Clean Energy Research Center - Water Energy Technologies

Water Use Reduction at Thermoelectric Plants

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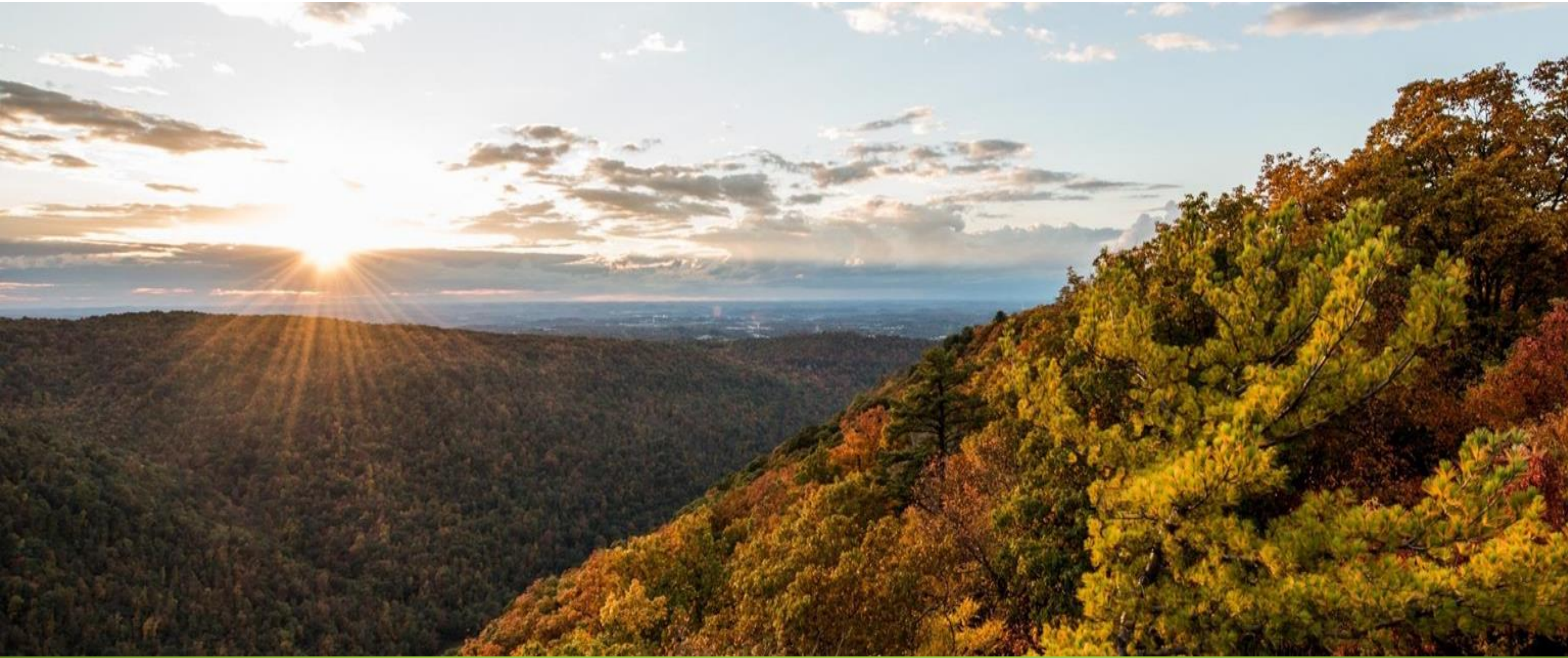

CERC-WET Project Area 1

Water Use Reduction at Thermoelectric plants

Outcomes

Our goal is to achieve breakthroughs to address electricity needs in regions with water scarcity.

Conventional approaches to reduce water consumption by thermoelectric plants cause significant reductions in plant efficiency and increase plant CO_2 emissions. We are pursuing breakthroughs in dry cooling, non-conventional power conversion technologies, dry carbon-capture methods, and reduced fuel consumption.

CERC-WET Project Area 1

Water Use Reduction at Thermoelectric plants

Projects:

1.1: Dry CO_2 Capture Based Upon Nanoscale Framework Materials
Jeffrey Long, UC Berkeley

1.2: Reheat Air-Brayton Combined Cycle (RACC) Development and Thermal Storage
Per Peterson, UC Berkeley

1.3: Integrated Gasification & Natural Gas Hybrid Fuel Cell Power Plants
Scott Samuelsen, UC Irvine

1.6: Nanostructured Surface Enhancement of Spray Cooling Water Vaporization
Van Carey, UC Berkeley

1.7: Management and Encapsulation of Solid- and Liquid- Waste Streams Generated by Thermoelectric Power Plants
Gaurav Sant, UCLA

CERC-WET Project Area 1

Water Use Reduction at Thermoelectric plants

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Key Industry and Research Partners

University of California, Berkeley	Duke Energy
University of California, Irvine	Boral Minerals
University of California, Los Angeles	Evapco
Southern California Edison	Guodian New Energy Technology Research Institute (GNETI)
Southern California Gas	Institute of Engineering Thermophysics, Chinese Academy of Sciences (IET-CAS)
Southern California Air Quality Management District	PetroChina Research Institute of Petroleum Exploration and Development (RIPED)
Electric Power Research Institute (EPRI)	

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CERC-WET Project Area 1

Water Use Reduction at Thermoelectric plants

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Challenges

1. Conventional approaches to reduce water consumption by thermoelectric plants cause significant reductions in the plant efficiency and increase the plant CO_2 emissions.

2. Water resources consumption in thermal power plants mainly includes system losses, flue gas losses, desulfurization wastewater, and cooling water.

3. Traditional methods have disadvantages of high energy consumption or pollution.

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CERC-WET Project 1.1

Dry CO_2 Capture Based Upon Nanoscale Framework Materials

Project 1.1 Objective:

- Using a new class of switch-like, amine-grafted adsorbents to dramatically improve the efficiency of CO_2 capture

Major Accomplishments:

- Down-selected most promising candidate materials
- Filed patent application for Gen-1 material; licensed by Mosaic Materials, Inc.
- Conducted SO_2 stability testing on Gen-1 material
- Established structure-property relationship governing humid SO_2 stability in this class of materials

Collaboration Partners:

- Guodian New Energy Technology Research Institute (GNETI)
- PetroChina Research Institute of Petroleum Exploration and Development (RIPED)

CERC-WET Project 1.1

Milestones

Task Name	Task Description	End Date
Milestone 1.1.7A	Report proposed strategies for hydrogen purification.	02/28/21
Milestone 1.1.8A	Report structure–activity relationship from SO_2 exposure tests.	12/31/19
Milestone 1.1.9A	Report adsorbent performance under Chinese flue gas.	05/29/21

CERC-WET Project 1.2

Reheat Air-Brayton Combined Cycle (RACC) Development and Thermal Storage

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Project 1. 2 Objective

- Evaluate RACC system performance with computer simulation and experiments, with specialized models for heat exchange, duct, and thermal storage systems
- Compare RACC to conventional power conversion systems on water consumption, GHG emissions, efficiency, reliability, flexibility, and profitability

Major 1.2 Accomplishments:

- Developed steady state and dynamic performance models for RACC
- Implemented performance model into control system for of the Compact Integral Effects Test (CIET) facility
- Designed and performed experiment to evaluate performance of tube to tubesheet joints for salt-to-air Coiled Tube Air Heater CTAH). Recent experiment demonstrated performance to 2% creep strain
- **Developed remote operation techniques for experiments to continue work during COVID**

Collaboration Partners: Guodian New Energy Technology Research Institute (GNETI)

- Institute of Engineering Thermophysics, Chinese Academy of Sciences (IET-CAS)

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CERC-WET Project 1.2

Milestones

Task Name	Task Description	End Date
Milestone 1.2.7.A	Report on results of remote operation.	6/30/2020
Milestone 1.2.8.A	Report results for subsystem modeling and experiments.	9/30/2020
Milestone 1.2.9.A	Complete and report results of system design options reassessment.	12/31/2020

CERC-WET Project 1.3

Integrated Gasification & Natural Gas Hybrid Fuel Cell Power Plants

Project 1.3 Objective:

- Integration of SOFC & GT hybrids
  - 10 to 100 MW dry cooled
  - Natural gas, coal & renewable bio fuels
  - With & without water recovery

- Advanced IGCC & IGFC
  - High efficiency
  - Reduced water use

Collaboration Partners:

Southern California Edison
Southern California Gas
South Coast Air Quality Management District

CERC-WET Project 1.3

Integrated Gasification & Natural Gas Hybrid Fuel Cell Power Plants

Major 1.3 Accomplishments:

Publications:

- **F. Rosner, Qin Chen, A. Rao, S. Samuelsen. Thermo-Economic Analyses of Isothermal Water Gas Shift Reactor Integrations into IGCC Power Plant. Applied Energy (2020).**

- **F. Rosner, A. Rao, S. Samuelsen. Water Gas Shift Reactor Modelling and New Dimensionless Number for Thermal Management/Design of Isothermal Reactors. Applied Thermal Engineering (2020).**

- **F. Rosner, A. Rao, S. Samuelsen. Economics of Cell Design and Thermal Management in Solid Oxide Fuel Cells under SOFC-GT Hybrid Operating Conditions. Energy Conversion and Management (2020).**

CERC-WET Project 1.3

Milestones

Task Name	Task Description	End Date
Milestone 1.3.8.A	Complete and report results of techno-economics analysis of large SOFC/GT systems.	09/30/20
Milestone 1.3.9.A	Issue report documenting assessment of development needs and trade-offs for all SOFC/GT systems developed.	09/30/20
Milestone 1.3.10.A	Issue final report documenting results of techno-economics analysis of all promising SOFC/GT systems developed and commercialization plan.	09/30/20

CERC-WET Project 1.6

Nanostructured Surface Enhancement of Spray Cooling Water Vaporization

Project 1.6 Objective:

- Develop nanoporous superhydrophilic coatings that can be used to strongly enhance heat transfer and reduce water in spray cooling for air-cooled condensers
  - Make evaporative heat rejection process substantially more energy efficient
  - Reduce the amount of water used for evaporative cooling

Major 1.6 Accomplishments:

- Development of optimized thermal growth processes for creating nanoporous superhydrophilic coatings on metals used in heat exchangers
- Modeling of droplet spreading and evaporation on nanoporous surface
- Experimental testing of prototype surfaces of different nanosurface morphologies
- Demonstrated durability of surfaces and sustained performance with moderate mineral deposition
- Fabrication and testing of prototype evaporative cooling system with nanoporous matrix (in progress)

Collaboration Partners:

- Evapco

CERC-WET Project 1.6

Milestones

Task Name	Task Description	End Date
Milestone 1.6.8.A	Establish a best manufacturing strategy for applying ZnO and/or other superhydorphilic coatings to aluminum fins on air-cooled power plant condensers, and summarize findings in a progress report.	12/31/19
Milestone 1.6.9.A	Define best nanoscale superhydrophilic ZnO coating, or other coating option, for spray cooling of power plant condensers, issue final project report, and publish papers presenting results.	05/29/20
Milestone 1.6.10.A	Issue commercialization plan for air-cooled power plant condensers with superhydrophilic air-side surface coatings.	09/29/20

CERC-WET Project 1.7

Management and Encapsulation of Solid- and Liquid-Waste Streams Generated by Thermoelectric Power Plants

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Project 1.7 Objective:

- Study methods to simultaneously stabilize (solidify) solid and liquid waste streams from coal combustion in order to:
  - Progress towards 'zero liquid discharge' for the power plant
  - Create more durable waste form than simply landfilling fly ash
  - Encapsulate contaminants within a permanent, durable engineered materials

Major 1.7 Accomplishments:

- Developed a thermodynamic (Gibbs free energy minimization) methodology for choosing additive selection based on a specified design criteria
- Design criteria considers the contaminant anion consumption, percentage of bound water, pH and cost of different additives. This provides an effective means to compare different additives for brine encapsulation.

Collaboration Partners:

- EPRI, Duke Energy, Boral Materials, Guodian New Energy Technology Research Institute (GNETI)

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CERC-WET Project 1.7 Milestones

Task Name	Task Description	End Date
Milestone 1.7.3.A	We have identified common electrolytes found in coal combustion wastewater and analyzed which additives are provide the maximum brine uptake.	04/10/2019
Milestone 1.7.4.A	Link Coarse porosity with leachability predictions and hydraulic conductivity to meet landfilling regulations. Or identify a means to relate brine volume reduction with regulatory methods.	05/31/2019
Milestone 1.7.6.A	Compare predictive costing analysis with on-site demonstrations of encapsulation of the brines	9/30/2021

Concluding Remarks

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CERC-WET is an ongoing 5-year project. We received a No-Cost Extension through September, 2021 and will continue to work toward successful conclusion of our projects.

Preparing Project for Next Steps

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Technology-to-Market Path

CERC-WET has an active Industry Advisory Board. Our latest meeting took place on October 26, 2020 in a virtual format. We have ongoing collaborations with Industry and non-profit partners as noted in each individual project above.