofitting
- Potential to further enhance hybrid systems

Project Scope

- Develop an advanced fill
- Perform CFD and other types of 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
Potential Project 4 for 2012 Start: Multi-functional Nanoparticles for Reducing Cooling Tower Evaporative Loss By Argonne National Lab

Project Scope

- Develop multi-functional nanoparticles with ceramic/metal 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

Key Potential Benefits

- Cooling Water Consumption:
  - 20% less evaporative loss potential
  - Less drift loss
  - 20% annual makeup water use reduction potential
- Nanoparticles
  - Enhanced thermo-physical properties of coolant
  - Heat of vaporization shown to increase by 20-25% with addition of ceramic nanoparticles
  - Reduced flow rates by 15% for same heat removal due to increased heat transfer coefficient & heat capacitance
  - Inexpensive
- Reduced pumping requirements & Ease of retrofitting
- Broad application (hybrid/new/existing cooling systems)
Summary and Future Plan

2011 Progress

• Initiated cooling technology development program to conserve water.
• Received more than 70 responses from Request for Information.
• Funded one project.
• Working on funding four more projects (One More on Thermoelectric Technology with Purdue Univ.).

2012 Plan

• Expand technology scouting activity.
• Start second round of Request for Information.
• Fund more technologies in cooling and other types of water conservation technologies.
• Explore co-funding opportunities with other funders.
• Publish three Phase I reports.
Thank You!

Any Questions?

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Together…Shaping the Future of Electricity
# Appendix Selected EPRI Research Reports on Water/Energy Sustainability

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<td>Air-Cooled Condenser Design, Specification, and Operation Guidelines</td>
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<td>Framework to Evaluate Water Demands and Availability for Electric Power Production Within Watersheds Across the U.S.: Development and Applications</td>
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<td>The Formation and Fate of Trihalomethanes in Power Plant Cooling Water Systems</td>
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<td>Comparison of Alternate Cooling Technologies for U.S. Power Plants: Economic, Environmental and other Tradeoffs</td>
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<td>Spray-Cooling Enhancement of Air-Cooled Condensers</td>
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<td>Use of Degraded Water Sources as Cooling Water in Power Plants</td>
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