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Developing Potential Game Changing Cooling Technologies for Reducing Power Plant Fresh Water Consumption

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2012 ASME Summer Heat Transfer Conference

San Juan, Puerto Rico

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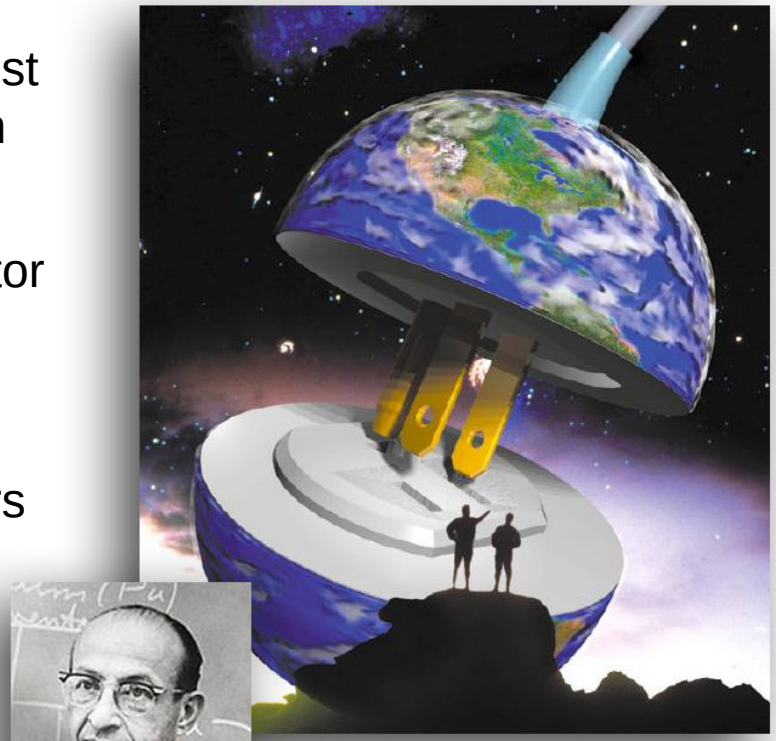
Outline

- Overview of EPRI Program
- Request for Information (RFI) (**Max $500k for a three year project**)
  - 2011 Response Summary
  - Proposal Selection Criteria for 2012 RFI
    - **Proposals Due by 5pm PDT on July 24**
    - Google key words: “EPRI Water RFI 2012”
  - **2013 Joint Solicitation with National Science Foundation (NSF) on cooling**
- Technologies under Development
- Next Steps

Recordings about our Webcasts can be found here (at the right bottom).

About EPRI

- Founded in 1972
- Independent, nonprofit center for public interest energy and environmental research (~$375 m funding in 2011)
- **Collaborative** resource for the electricity sector
  - 450+ funders in more than 40 countries
  - More than 90% of the electricity in the United States generated by EPRI members
  - More than 15% of EPRI funding from international members
- Major offices in Palo Alto, CA; Charlotte, NC; Knoxville, TN
  - Laboratories in Knoxville, Charlotte, and Lenox, MA



Chauncey Starr
EPRI Founder

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TI Water Conservation Program Overview and Objective

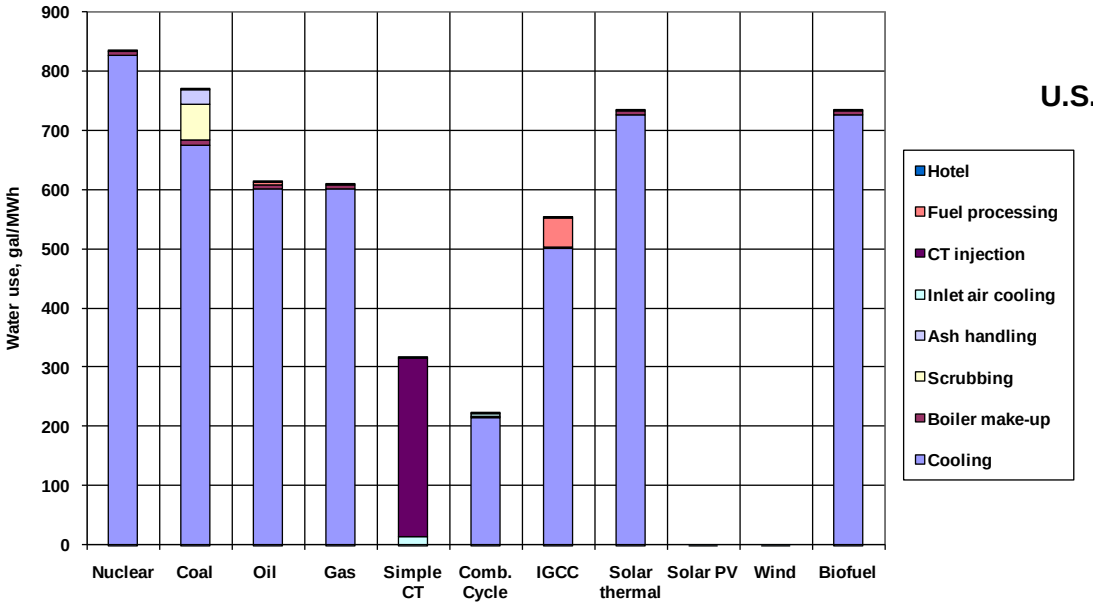
- Initiated in early 2011
- Funded by EPRI Office of Technology Innovation
- Collaborated by all EPRI Sectors (Environment, Nuclear, Generation, and Power Distribution Unit)
- Broadly distributed Request for Information (RFI) to solicit top technologies for development in Feb., 2011 and June 2012

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.

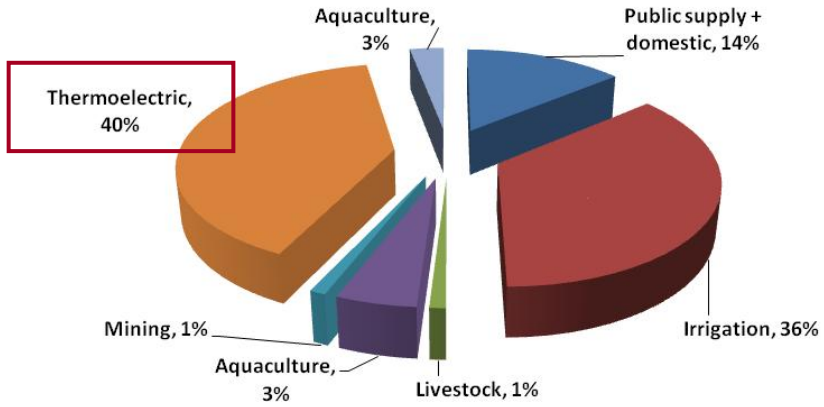
Industry Specific Needs: Fresh Water Consumption Reduction

- Thermal-electric power plants withdraw 40% and consume 3% of US fresh water.
- 90% of power plant water demand is for cooling.
- Water demand will continue in a "Low Carbon World"

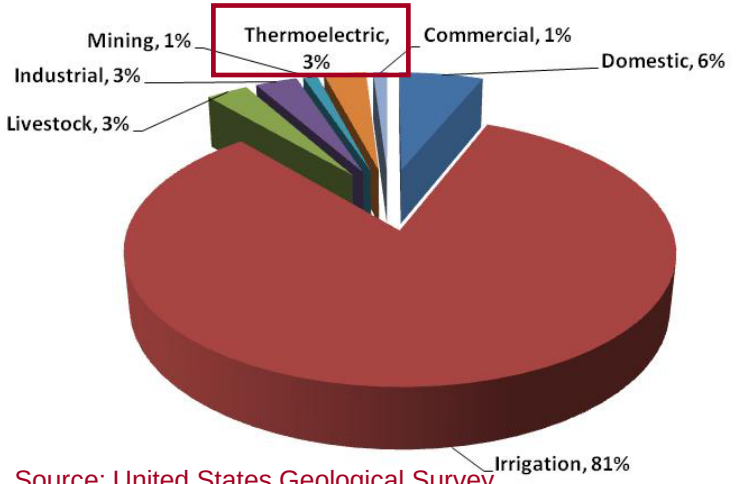


Source: EPRI Report , "Water Use for Electric Power generation", No. 1014026, 2008

U.S. Freshwater Withdrawal (2005)



U.S. Freshwater Consumption (1995)



Source: United States Geological Survey

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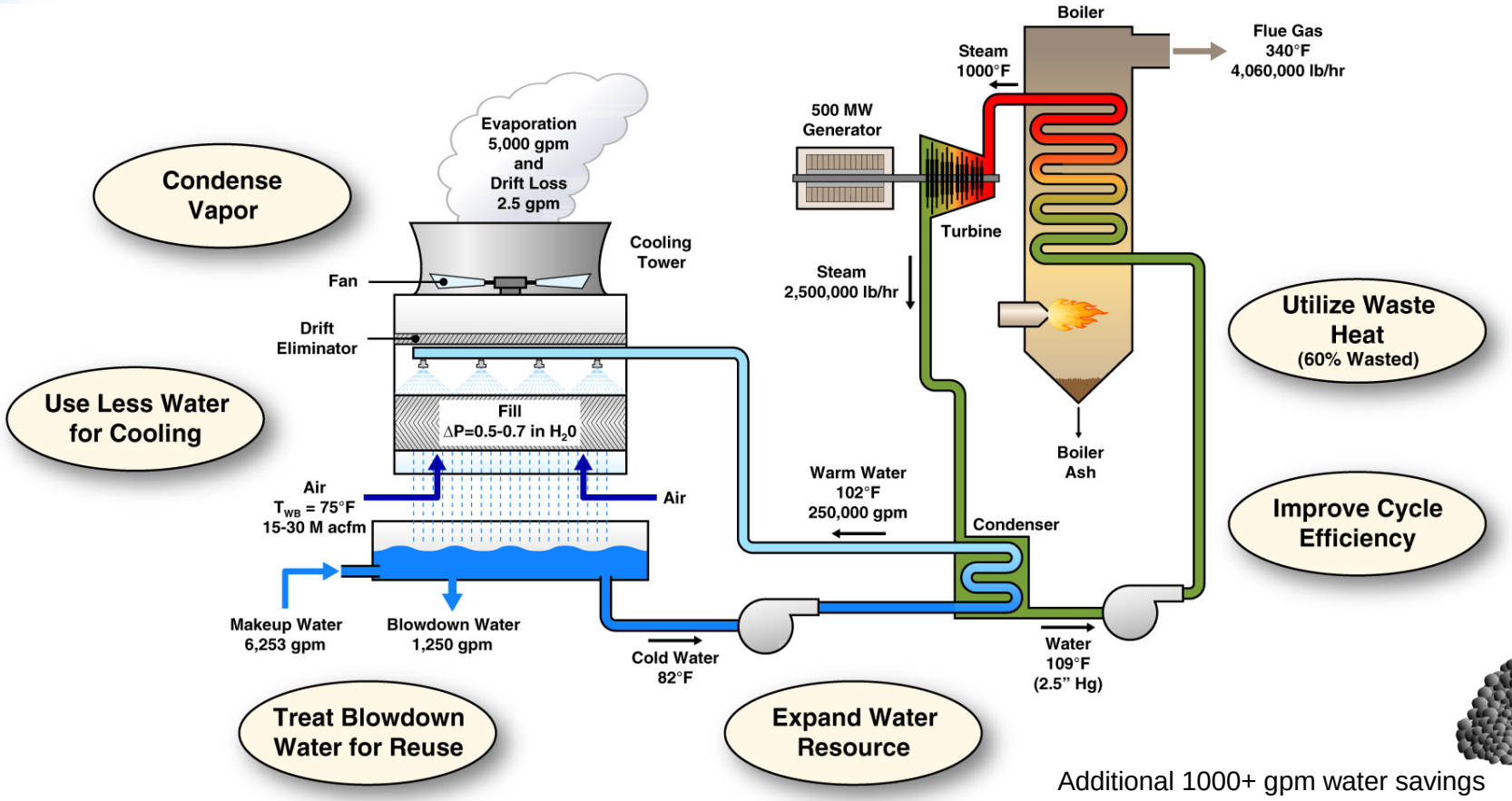
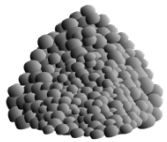
Opportunities for Power Plant Fresh Water Use Reduction





Additional 1000+ gpm water savings possible through fuel moisture recovery innovations

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

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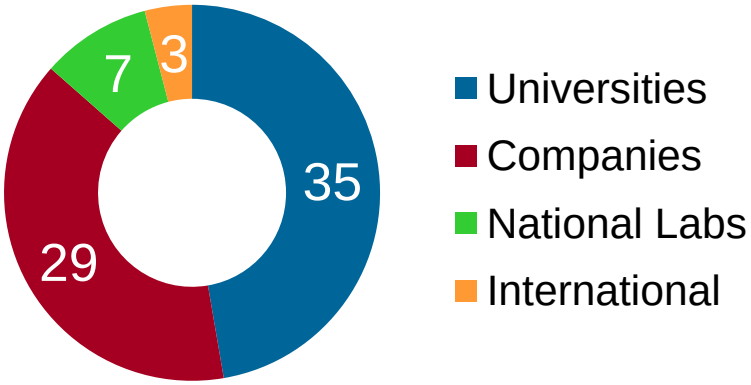
Received More Than 70 RFI Responses in 2011

Responding Organization Summary



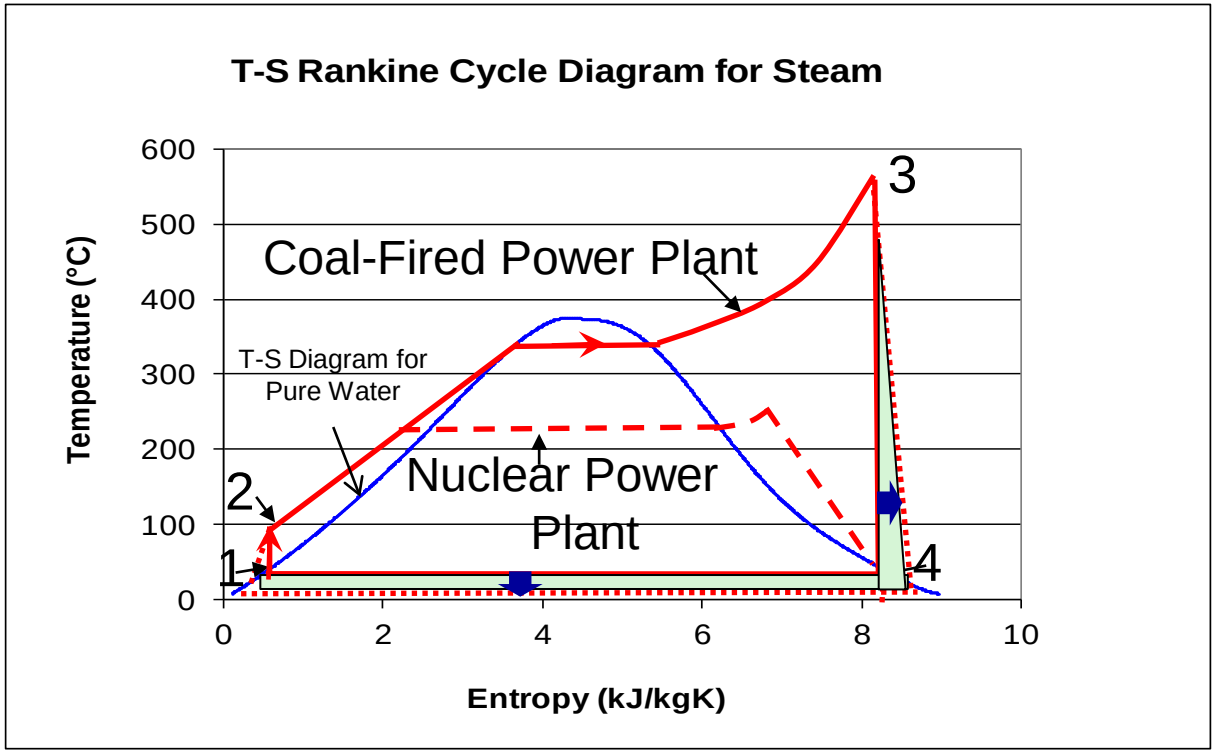
Technology Type	Number of Proposals
Cooling/Thermal Technologies	35
Green Chillers	4
Thermal-Electric Cooling	1
Evaluation	3
Water Treatment	19
Membrane	7
Scrubber Water	9

- **Five cooling proposals selected for funding.**
- **Success rate of 1 out of 7 for cooling proposals.**
- **Many respondents unfamiliar with power industry.**
- **More than 35 proposals kept for future considerations**

Selection Criteria for 2012 RFI

- Innovation ("out of the box", game changer, cutting edge)
- Potential Impacts
  - Significant reduction of water (especially fresh water) consumption and/or withdrawals across industry
  - 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

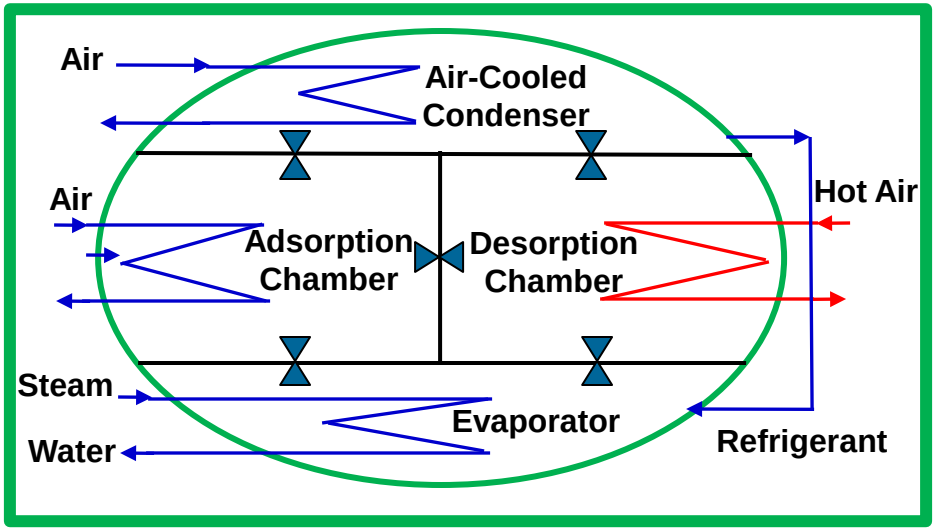
Effect of Reducing Condensing Temperature on Steam Turbine Rankine Cycle Efficiency



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.

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

Schematic Illustration of a Typical Adsorption Chiller



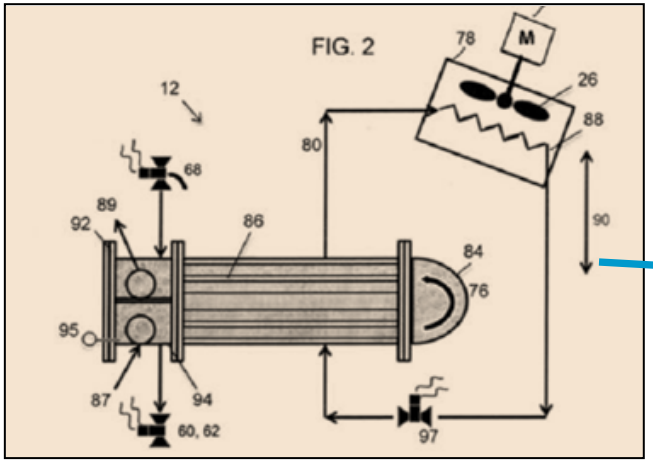
Key Potential Benefits

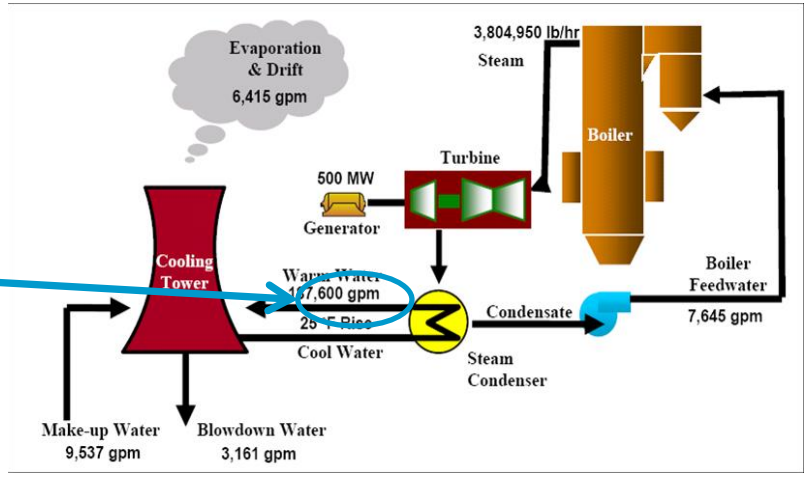
- Dry cooling system
  - **Near Zero** water use and consumption
- Reduced condensation temperature
  - As low as **35 ℃**
  - Potential for annual power production increase by up to 5%
- Full power production even on the hottest days compared to air cooled condensers.

Phase 1 Project Scope

- Explore best power plant system level approaches to utilize waste heat or solar heat for desorption
- Perform system integration energy and mass flow balance analysis for a 500 MW coal-fired power plant
- Perform technical and economic feasibility study(EPRI Patent Pending)

Project 2:Thermosyphon Cooler Technology (Collaboration with Johnson Controls)





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 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 (hybrid, new, and existing cooling systems)

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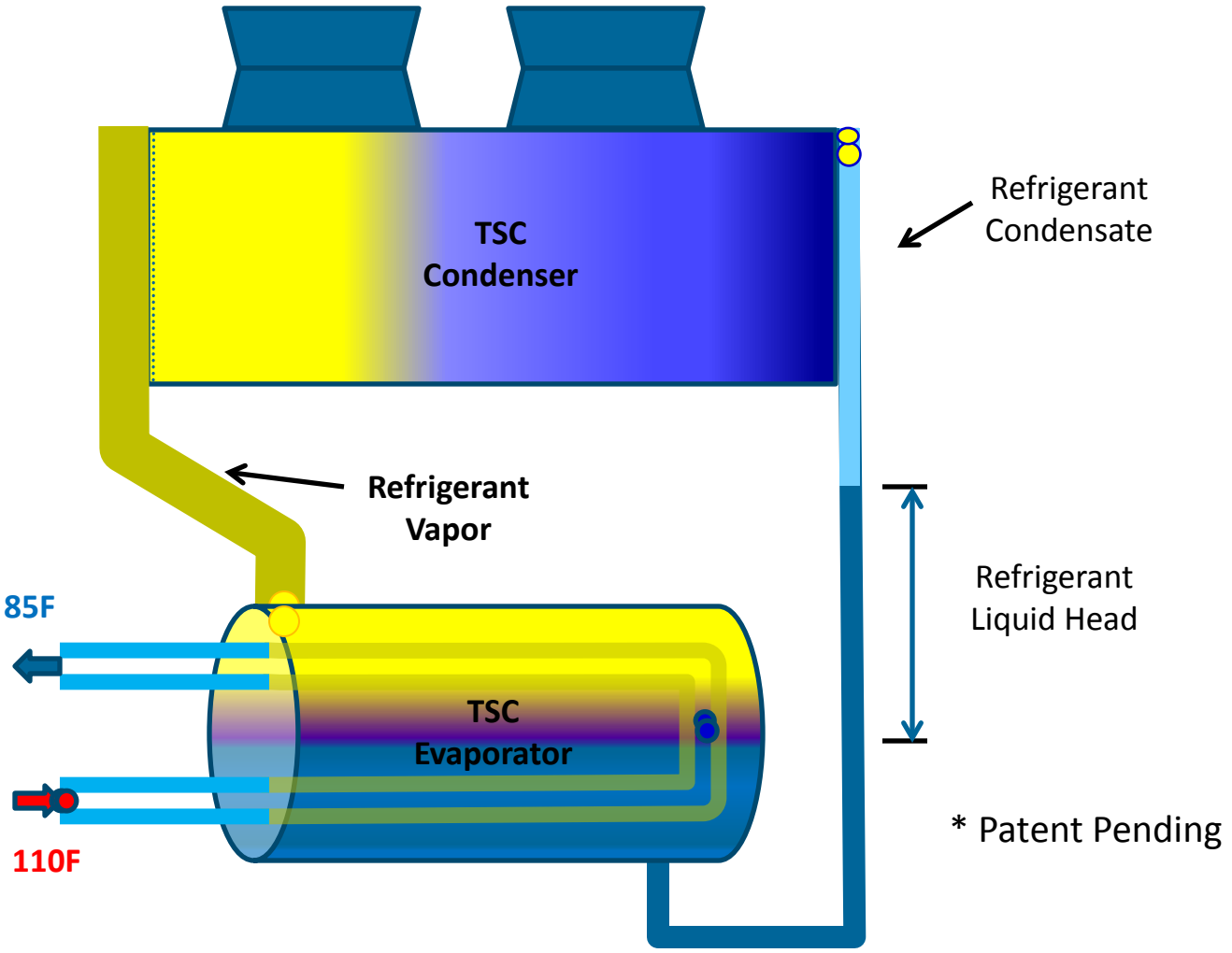
Animation: Thermosyphon Cooler

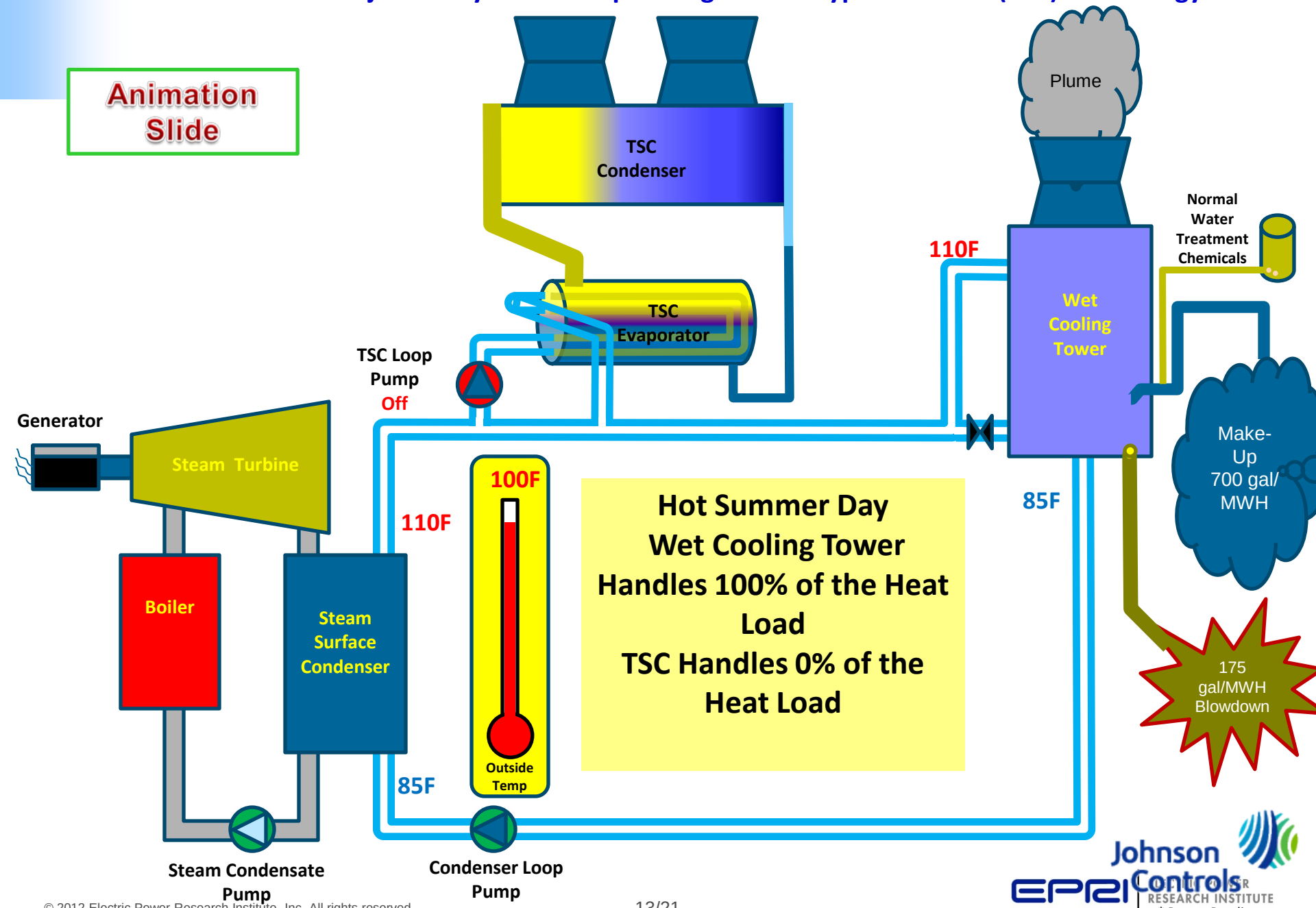
Animation Slide

Efficient, Reliable, and Cost Effective Dry Cooling

- **Evaporator Designed For:**
  - Low Waterside Pressure Drop
  - Waterside Cleanability
  - Freeze Protection
  - Optimized Water to Refrigerant Heat Transfer
- **Condenser Optimized for Refrigerant to Air Heat Transfer**
- **Natural Thermosyphon Refrigerant Circulation**
- **Controls Continuously Adjust Fan Speed to Provide Lowest Total Utility (Water + Electricity) Cost of Operation**



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



Johnson Controls

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* Patent Pending

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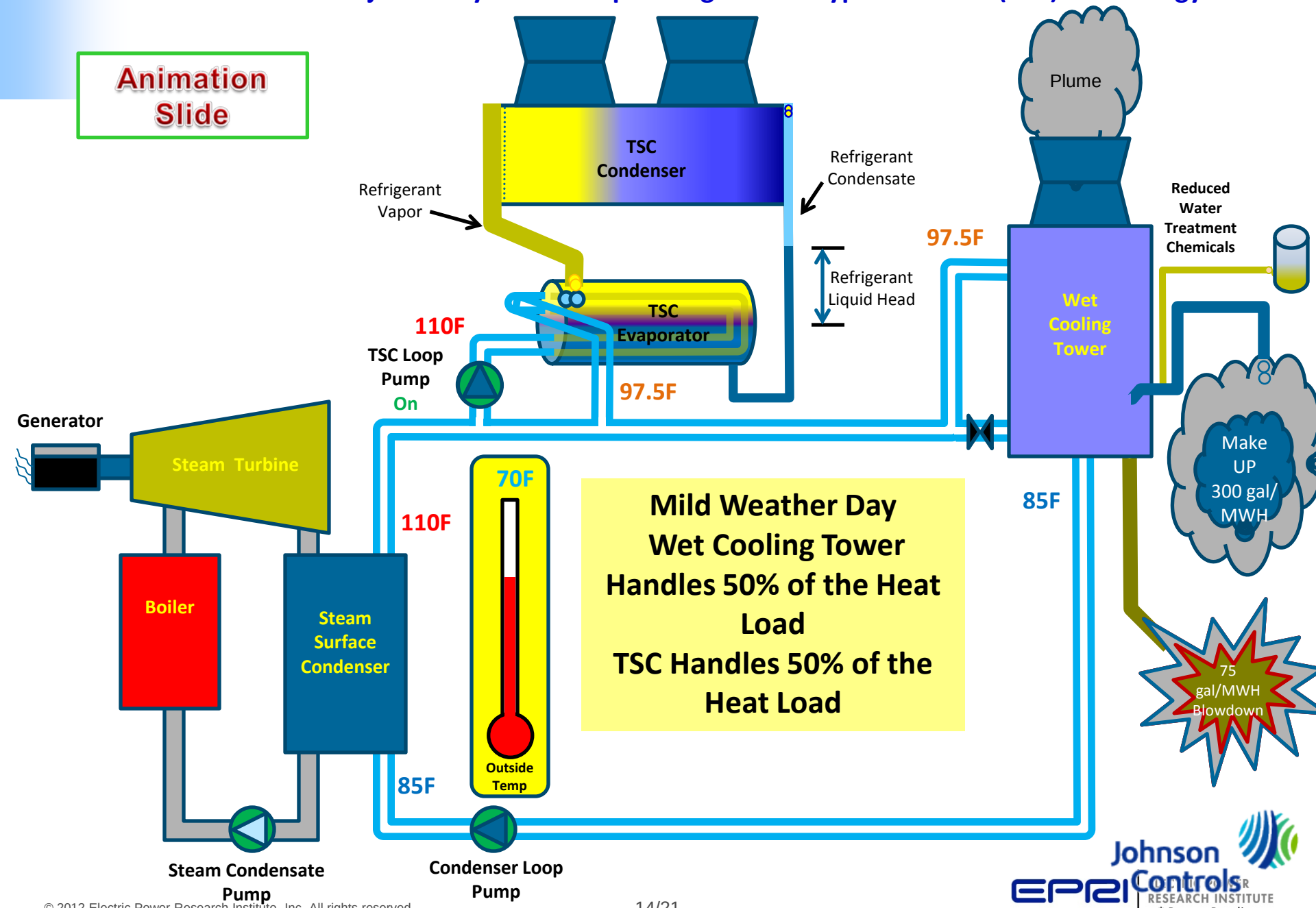

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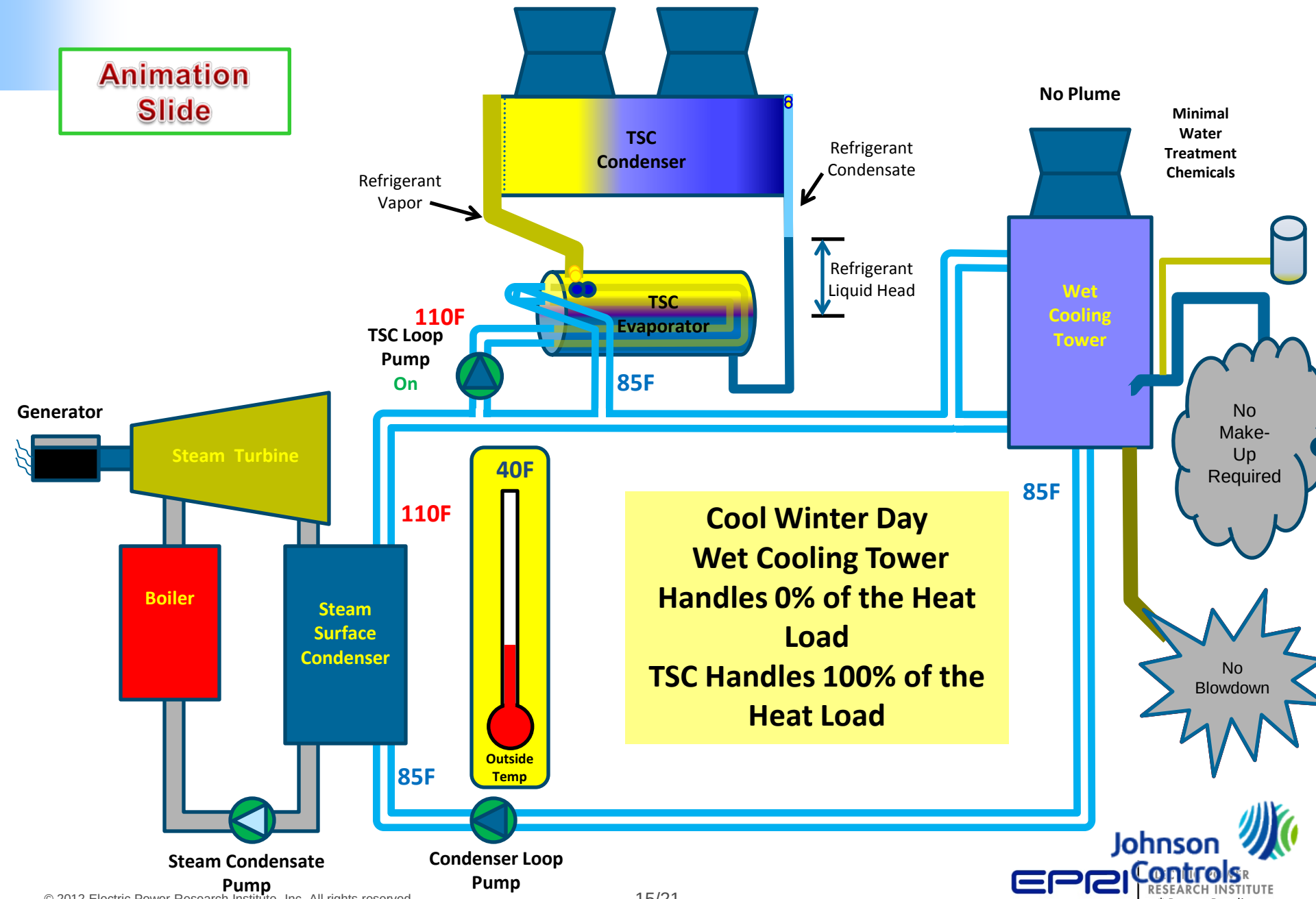
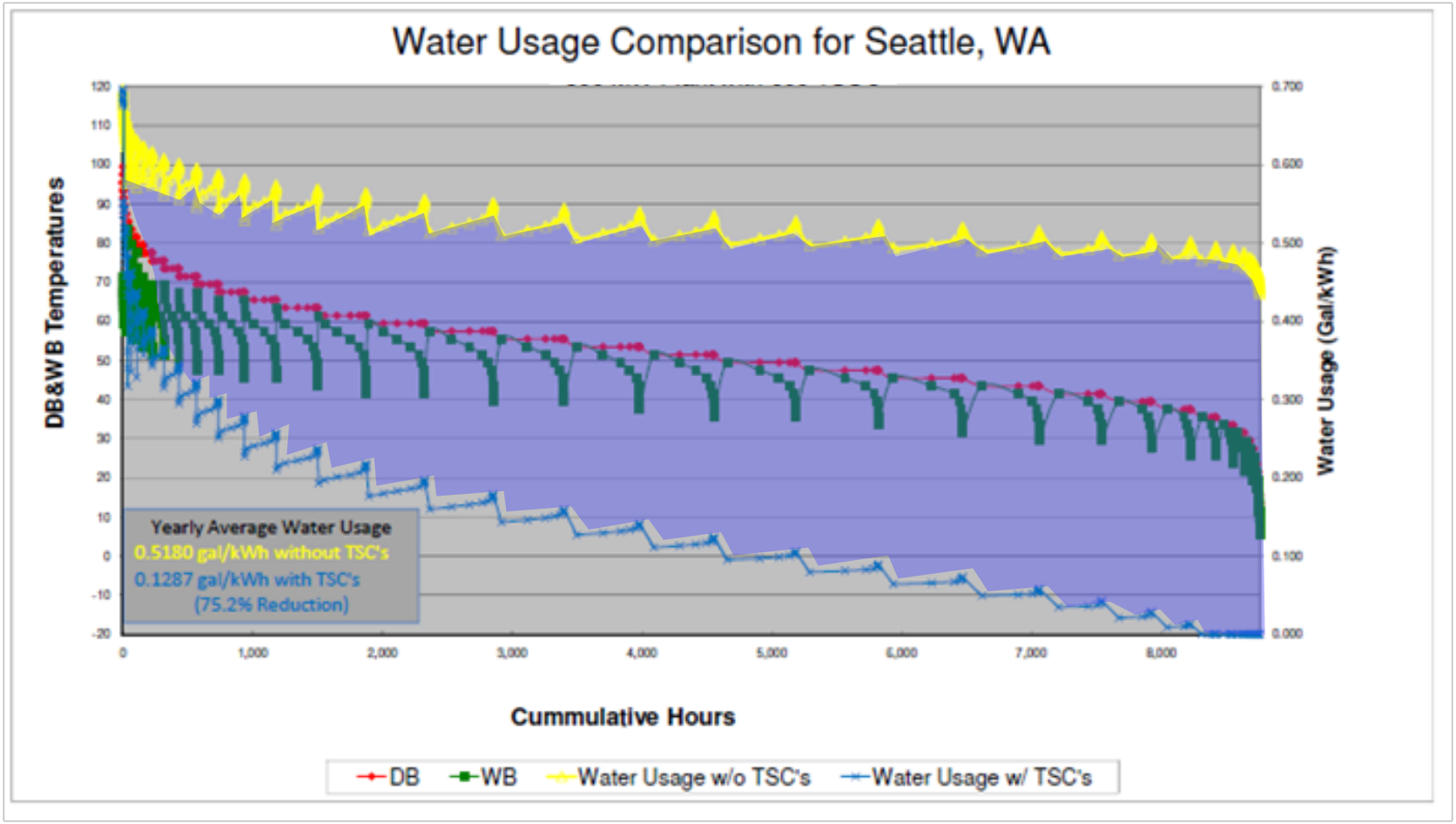


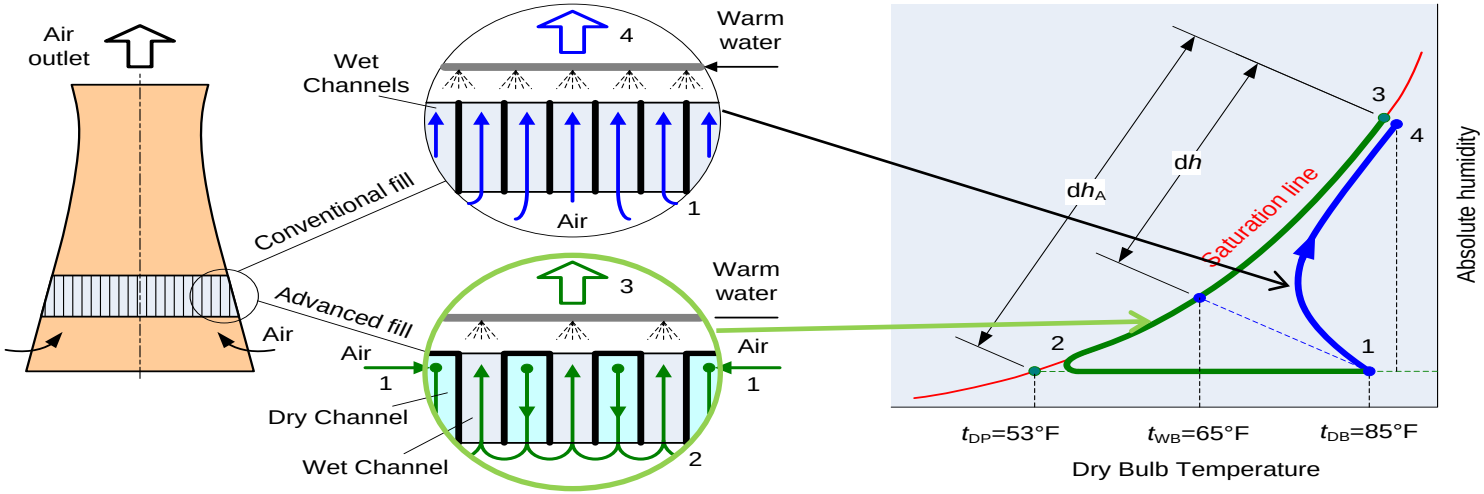
* Patent Pending

Sample 500 MW Power Plant Opportunity



Water Saving of Approximately 75% (3.4 Million Gallons / MW-Year (1.7 Billion Gallons/Year for a 500 MW Plant)

Project 3 : Advanced M-Cycle Dew Point Cooling Tower Fill (Collaboration with Gas Technology Institute)



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 lab 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
- Broad applications

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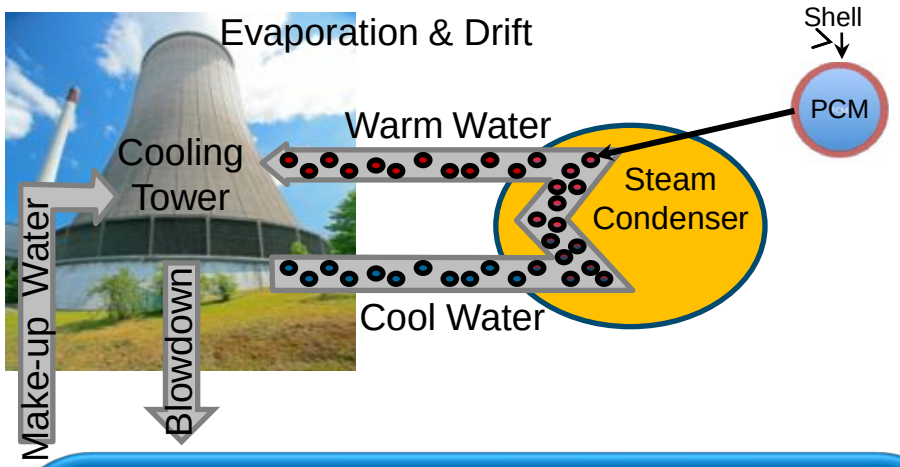
Breakthrough Project: Heat Absorption Nanoparticles in Coolant (Collaboration with Argonne National Laboratory)

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

Phase Change Material (PCM) Core/Metal 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)

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Upcoming EPRI Conferences

- EPRI Cooling Tower Conference
  - Aug. 8 to 9, 2012 at Hilton Pensacola Beach Gulf Front in FL
  - Contact: Jeff Stallings at jstallings@epri.com
- **EPRI/NSF Joint Workshop** on Advancing Power Plant Cooling Technologies for Water Conservation
  - Tentatively on Nov. 15, 2012 , open to attendees of 2012 ASME Congress Conference at Hilton Americas in Houston, TX,
  - Contact: Jessica Shi at jshi@epri.com
- EPRI Conference on Water Management Technology Innovations for Electric Power Generation
  - March 2013 in Georgia Tech Conference Center in Atlanta, GA
  - Contact: Richard Breckenridge at rbreckenridge@epri.com

EPRI Water Innovation Program: Summary and Future Plan

Progress Since 2011 Program Initialization

- Received more than 70 responses from Request for Information.
- Started four projects.

Status/Plan for 2012

- Lunched second round of Request for Information on June 12.
- Starting three more projects:
  - Thermoelectric Cooling and Waste Heat Recovery Technology (Purdue)
  - Near 100% Vapor Capturing Technology (UMD)
  - Emerging Heat Transfer Enhancement Technology Evaluation (UIUC)
- **Co-host Joint workshop and 2013 solicitation with National Science Foundation.**
- Start contracting processes with 2012 RFI proposals

Thank You!

Please feel free to contact us:

Jessica Shi at JShi@epri.com

General Questions: Vivian Li at VLi@epri.com

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