CRADA with Palo Alto Research Center (PARC): Supporting Development and Analysis of a Liquid Desiccant Regeneration Technology

NREL
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Project Summary

Timeline:
Start date: 2021 March
Planned end date: 2023 March
Key Milestones
1. Modeling results and design selected of PARC dehumidification system; 10/30/2021
2. Experimental results on PARC prototype demonstrating required performance from NREL’s lab; 04/30/2022

Budget:
Total Project $ to Date:
• DOE: $505,000
• Cost Share: $58,000

Total Project $:
• DOE: $855,000 (expected)
• Cost Share: $100,000

Key Partners:
Palo Alto Research Center

Project Outcome:
NREL is supporting PARC in their development of a liquid desiccant dehumidifier using electrodialysis for regenerating the desiccant.

This support BTO’s MYPP outcomes of:
- Equipping researchers with validated solutions to develop and improve components at reduced cost
- Developing higher performing, efficient, cost-effective systems with less environmental impact
Team

NREL

Dr. Jason Woods (PI)  Dr. Allison Mahvi
Eric Kozubal  Dr. Nelson James

Liquid desiccant system modeling and design
Liquid desiccant system experiments
Packaged HVAC system experiments

Palo Alto Research Center

Aaron Meles  Dr. Rachel Ellman
Dr. Jessy Rivest  Dr. Frank Torres

Electrodialysis modeling and design
Electrodialysis & liquid desiccant system build
Electrodialysis system experiments
Challenge: Moisture removal is often as important as temperature control

Of the 360 tonnes of CO₂ from US air conditioning energy use¹, nearly half is due to removing water vapor from air.

The latent cooling load is on the same order of magnitude as sensible cooling

¹ https://www.epa.gov/rhc/renewable-space-cooling
There is a >10x potential for reducing energy used to remove water vapor from air.
Approach: Desiccants Can Efficiently Remove Moisture from Air

Moisture removal from condensation on cold surface

Moisture removal with concentrated liquid desiccant

Need to regenerate this desiccant after absorbing moisture
Approach: Evaporating Water from Desiccants Is Energy Intensive

Electrodialysis ion separation: Transport ions across a membrane rather than evaporate water. A fundamentally different approach to desiccant regeneration.
This technology is efficient, with a technical potential energy savings of 0.5 quads.

But it also:

- Improves comfort by enabling separate sensible and latent cooling
- Enables grid flexibility by storing air-drying potential in the concentrated desiccant (this is possible because the system uses electricity, not natural gas).

This project will move this technology closer to realizing this potential and closer to commercialization through prototype construction, scale-up, and third-party validation at NREL.
Progress

System modeling and design

• Baseline systems for comparison
  – Standard vapor-compression cycle
  – Vapor compression system with desiccant wheel
  – Vapor compression system with liquid desiccants

• Electrodialysis-based desiccant system

Laboratory experiments on electrodialysis-based dehumidifier (future work)

• Electrodialysis-based desiccant system
  – Breadboard prototype with a simulated vapor-compression cycle
  – Packaged prototype integrated into a vapor-compression cycle
NREL developed models to predict the moisture removal efficiency of existing technologies. These are the benchmarks for comparison.
NREL also developed models of PARC’s electro-dialysis dehumidification technology, to predict its performance and aid in system design.
Electrodialysis efficiency improves considerably if we avoid creating nearly-pure water. This also prevents losing ions down the drain over time.
Electrodialysis system (PARC RAD-AC) shows significant potential for improved humidity control.

Current expected performance is lower - multiple system designs are being modelled to analyze best fit for this electrodialysis system’s current capabilities.
Stakeholder Engagement

• Palo Alto Research Center – commercialization partner
  – Creator of efficient electrodialysis stacks for high-concentration brines
  – Inventor of Redox-Assisted Dehumidification Air Conditioning (RAD-AC)
  – Performed techno-economic analysis, predicting a 3-year payback*

* Note: This considers the performance of system capturing long-term expected efficiency.
Remaining Project Work

- Finalize design of alpha prototype for electrodialysis based dehumidifier
- Experiments at NREL:
  - April 2022: Prototype of electrodialysis regenerator and absorber, conditioning ~300 ft³/min of air, with inlet conditions set by real-time vapor-compression system model
  - July 2022: Longevity experiments on electrodialysis regenerator and absorber
  - December 2022: Complete HVAC system experiments with realistic and dynamic conditions, with inputs based on real-time building model
Thank You

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REFERENCE SLIDES
Project Budget: NREL received $505,000 in FY21 for this project. The DOE budget for the agreed-upon scope of work is $855,000. PARC agreed to $100,000 in cost share, with $58,000 coming in FY21.

Variances: As described on the next slide, the original plan was to perform experiments in FY21. However, this was delayed because the prototype from PARC was not ready. This affected the spend rate in FY21.

Cost to Date: $68,500

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<tr>
<th>Budget History</th>
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<td>FY 2020 (past)</td>
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<td>FY 2021 (current)</td>
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<td>FY 2022 (planned)</td>
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<td>Start date: March 2021</td>
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<td>End date: March 2023</td>
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<td>DOE Cost-share DOE Cost-share DOE Cost-share</td>
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<td>$0 $505,000 $350,000 $0 $58,000 $42,000</td>
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Project Plan and Schedule

Notes:
- Original plan for experiments was in FY21 (now April 2022), and was changed due to a delay in PARC’s prototype design/development. This change was approved by BTO.

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<th>Completed milestones</th>
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<th>Future milestones</th>
<th>FY21</th>
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<td>FY21Q4</td>
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<tr>
<td>Summary report on modeling performed in FY21 for different electrodialysis + liquid desiccant based HVAC systems</td>
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<td>FY22Q1</td>
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<td>Modeling results and design selected of PARC dehumidification system based on their prototype (Oct 2021)</td>
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<td>FY22Q2</td>
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<td>Commissioning of PARC prototype in NREL’s HVAC laboratory</td>
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<td>FY22Q3</td>
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<td>Experimental results on PARC prototype demonstrating required performance in NREL’s lab</td>
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<td>FY22Q4</td>
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<td>Draft report or journal article on experimental performance of PARC electrodialysis technology</td>
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<td>FY23Q1</td>
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<td>Experimental results on packaged HVAC prototype, including hardware-in-the-loop experiments</td>
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