Driving Innovation in Dry-Cooling at ARPA-E

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ARPA-E Mission

Catalyze the development of transformational, high-impact energy technologies

Reduce Energy-Related Emissions

Ensure the U.S. maintains a lead in the development and deployment of advanced technologies

Reduce Energy Imports

Improve Energy Efficiency
# Focused Program Portfolio

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*Note: The table includes various companies and technologies related to energy and transportation, focusing on innovations in 2010-2016.*
Energy as a Water Problem
Energy/Water as a U.S. Problem

- 41% of freshwater drawn in the U.S. is for thermoelectric power plant cooling
- 3% of cooling tower water load is evaporated and dissipated
- Approximately 2.1 billion fish, crabs, and shrimp killed per year due to power plant intake on once through cooling
- Warming trend and over-pumping of natural water bodies puts water cooling for thermoelectric power at risk

![Pie chart showing water use distribution]

- Total 483 Billion m³
- Thermoelectric 41%
- Irrigation 36%
- Domestic and public supply 14%
- Livestock and aquaculture 3%
- Industrial 5%
- Mining 1%
EPRI Study Suggests that Water Availability in 2030 puts >3 Quads Electricity Generation at Risk

3.29 of 13.5Q electricity generation at risk due to population growth alone

Notes/Assumptions
- Only considers existing production
- Water use per capita remain at 2005 levels
- Population growth ~1%/yr (US Census Bureau)
- Water supply/trends at 2005 levels, No climate change

How will climate change impact water availability?
ARPA-E contract with Northeastern University addresses issue
Between 4.5 and 9 Quads of power production could be at risk between 2030 and 2040

Aggregate wet cooled power production in counties at risk

Based only on water availability

(does not account for power at risk from rising water temperatures)
U.S. Power Plant Infrastructure is Heavily Reliant on Water Cooling

- Water Cooling
  - Cooling Tower (42% in US)
  - Once Through Cooling (43% in US)
  - Cooling Pond (14% in US)

- Dry Cooling
  - Direct Dry Cooling: Air Cooled Condenser (1% Usage in US)
  - Indirect Dry Cooling

- Hybrid Cooling

Increasing demand for dry cooling in water scarcity regions.

Conclusion: Continued Reliance on Water Cooling for Thermoelectric Power Plants is Risky

- Negative water recharge expected to grow significantly over next 15 years

- More stringent EPA regulations on water intake and thermal discharge will render once-through cooling obsolete

- Rising water temperatures adversely impact power production and efficiency
  - Potential for more frequent curtailment events
  - EPRI study: 3° C rise in condenser temperature results in 1% reduction in power production
The ARID Program Vision and Transformative Technology Solutions
Program Approach

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Approach:
- Combine expertise from thermal engineering and manufacturing community to realize new indirect dry-cooling concepts at low cost
- Drastically enhance air side heat transfer coefficient with minimal pressure drop increase
- Sorption cooling systems with COP >2
- Integration of cool storage systems to mitigate temperature excursions
- Radiative supplemental cooling
Program Technologies (14 total)

- Air-cooling heat exchangers (3 projects)
- Sorption & other supplemental cooling (4 projects)
- Radiative cooling and cool storage (3 projects)
- Flue gas H$_2$O recovery & cool storage (2 projects)
- Combined ACC & cool storage (2 projects)

Sample Indirect Dry-Cooling System that Satisfies ARID Program Objectives
ARID Project – University of Maryland

Novel Polymer Composite Heat Exchanger for Dry Cooling of Power Plants

Funding: $1.9 million
Tech Area: Air-cooled Heat Exchangers
Location: College Park, MD

Technology & Impact
• Polymer based composite heat exchanger manufactured via advanced additive manufacturing.
• Potential for very low-cost and high COP (>200)
• High air-side heat transfer coefficient enhancement
• Potential for on site additive manufacturing
ARID Project – Colorado State University

Ultra-efficient Turbo-Compression Cooling

Funding: $1.9 million
Tech Area: Supplemental Cooling
Location: Fort Collins, CO

Technology & Impact:
• Dry cooling driven by flue gas waste heat
• Optimal working fluids used in separate power and cooling cycles
• Highly efficient turbo-compressor enables transformational thermally activated cooling COP under realistic conditions.
• Heat exchanger technology developed for HVAC and large vehicle industries enables modularity and low system capital cost.
• MW-scale, domestically fueled power plants are made feasible in arid regions
ARID Project – Palo Alto Research Center

Metamaterials-Enhanced Passive Radiative Cooling Panels

Funding: $1 million
Tech Area: Radiative Cooling
Location: Palo Alto, CA

Technology & Impact

• Scalable and low-cost passive radiative cooling architecture, capable of “self-cooling” water temperatures 8°C below ambient temperatures

• Novel metamaterial surface consists of engineered nanostructures tailored to exhibit an emissivity close to unity, emitting heat in the atmospheric transparency window (8-13 µm)

• Key innovation is a simple photonic design that is scalable to a large-area roll-to-roll process that does not require expensive photolithographic patterning
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