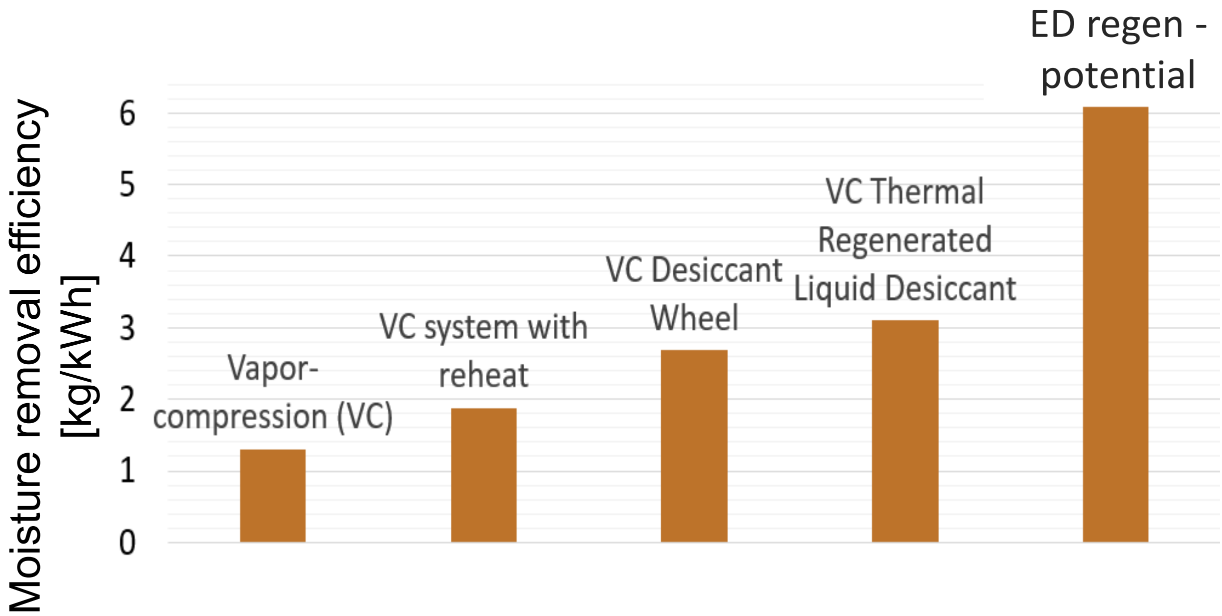
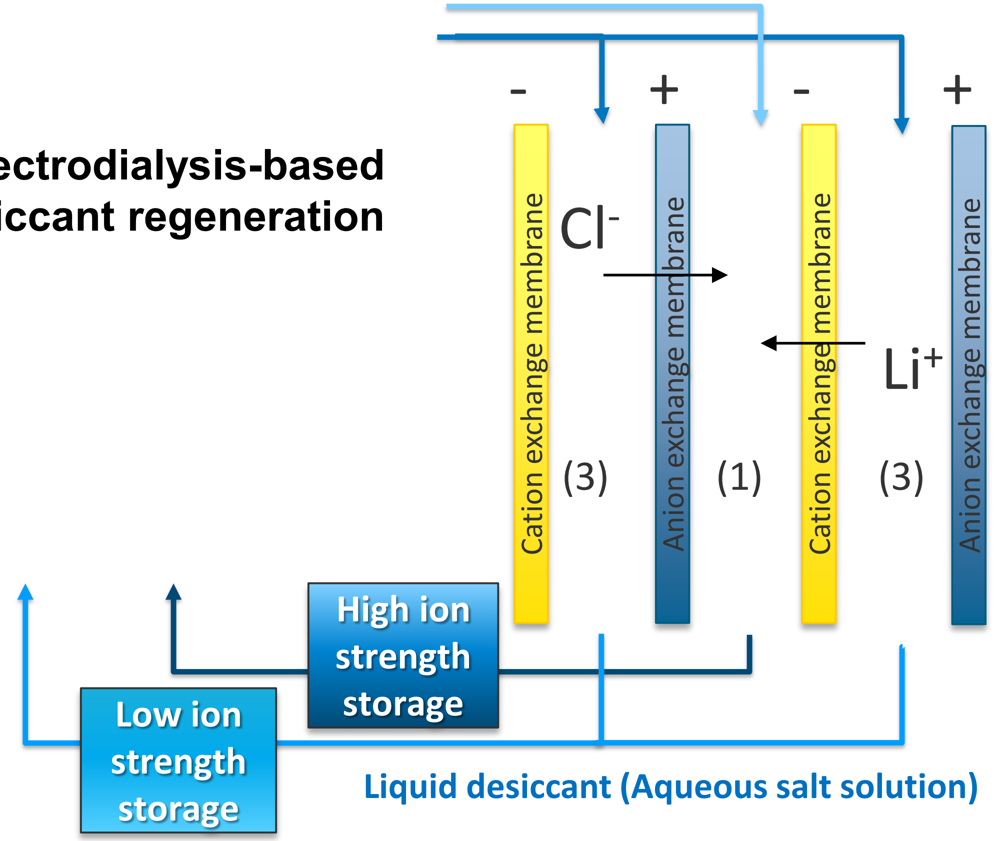
CRADA with Palo Alto Research Center (PARC): Supporting Development and Analysis of a Liquid Desiccant Regeneration Technology



NREL
Dr. Jason Woods, Sr. Research Engineer
720.441.9727 | jason.woods@nrel.gov

Electrodialysis-based desiccant regeneration



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

Key Partners:

Palo Alto Research Center

Budget:

Total Project $ to Date:

- DOE: $505,000
- Cost Share: $58,000

Total Project $:

- DOE: $855,000 (expected)
- Cost Share: $100,000

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

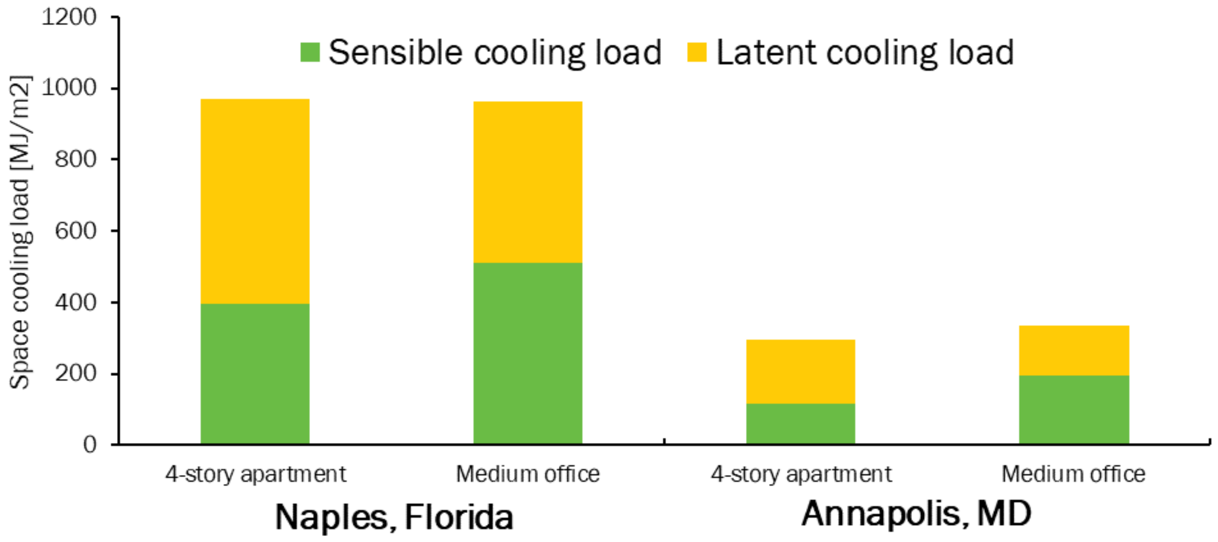
Dr. Rachel Ellman

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

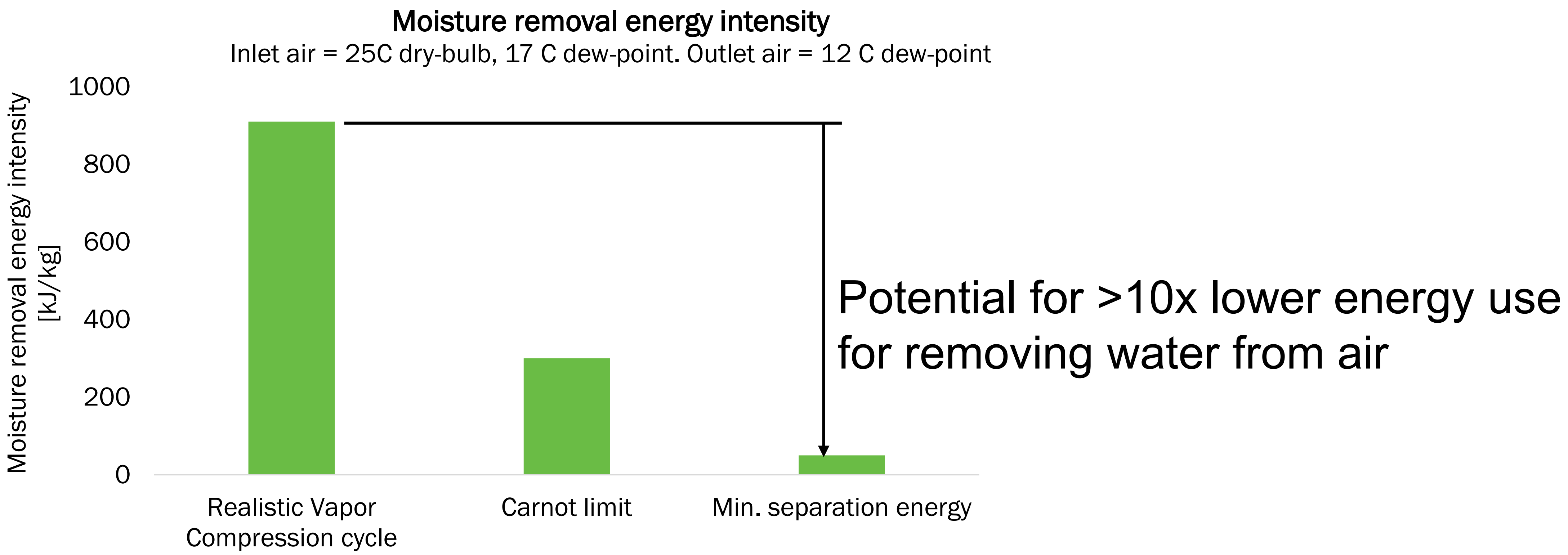


The latent cooling load is on the same order of magnitude as sensible cooling

Of the 360 tonnes of CO_2 from US air conditioning energy use[1], nearly half is due to removing water vapor from air.

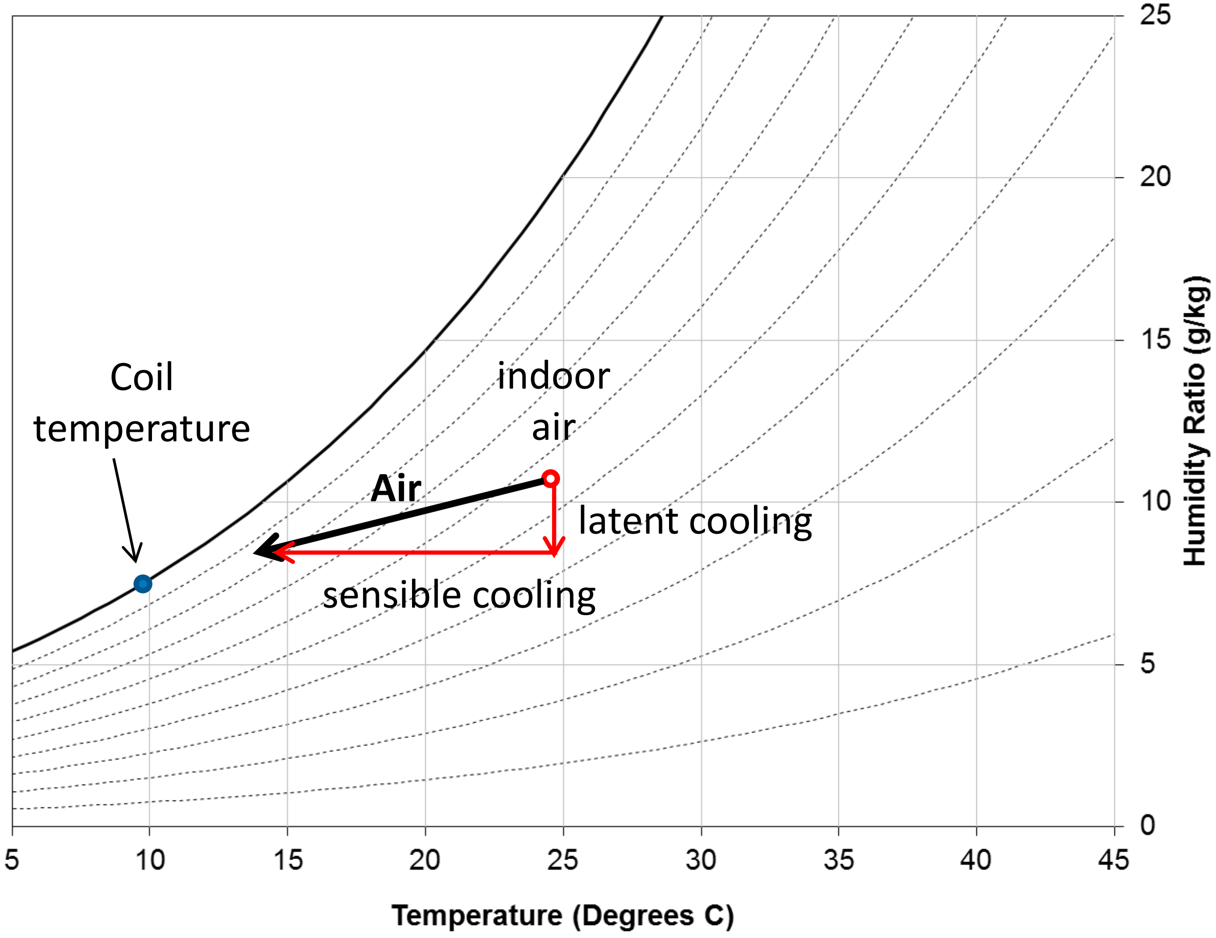
[1] https://www.epa.gov/rhc/renewable-space-cooling

There is a >10x potential for reducing energy used to remove water vapor from air

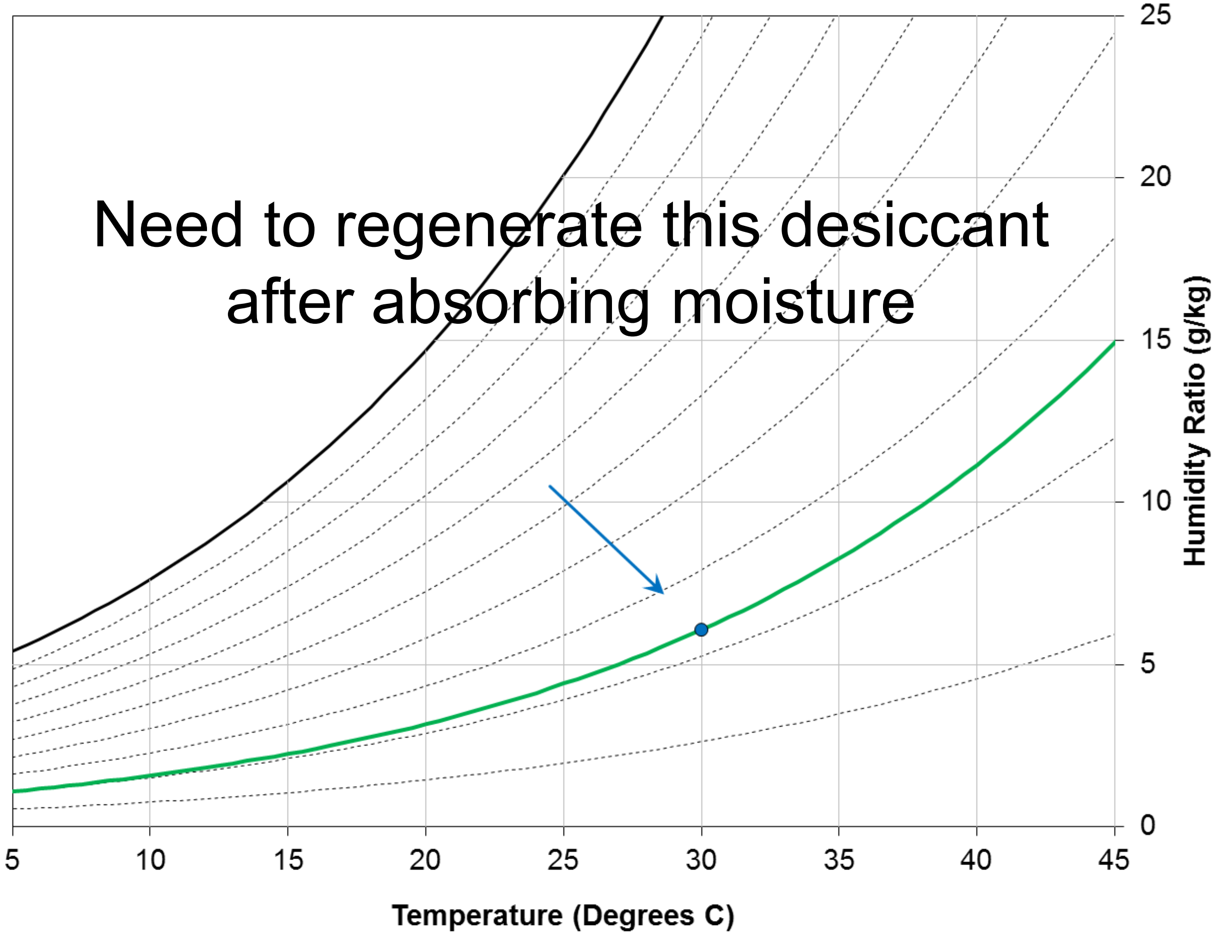


Approach: Desiccants Can Efficiently Remove Moisture from Air

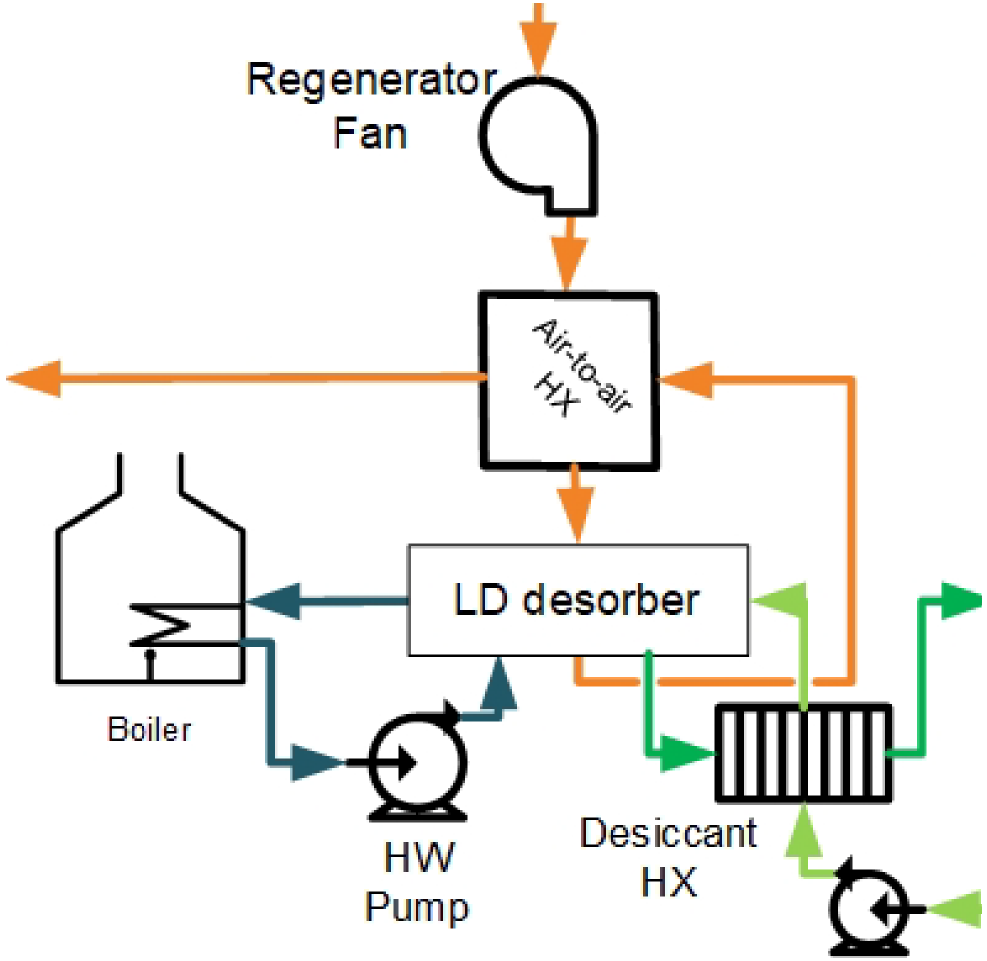
Moisture removal from condensation on cold surface

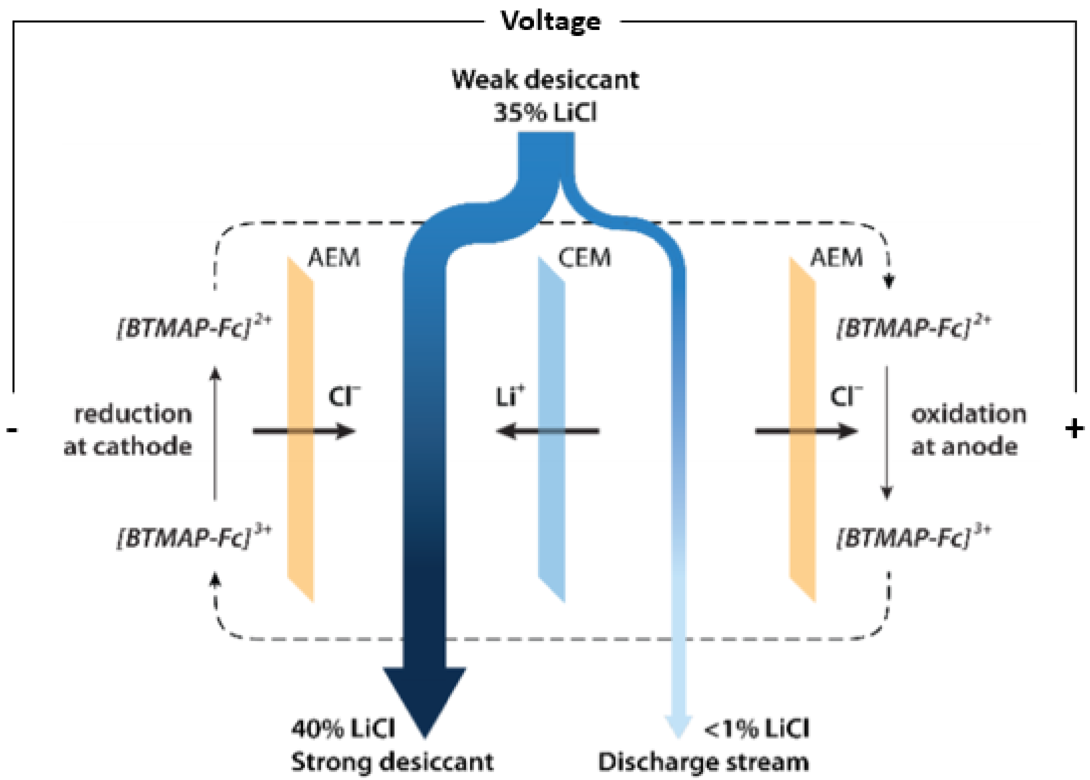


Moisture removal with concentrated liquid desiccant



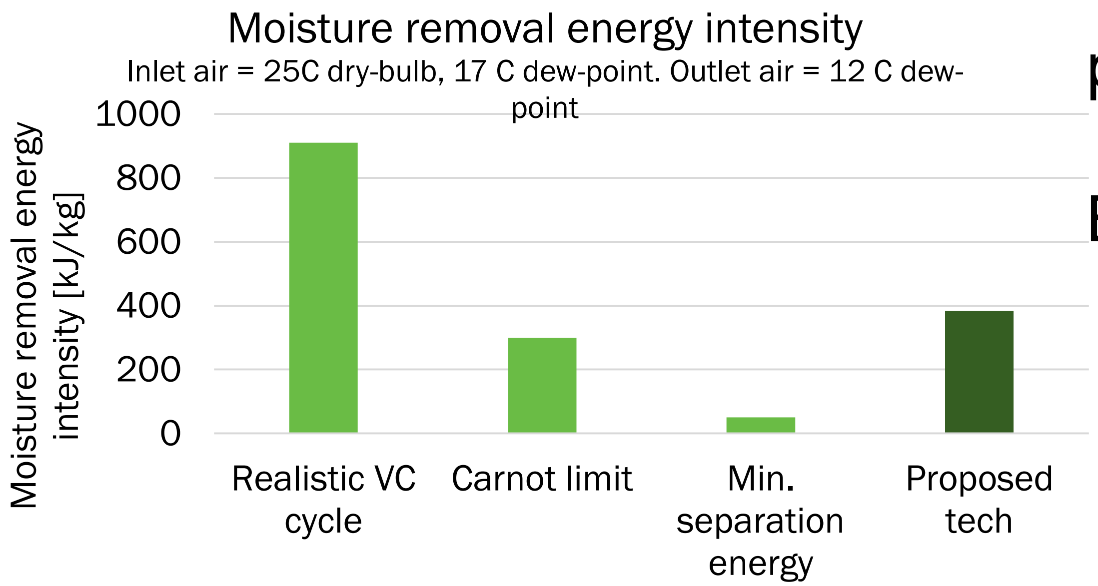
Approach: Evaporating Water from Desiccants Is Energy Intensive





Electrodialysis ion separation: Transport ions across a membrane rather than evaporate water. A fundamentally different approach to desiccant regeneration.

Impact: Efficiency, Comfort, Flexibility



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

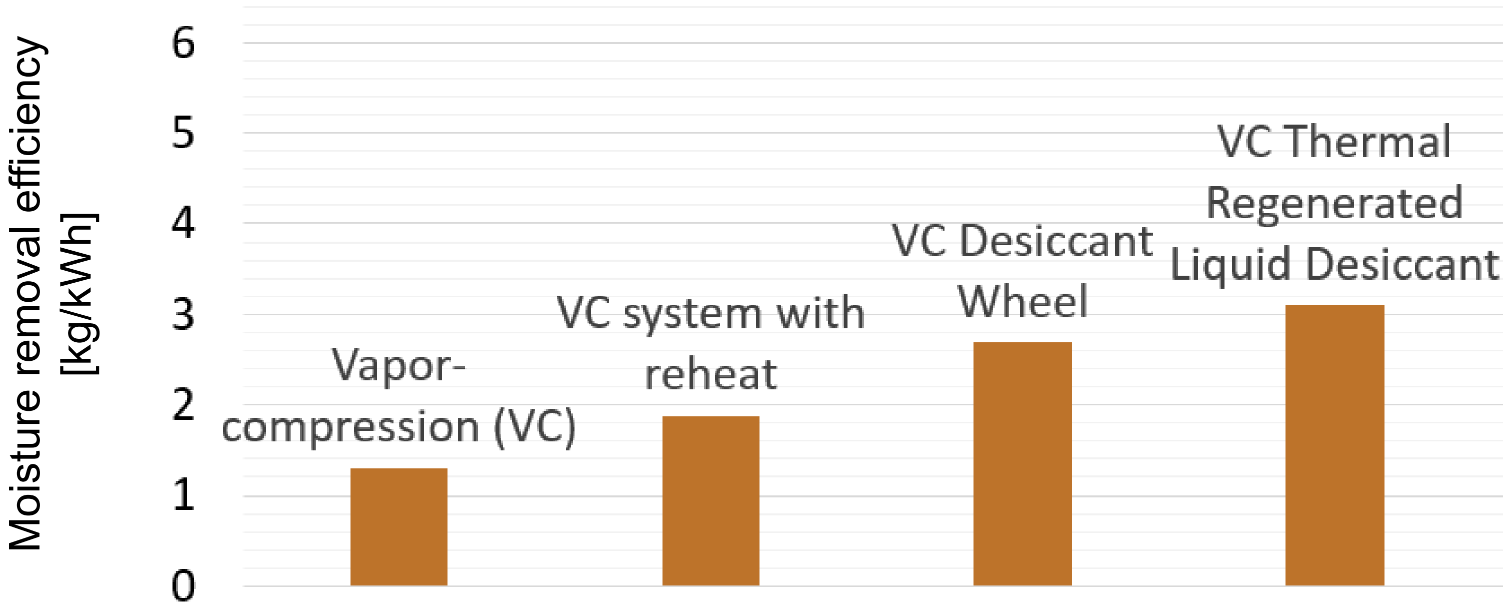
System modeling and design

- **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

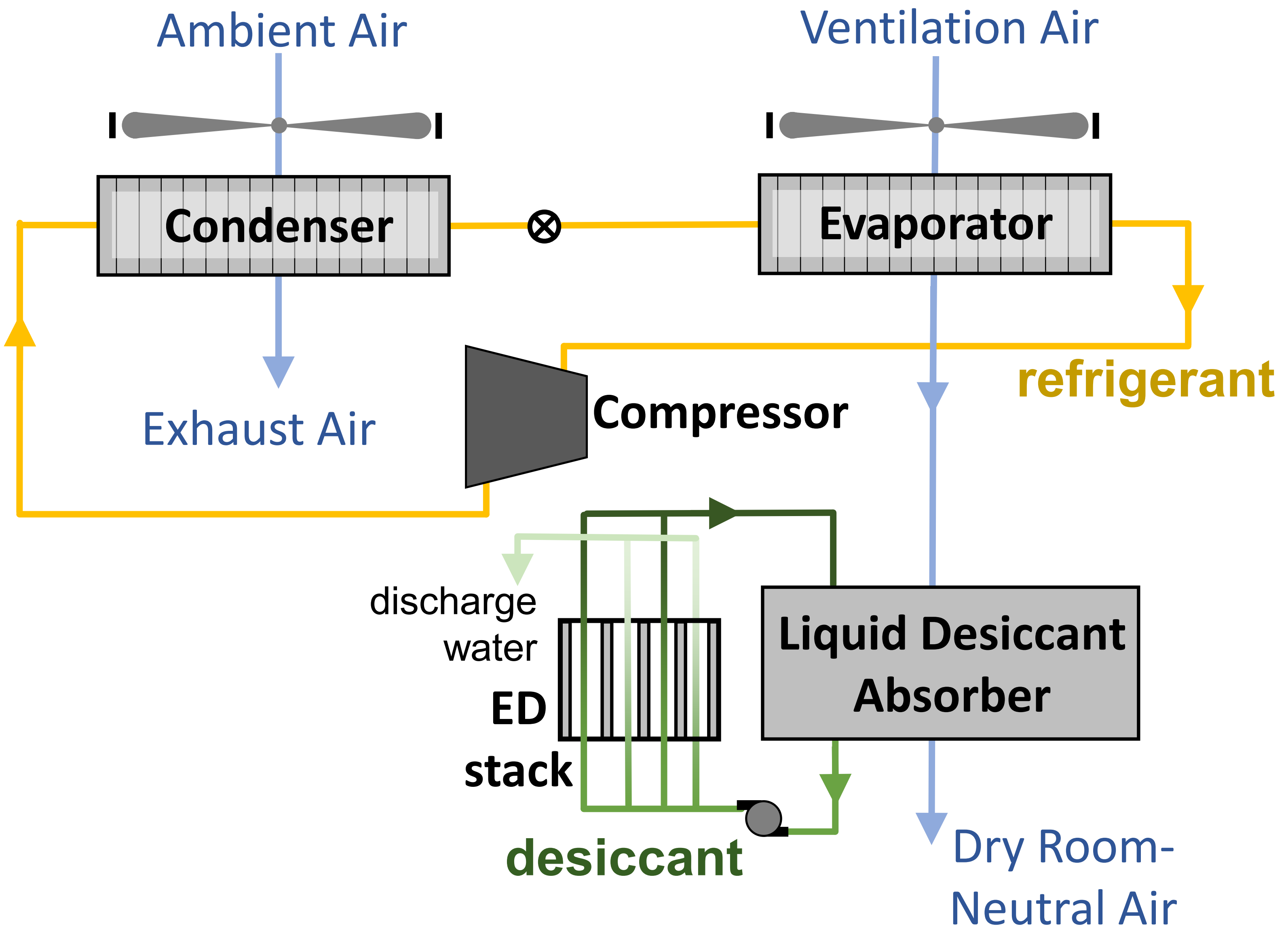
Progress: Benchmarking Performance of State-of-the-Art Systems



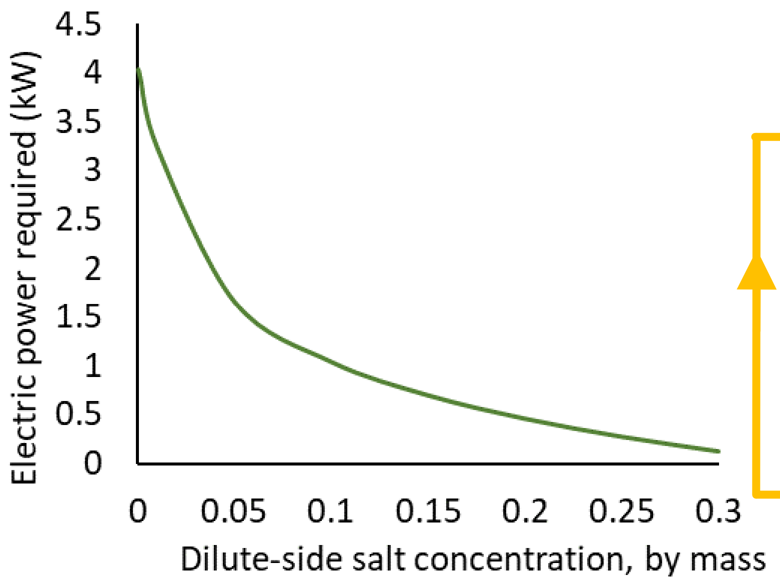
NREL developed models to predict the moisture removal efficiency of existing technologies. These are the benchmarks for comparison.

Progress: Initial Design – Discharge Water Down the Drain

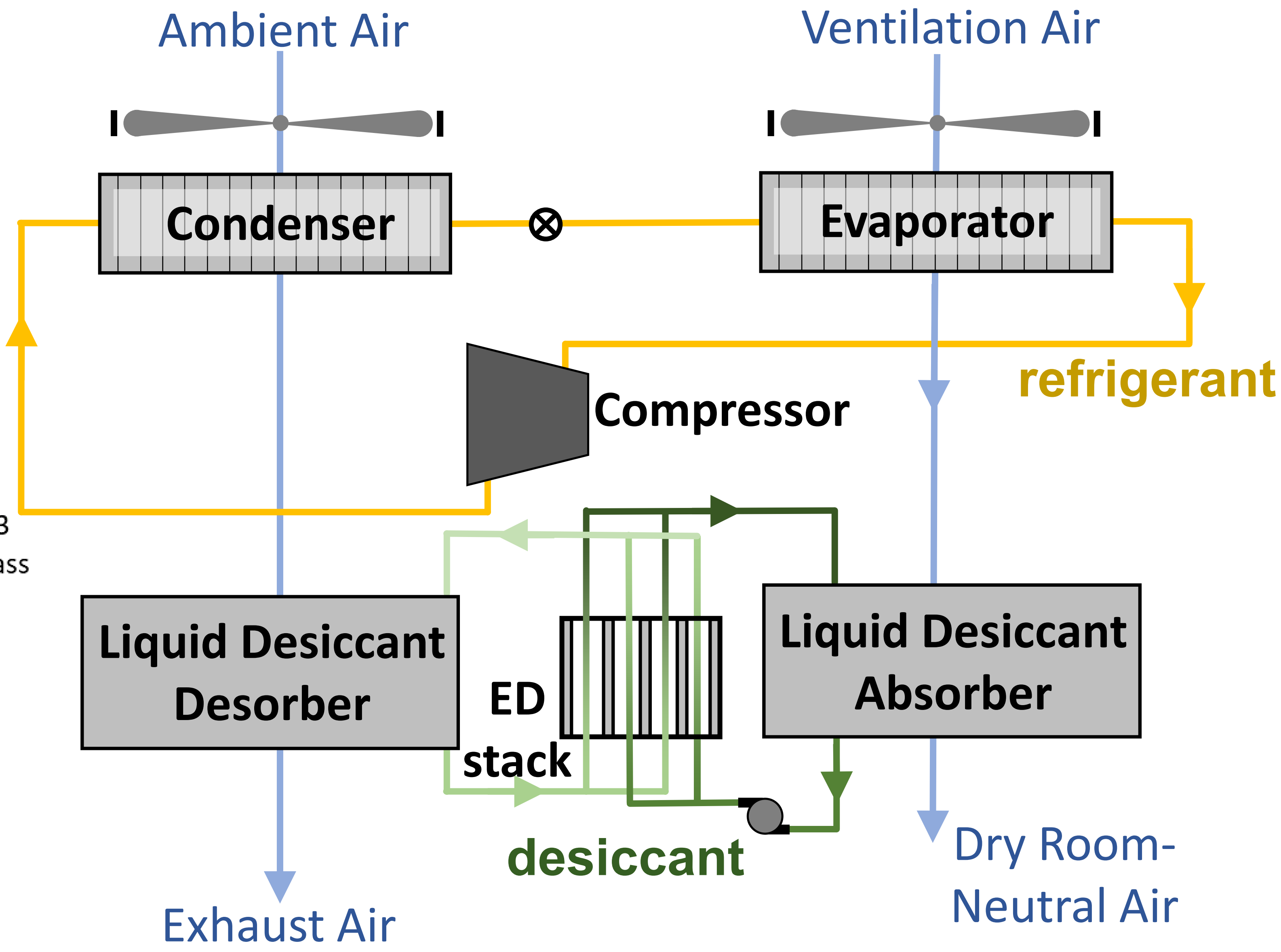
NREL also developed models of PARC's electro-dialysis dehumidification technology, to predict its performance and aid in system design.



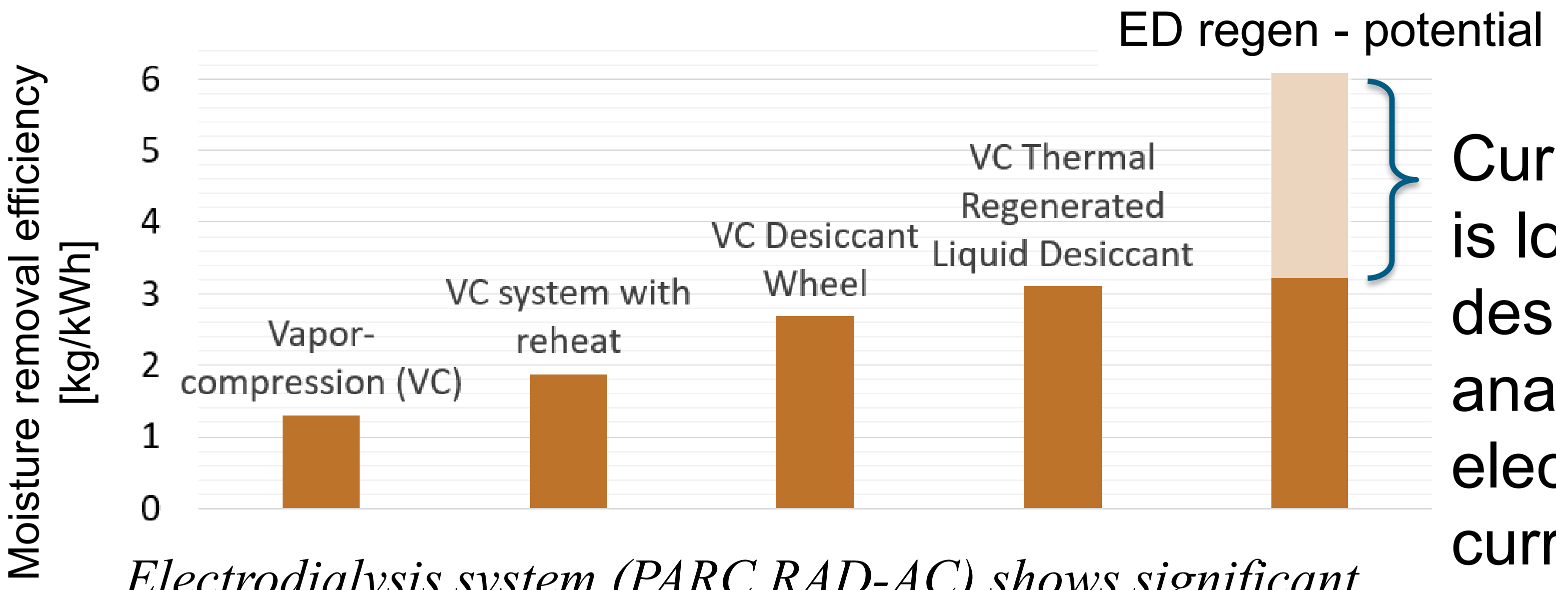
Progress: Improved Design – Discharge Water through Evaporation



Electrodialysis efficiency improves considerably if we avoid creating nearly-pure water. This also prevents losing ions down the drain over time.



Progress: System Design



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 ft^3/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

National Renewable Energy Laboratory
Dr. Jason Woods | Sr. Research Engineer
720.441.9727 | jason.woods@nrel.gov

REFERENCE SLIDES

Project Budget

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

Budget History					
FY 2020 (past)		FY 2021 (current) Start date: March 2021		FY 2022 (planned) (End date: March 2023)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$0	$0	$505,000	$58,000	$350,00	$42,000

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.

Project start: March 2021
Project end: March 2023

Completed work
Future work

		FY21				FY22				FY23			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Completed milestones													
FY21Q3	Layout of system architectures combining electrodialysis with liquid desiccant based HVAC systems												
Future milestones													
FY21Q4	Summary report on modeling performed in FY21 for different electrodialysis + liquid desiccant based HVAC systems												
FY22Q1	Modeling results and design selected of PARC dehumidification system based on their prototype (Oct 2021)												
FY22Q2	Commissioning of PARC prototype in NREL's HVAC laboratory												
FY22Q3	Experimental results on PARC prototype demonstrating required performance in NREL's lab												
FY22Q4	Draft report or journal article on experimental performance of PARC electrodialysis technology												
FY23Q1	Experimental results on packaged HVAC prototype, including hardware-in-the-loop experiments												