Crosscutting Research

Water Management Program Workshop

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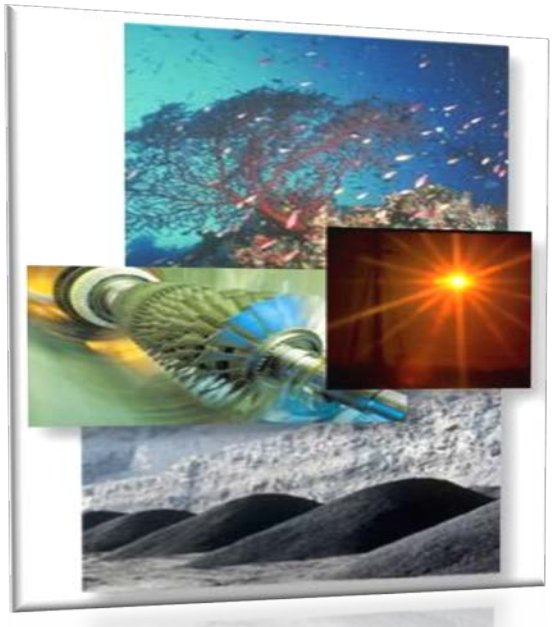
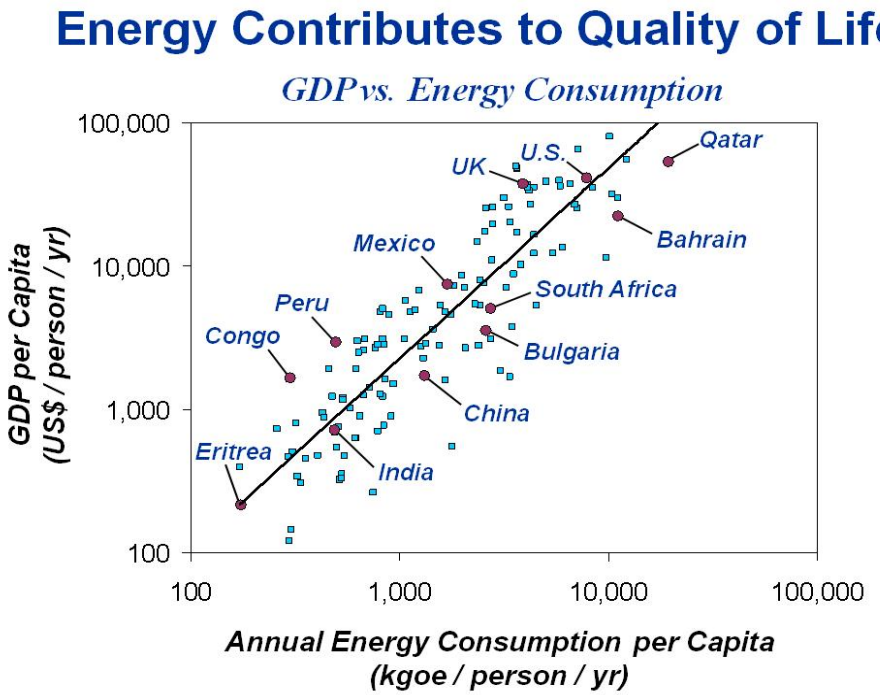
Solutions for Today | Options for Tomorrow

U.S. DEPARTMENT OF ENERGY

Point of Reference

- Competing demands for reliable, low-cost energy and climate change mitigation
- Uncertainty of regulatory outcomes and rising costs impact opportunities for capital investment, production capacity, and other factors in an integrated infrastructure





- Carry out research and development to foster new processes that address conflicting energy objectives
- Our laboratory's mission is to increase efficiency and mitigate CO_2 emissions in current plants and to develop novel carbon capture ready power generation processes

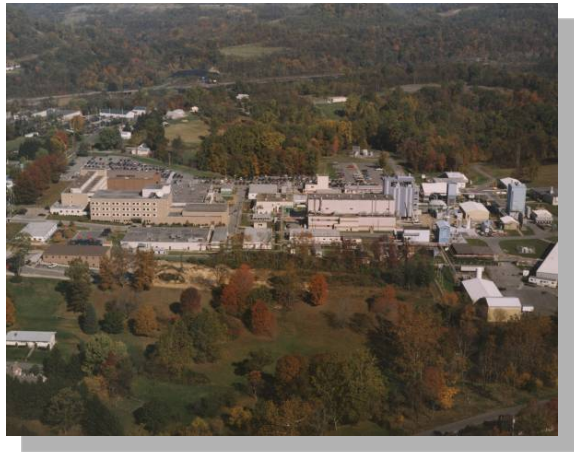
National Energy Technology Laboratory

Where Energy Challenges Converge and Energy Solutions Emerge

- Only government owned & operated DOE national lab
- Dedicated to energy RD&D, domestic energy resources
- Fundamental science through technology demonstration
- Unique industry–academia–government collaborations

Oregon

Pennsylvania

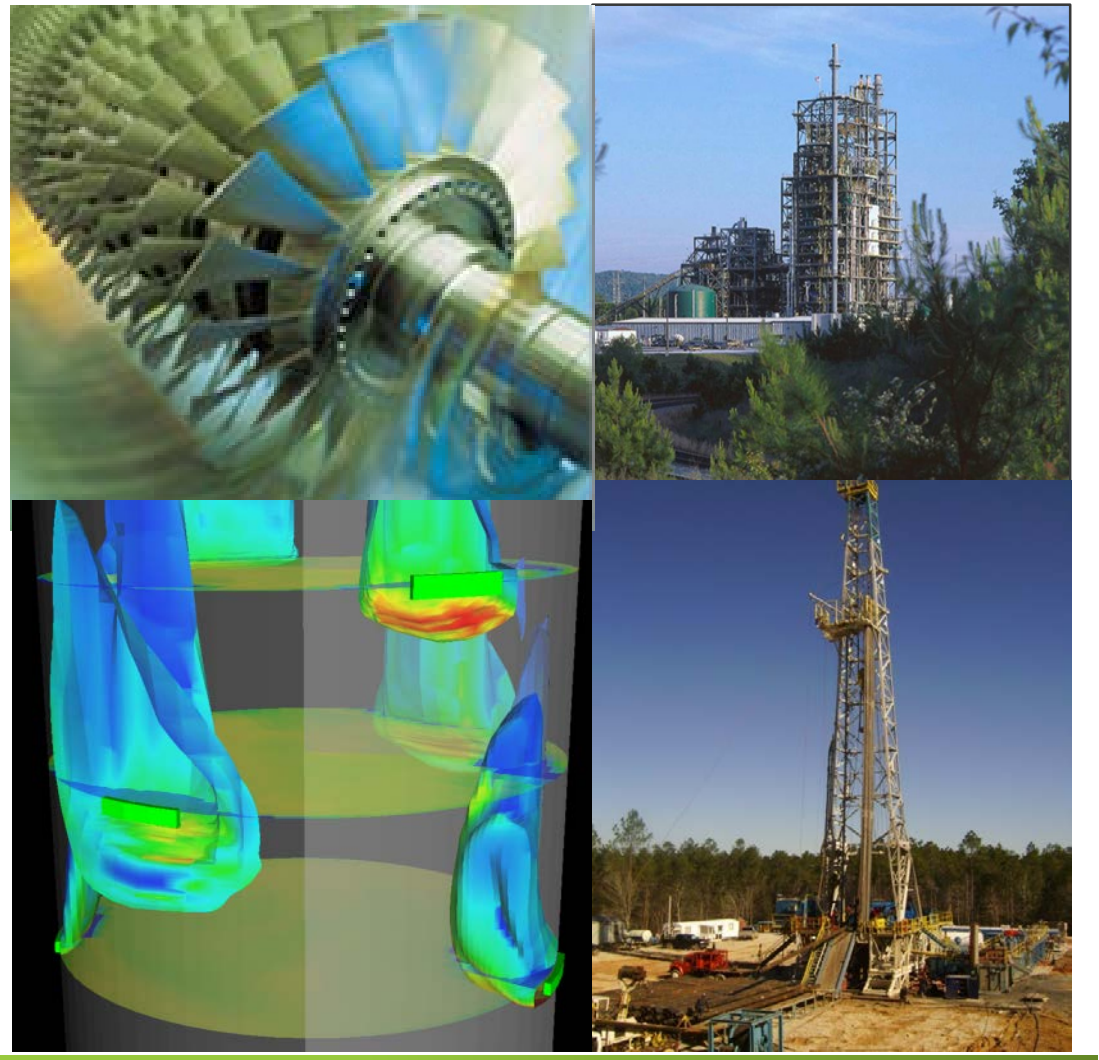


West Virginia

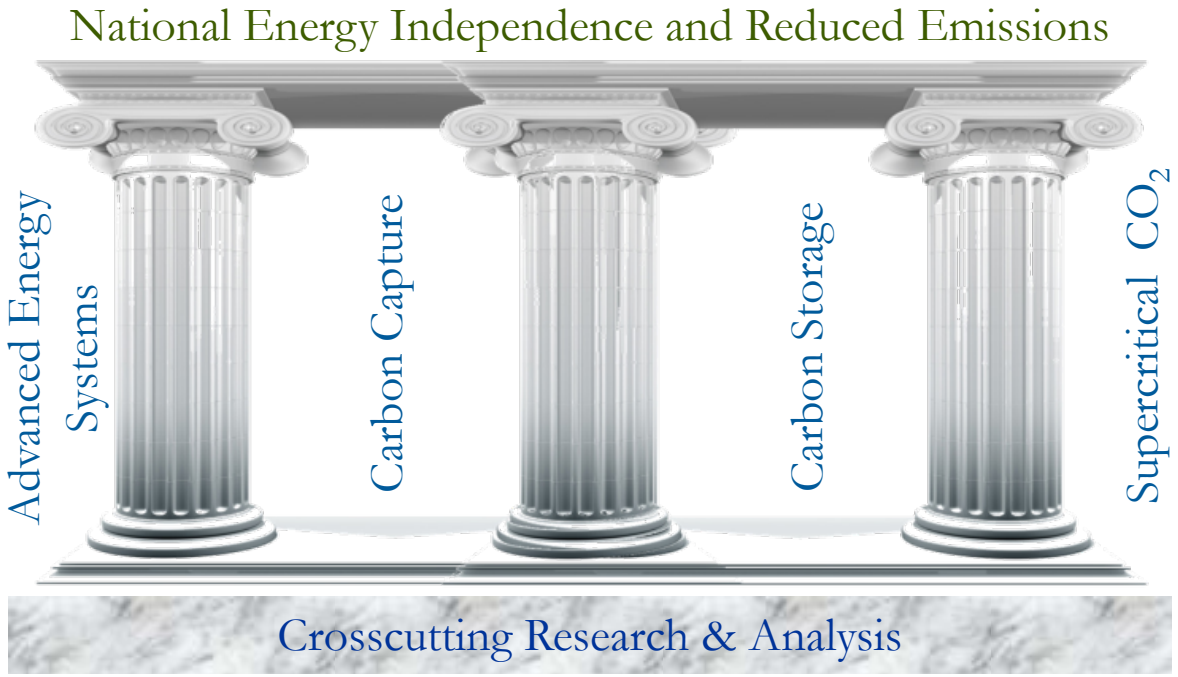
Fiscal Year 2016
NETL Office of Coal and Power R&D Core Programs

- **Carbon Capture**
- **Carbon Storage**
- **Advanced Energy Systems**
  - Advanced Combustion
  - Gasification Systems
  - Hydrogen Turbines
  - Fuel Cells
  - Fuels
  - **Crosscutting Research**
  - Systems Analysis and Planning

Working in synergy, these programs are developing technologies to increase power plant efficiency, lower electricity costs and mitigate GHG emissions in both existing and advanced power facilities



Crosscutting Research & Analysis
Targets Support Across Multiple Program Areas



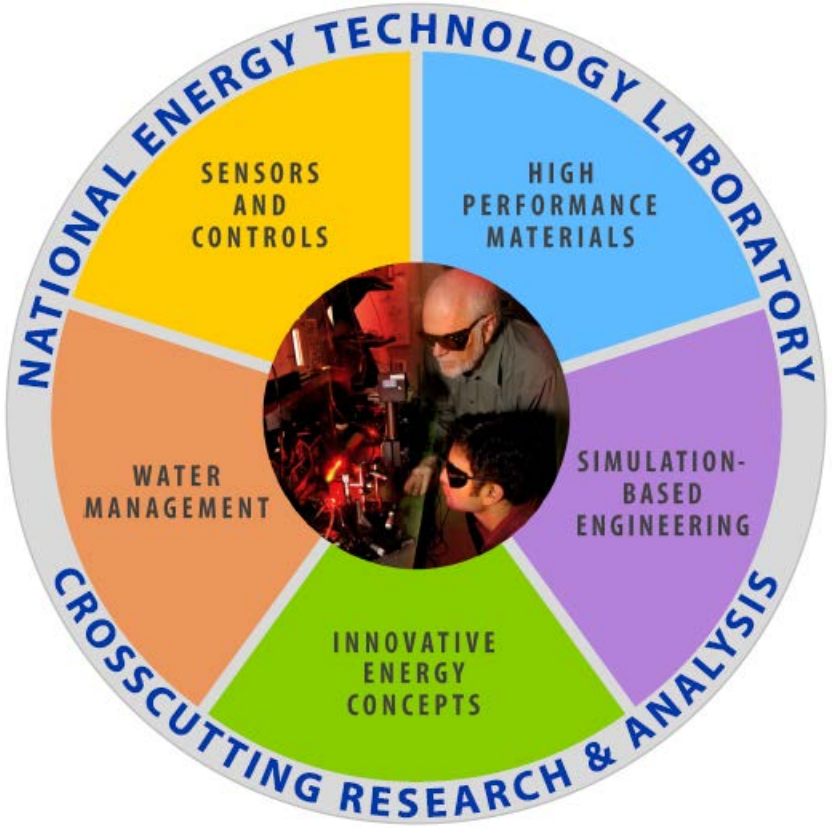
Key Technologies

- High Performance Materials
- Sensors & Controls
- Simulation-Based Engineering
- Water Management R&D
- Innovative Energy Concepts

Key Drivers

- Higher Efficiency
- Process Intensification
- Improve Design Tools
- Improve Process Control
- Lower Water Use

Crosscutting Research & Analysis



- **High Performance Materials**
  - Ultrasupercritical Boilers & Turbines
  - High-strength metallic & intermetallic alloys
  - Computational Material Modeling
- **Sensors and Controls**
  - Advanced Sensing
  - Distributed Intelligent Control
  - High Temperature & Harsh Environment Application
- **Simulation-based Engineering**
  - High fidelity models of advanced power systems
  - Advanced power system simulations
  - Carbon Capture Simulation Initiative
  - National Risk Assessment Partnership
- **Innovative Energy Concepts**
  - Direct Power Extraction
  - Thermoelectric Materials
  - Pulse Detonation/Pressure Wave Combustion

- **Water Management R&D**
  - Advanced / Novel Heat Transfer and Cooling Systems
  - Water Treatment and Reuse
  - Process Efficiency and Heat Utilization
  - Data, Modeling, and Analysis

Crosscutting Water Mission

Program Mission

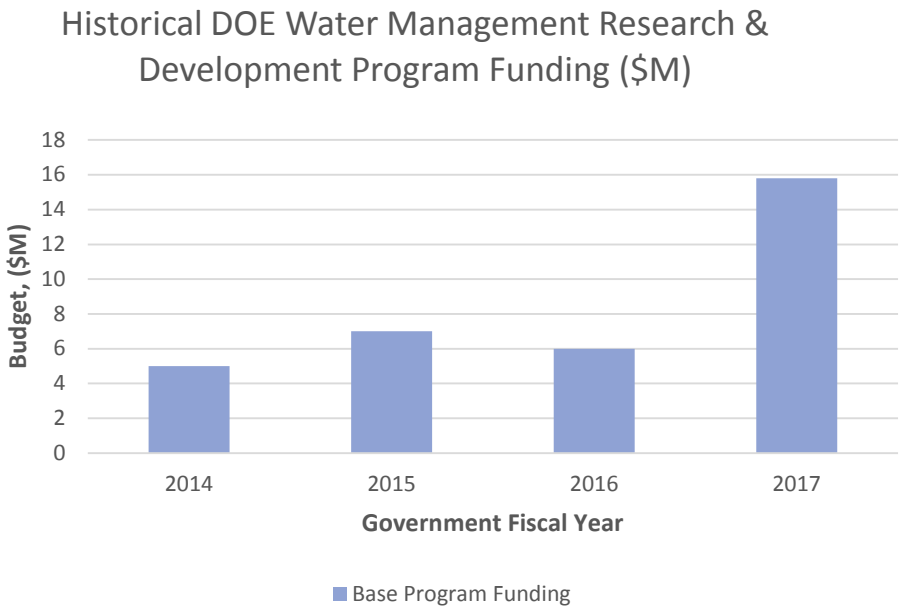
To lead a critical national effort directed at removing barriers to sustainable, efficient water and energy use, developing technology solutions, and enhancing understanding of the intimate relationship between energy and water resources.

Drivers/Stakeholders

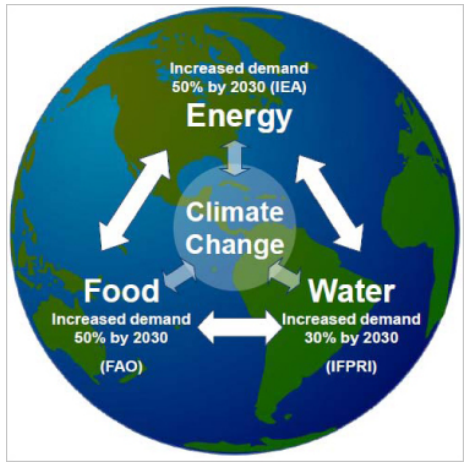
Driver:	Reduce the amount of freshwater used by power plants
Driver:	To minimize any potential impacts of power plant operations on water quality
Driver:	Clean brine extracted as part of CO_2 storage

BLUF

Water Management Research & Development (R&D) supports sustainability and improved water efficiency focusing on treatment and use of non-traditional waters, water-efficient cooling, and data modeling and analysis activities.

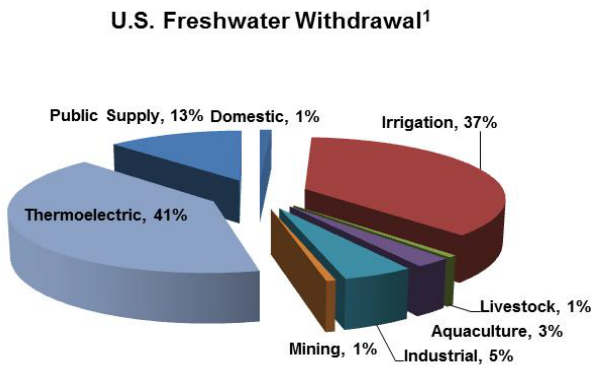


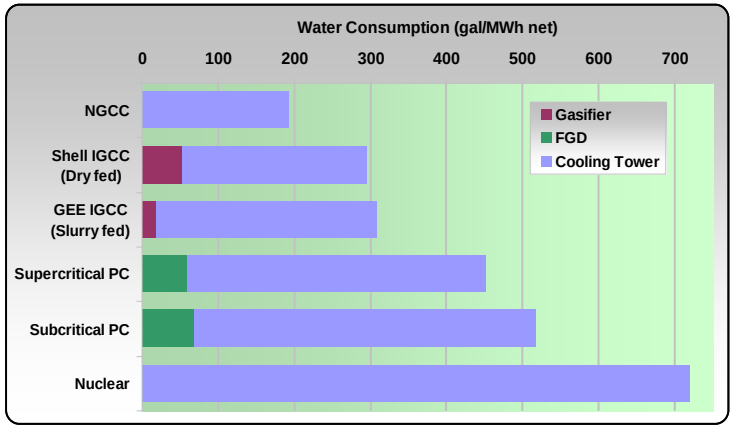
Energy Water Nexus: Water Management



- **Water Withdrawal vs Consumption**
  - Technologies that reduce or are alternatives to large volumes of freshwater withdrawal
- **Alternative Sources of Water**
  - Brackish, Brine and Salt water sources
- **Waste Heat Utilization**
  - Opportunities for large scale utilization of low grade or waste heat
- **Water Recovery and Treatment**

Thermoelectric water requirements: Withdrawal: ~ 143 BGD vs. Consumption: ~ 4 BGD





USGS 2005 data on water withdrawal vs consumption(2005)

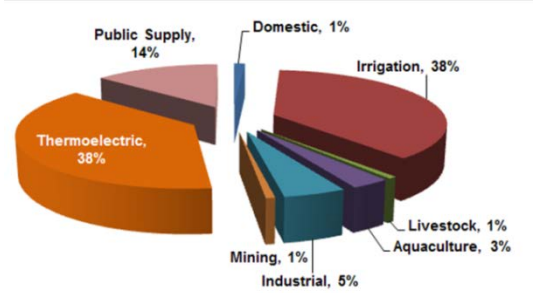
Why Water Management R&D?

Public Issue: Water Withdrawals and Consumptive Use
Thermo-electric Power Large User of Water, Relatively Small Consumer

New & Existing Power Plants Must Optimize Water Use

- Optimize the freshwater efficiency of energy production, electricity generation, and end use systems for Today's and Tomorrow's Power Plant Systems
- Optimize the energy efficiency of water management, treatment, distribution, and end use systems
- Enhance the reliability and resilience of energy and water systems
- Increase safe and productive use of nontraditional water sources (e.g., municipal wastewater treatment, extracted or produced waters, power plant effluent waste streams)
- Promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts
- Exploit productive synergies among water and energy systems

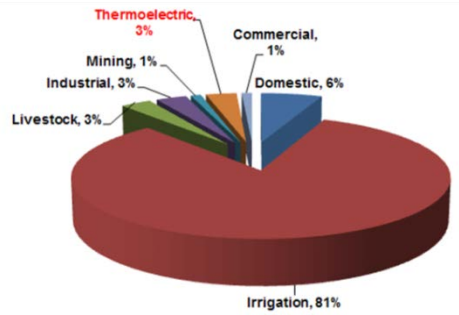
U.S. Freshwater Withdrawal[1]



2010 Thermoelectric Freshwater Requirements:
Withdrawal: ~ 117 BGD
Consumption: ~ 4 BGD

80% Increase in water consumption for CO_2 Capture & Storage

U.S. Freshwater Consumption[2]



Sources: [1]USGS, Estimated Use of Water in the United States in 2010, USGS Circular 1405, 2014
[2]USGS, Estimated Use of Water in the United States in 1995, USGS Circular 1200, 1998

Technical Overview

1. **What is the problem?**
   - Need to reduce water usage in power generation
   - Lack of cost effective water purification from fossil power generation and CO_2 storage processes

2. **What are the barriers to solve this problem?**
   - Cooling for power plants
   - Representative and improved water quality monitoring
   - Insufficient data to develop plans for water management on a regional and nationwide basis
   - Cost-effective water purification methods

3. **How will the barriers be overcome?**
   - Research advanced heat exchanger technologies that improve cooling system efficiency performance
   - Demonstrate technologies that purify water with high salinity total dissolved solids (TDS) content
   - Research sensor technologies that can be used to optimize water technology
   - Conduct research on technologies that produce value added by-products from solids removed from waste water
   - Integration studies for advanced technologies to improve efficiency and maximize freshwater savings
   - Gather and analyze data not captured elsewhere to characterize water-energy relationships (e.g. impaired waters)

4. **What is the capability being developed?**
   - Demonstration of multistage water purification methods for high TDS water sources
   - Demonstration of highly efficient heat exchangers for plant cooling

5. **What is the result/product of the effort?**
   - Lower cost water purity
   - Efficient Heat Exchangers for plant cooling
   - Value- added products from extracted waters

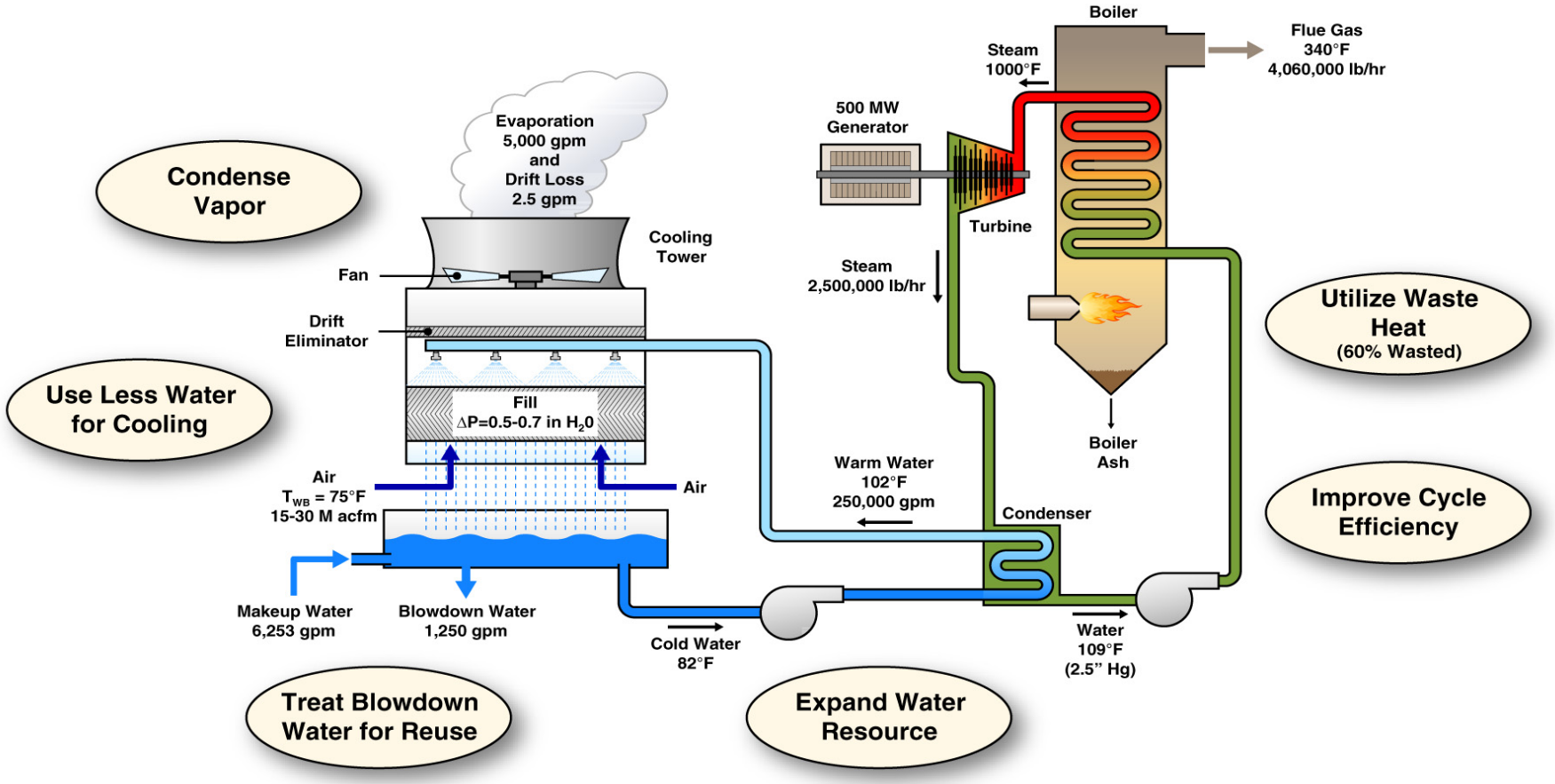
6. **What are the quantitative metrics?**

	Current	2020 Target	2025 Target
Brine Treatment % Fresh Recovery @ TDS	50% @ 35,000 ppm*	60% @ 60,000 ppm	70% @ 60,000 ppm 50% @ 180,000 ppm
Power plants using advanced technology scenarios would be able to maximize their freshwater savings.			

** Varies by treatment Type*

7. **How are other technology efforts being leveraged?**
   - Carbon Storage Program "BEST" FOA (providing test site and impaired water for water treatment field test);
   - Program discussions with Energy-Water Nexus Cross Cut

Water Research Opportunities



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

*Image courtesy of Dr. Jessica Shi of EPRI

Water Management Research Focus Areas

- **Advanced / Novel Heat Transfer and Cooling Systems**
  - Wet, Dry, Hybrid
  - Incremental & Step Change Improvements
  - Advanced Manufacturing of Recuperators for Combustion Turbines
- **Water Treatment and Reuse**
  - Economic Pathways for Zero Liquid Discharge
  - Treatment of high TDS Waters (promote greater Water Reuse – collaboration with Carbon Storage)
- **Process Efficiency and Heat Utilization:**
  - Pathways to produce more power per unit of water withdrawn, consumed, and treated
  - Utilization of Low-Grade Heat
  - Bottoming Cycles
- **Data Modeling and Analysis**
  - Tools to enable regional and plant level decision making
  - Develop a National Water for Energy Atlas
- **Breakthrough or Out of the Box**
  - Low / No water FE based Systems, Distributed Generation, Grid Upgrades

Leveraging Investment in NETL to Meet Program Goals

- **2nd Generation Goal**
  - Conduct field testing of brine treatment technologies that yield 60% fresh water (@ TDS 60,000 mg/L)
  - Develop lower cost (than existing technologies) that purify water with high TDS content
  - Power plants, using advanced technology scenarios, would be able to maximize their freshwater savings
- **2025 Transformational Goals**
  - Conduct field testing of brine treatment technologies that yield 70% fresh water (@ TDS 60,000 mg/L) and 50% freshwater (@ TDS 180,000 mg/L)
  - Validate and demonstrate advanced heat exchanger technologies that improve cooling system performance
  - Integration studies for advanced technologies to improve efficiency and reduce water requirements
- **Utilizing / Enhancing NETL Capabilities (By Key Technologies)**
  - Water Treatment
    - Complete development of water treatment membrane testing laboratory
    - Continue modeling and experimental work on Osmotically-Assisted Reverse Osmosis (OARO)
    - Conduct CO_2 storage brine extraction / purification testing
  - Plant Water Consumption
    - Evaluate feasibility and impact of including a ThermoSyphon (TS) cooling system on standard steam turbine condensation loops
    - Evaluate technology modifications required to utilize impaired water streams as electric plant process water.

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It's All About a Clean, Affordable, Energy Future

NATIONAL ENERGY TECHNOLOGY LABORATORY

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the ENERGY lab

Delivering Yesterday and Preparing for Tomorrow