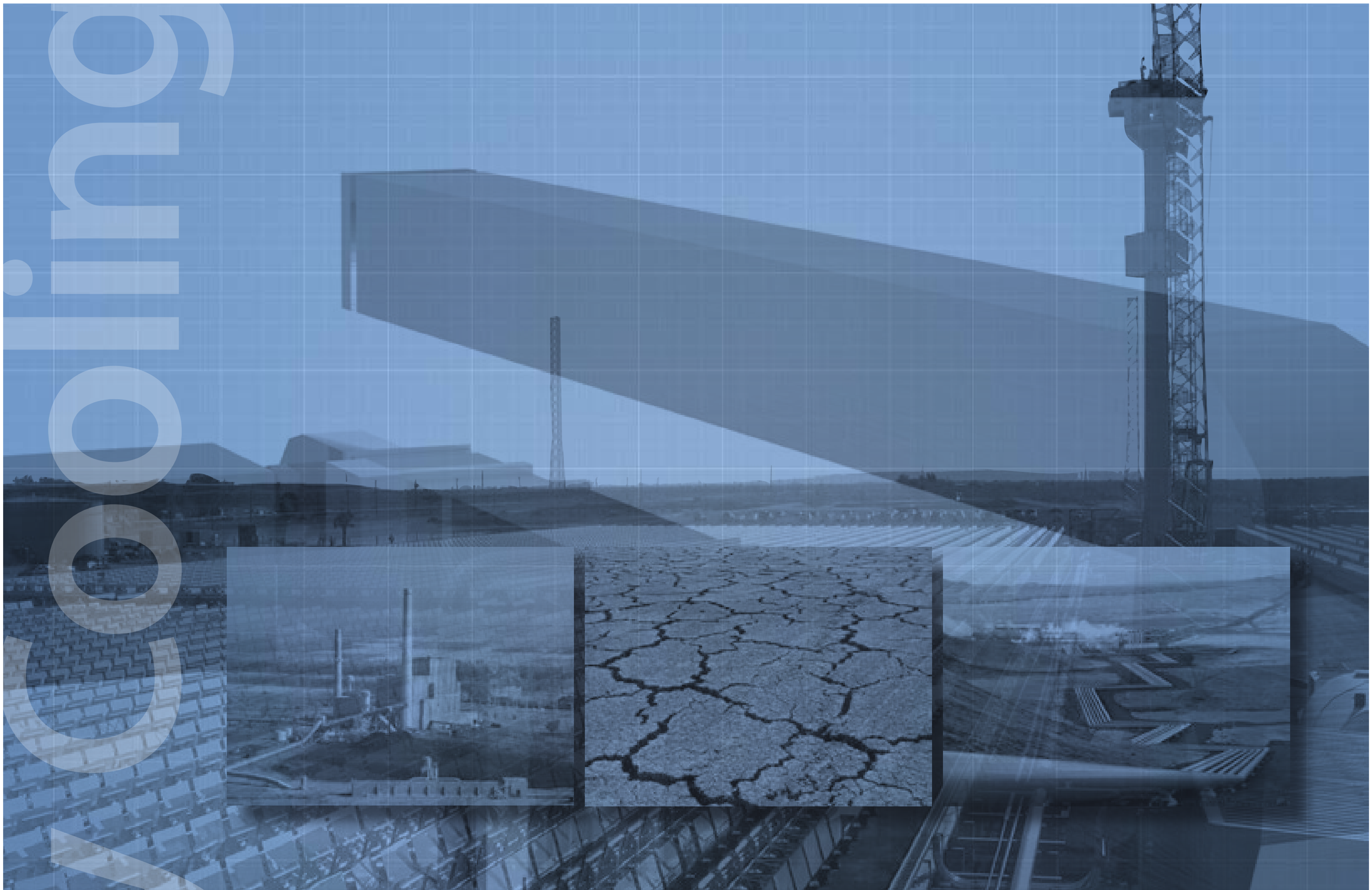


Dry Cooling
Technology

Conserve Tomorrow's Water Today

EERC FOUNDATION®

Eliminate the Need for Cooling Water

Thermoelectric power production accounts for 39% of freshwater withdrawals in the United States today. Of that, the largest use for water in the thermoelectric power industry is for cooling water to condense steam. Imagine a technology that would 1) eliminate the need for cooling water, 2) be less expensive, and 3) outperform other dry cooling technologies available today.

The Energy & Environmental Research Center (EERC) at the University of North Dakota (UND) is pursuing such a technology; partners have included the U.S. Department of Energy and the Wyoming Clean Coal Technologies Research Program. This novel dry cooling technology is applicable to all Rankine-based power plants and similar heat rejection loads.

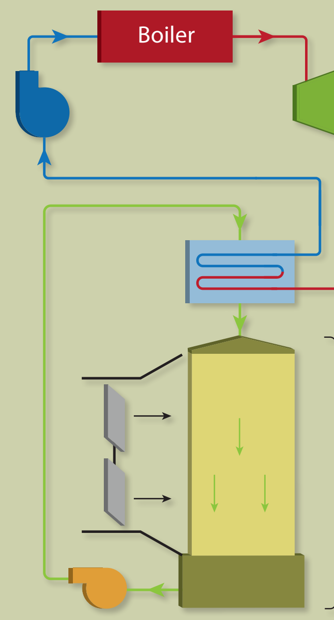
Commercial Opportunity

Cooling with heat dissipation to the atmosphere is a universal need for engineered systems that range from full-scale thermal power plants to residential air-conditioning condensers. Water-based cooling is an efficient design choice, but water availability frequently makes this option a contentious issue since cooling needs are often perceived to be in conflict with water sustainability. This tension creates a unique opportunity for an alternative dry cooling technology.

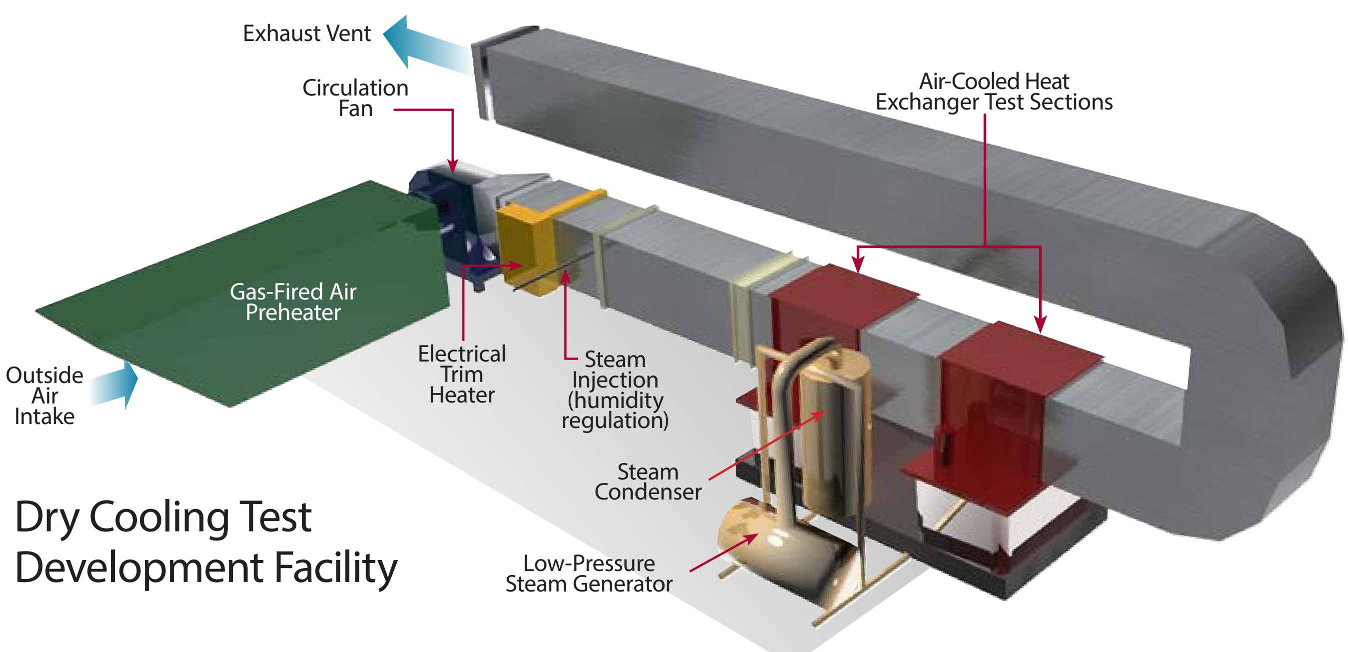
Unique Design Features

The EERC design has several unique features:

- Direct contact of the working fluid and air allows for large heat-transfer surfaces to be created from inexpensive, wetted packing structures.
- Combined heat and mass transfer occurs between the working fluid and the air, which improves heat-transfer efficiency. This makes it feasible to construct a heat rejection system with low ambient approach temperatures.
- Daily fluctuations in ambient temperature cause cyclic absorption and desorption of moisture in the working fluid. The cyclic periods of evaporation dampen daytime performance degradation that hinders conventional dry cooling systems.



System Operation. *A nonvolatile, hygroscopic working fluid is used for heat transfer to the atmosphere. Steam is condensed in a working fluid-cooled heat exchanger; the heated working fluid is then cooled through direct contact with ambient air. There is no net water consumption, and the initial charge of working fluid is expected to last for the life of the system.*



Dry Cooling Test Development Facility

The EERC has designed and built a pilot-scale test facility at its complex in Grand Forks, North Dakota. Procurement and fabrication began in late 2011. After pilot-scale evaluation, future developments will involve long-term testing at a power facility.

End-User Benefits

The EERC design provides several benefits:

- Can approach the performance of wet and hybrid cooling systems with no net water consumption.
- More cost-effective solution for large-scale heat rejection compared to current dry cooling options.
- A zero-liquid-discharge process with no blowdown. The initial charge of working fluid will last for the life of the system.
- No visible plume formation since sensible, rather than latent, heat transfer is the primary heat exchange mechanism.

Techno-economic analysis has shown that the technology will be most suitable for locations without adequate water, since the EERC technology offers improved cost vs. performance for a dry cooling system.

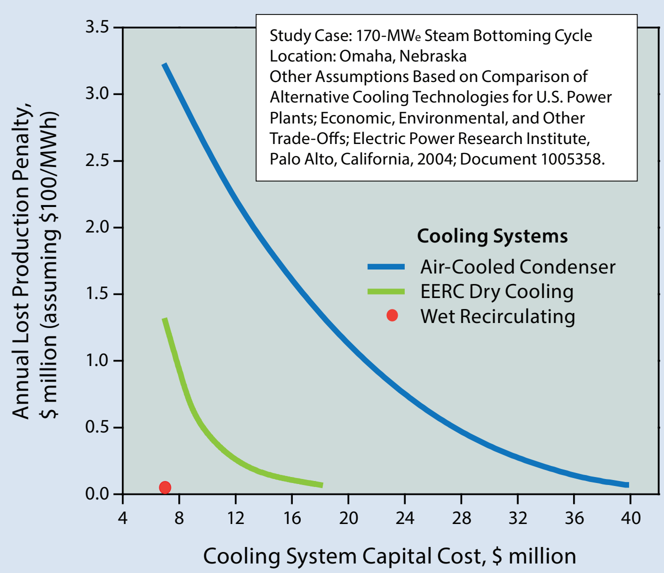
Techno-Economic Analysis

For areas with adequate water supplies, cooling performance is generally superior with conventional wet recirculating cooling. However, wet cooling has an ongoing water consumption charge that is not covered by capital cost estimates alone. The breakeven cost of water represents the ongoing water cost that would need to be applied to the wet system in order to offset the additional annualized cost associated with the dry cooling technologies, including lost power production. Estimates of breakeven costs are summarized in the table below for the cooling system of a natural gas combined-cycle plant. As the estimates show, the EERC cooling system offers a significant improvement over conventional air-cooling equipment, and depending on the local cost of water, it may offer a better long-term investment over wet cooling despite the associated potential lost production penalty.

Breakeven Water Cost Estimates for a Baseloaded Natural Gas Combined-Cycle Plant, 500 MW_e net

	Air Cooled Condenser, $/1000 gal	EERC Dry Cooling, $/1000 gal
Barstow, CA	$8.78	$3.87 to $2.92
Atlanta, GA	$6.86	$2.06 to $1.18
Gillette, WY	$7.09	$2.10 to $1.13
New Haven, CT	$5.03	$0.66 to $0.03

Estimated Cost and Performance Comparisons with Conventional Cooling Technologies



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Target Applications

- Economical, large-scale dry cooling for electric power production (2–1500 MWth).
- Heat rejection for niche power production such as renewables that would benefit from significant thermal storage (e.g., solar thermal) or that need low-temperature differentials (e.g., geothermal).
- Smaller-scale, modular systems for HVAC (heating, ventilation, and air-conditioning) and refrigeration systems (5–500 tons) that would benefit from a dry cooling option with low-temperature differentials, perhaps for LEED (Leadership in Energy and Environmental Design) certification.

Status

The EERC has completed an experimentally validated techno-economic evaluation of the technology and is seeking supporting partners to continue development and transition to a marketable technology.

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