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Achieving 50% Energy Reduction with Liquid Desiccant DOAS

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MOJAVE

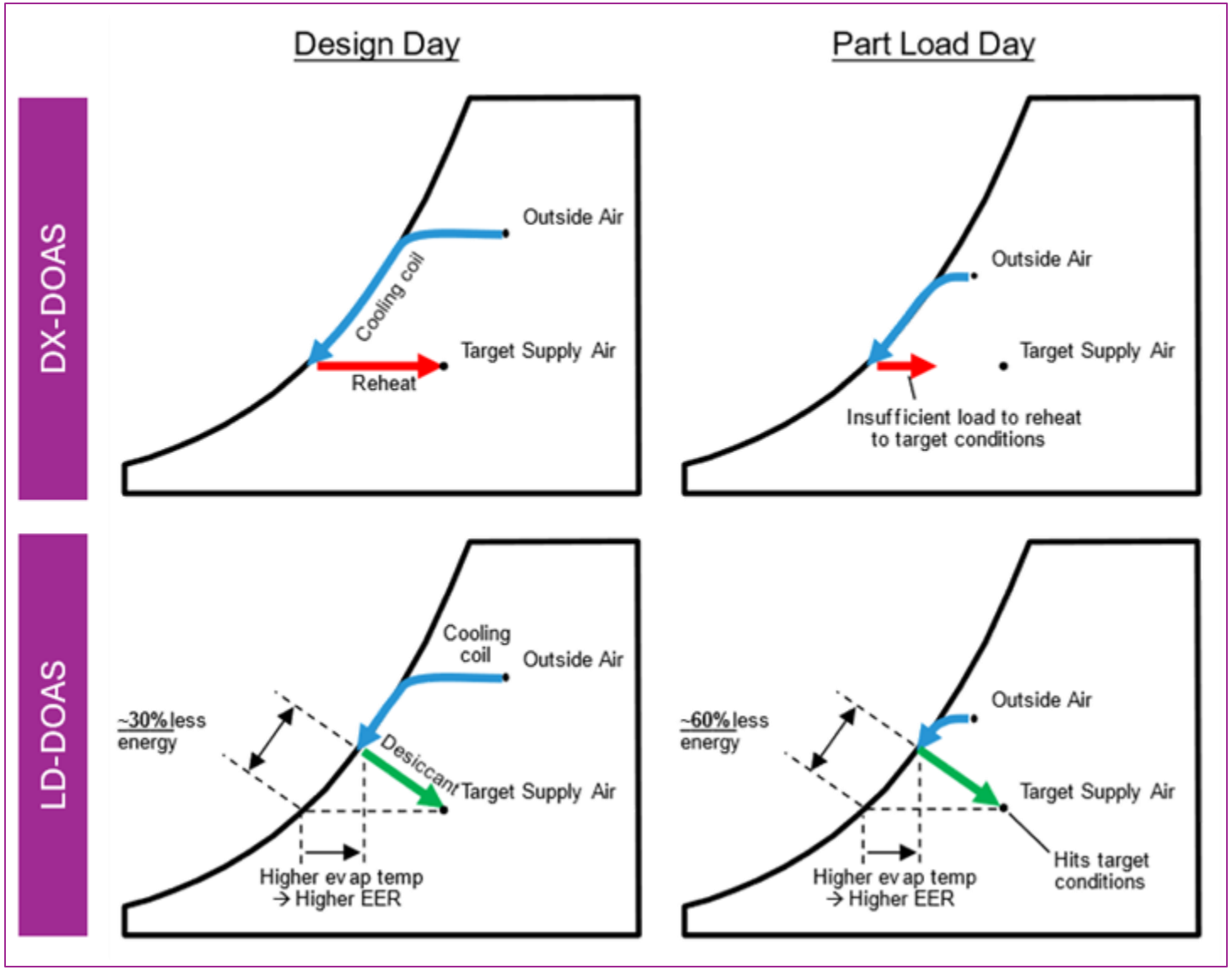
Learning Objectives

- **Explain how liquid desiccant air conditioners save 50% of the energy used by conventional Dedicated Outdoor Air Systems**
- **Describe how field reliability of a liquid desiccant air conditioner compares to the field reliability of a conventional air conditioner**
- To measure the SF6 and CO2 gases sorption isotherm of silica gel.
- To understand the transient behavior during adsorption process.
- Design the counter-flow absorber based on a solution atomization
- Describe the effect of air and solution flow rate on dehumidification performance

Outline/Agenda

- Liquid desiccant air conditioners can save 50%
- System architecture: refrigerant & liquid desiccant handling systems combine inside a packaged unit
- Field results support energy savings estimates
- Reliability of a liquid desiccant air conditioner (LDAC/ LD-DOAS) compares to the reliability of a conventional DX air conditioner (DX-DOAS)

Liquid desiccant air conditioners save 50%



Desiccant saves energy by "cutting the corner" on the psychrometric chart to reduce energy use:

- **Stop overcooling:** cooled to the target enthalpy rather than the target dew point
- **Improve compressor COP:** increased evaporator temperature
- **Packaged**: require no external heat input for regeneration of the desiccant

Liquids are more reliable than solids:

- **Require lower maintenance:** the desiccant lasts life of the unit & requires no additional maintenance
- **Operate consistently in all conditions**: reliably deliver air at the desired supply conditions at times when solids struggle

System architecture: refrigerant and liquid desiccant handling systems inside a packaged unit

Airside:

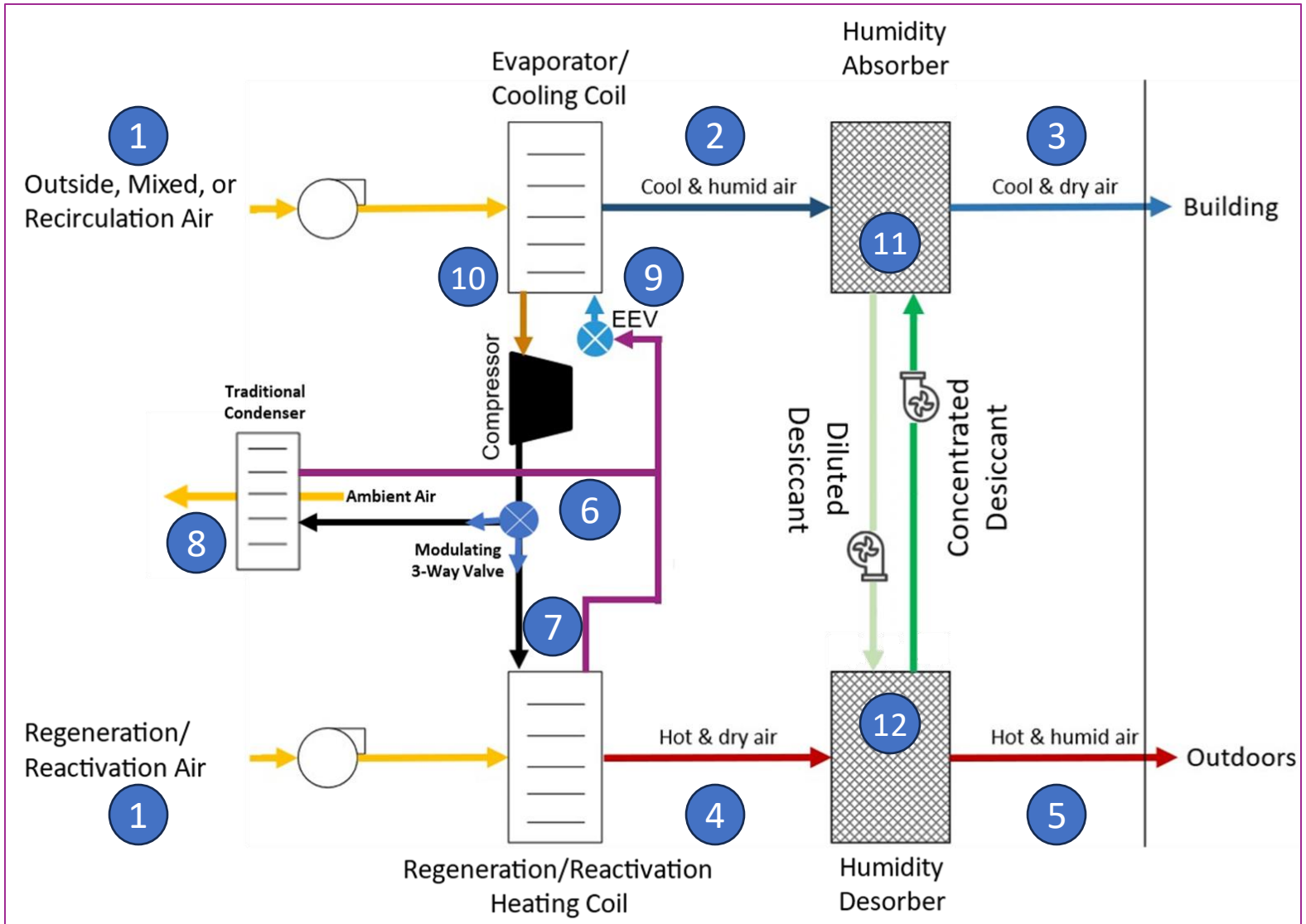
- **Outdoor** air (1) is cooled and dried by the coil (2) & then the desiccant (3)
- **Regeneration air** is heated by the coil (4) & receives water from desiccant (5)

Refrigerant side:

- **Hot gas** exits the compressor (6) with some heat used for regeneration (7) and the rest rejected (8)
- **Cooling** proceeds as in a DX: gas expands at EEV (9) & enters coil (10)

Desiccant side:

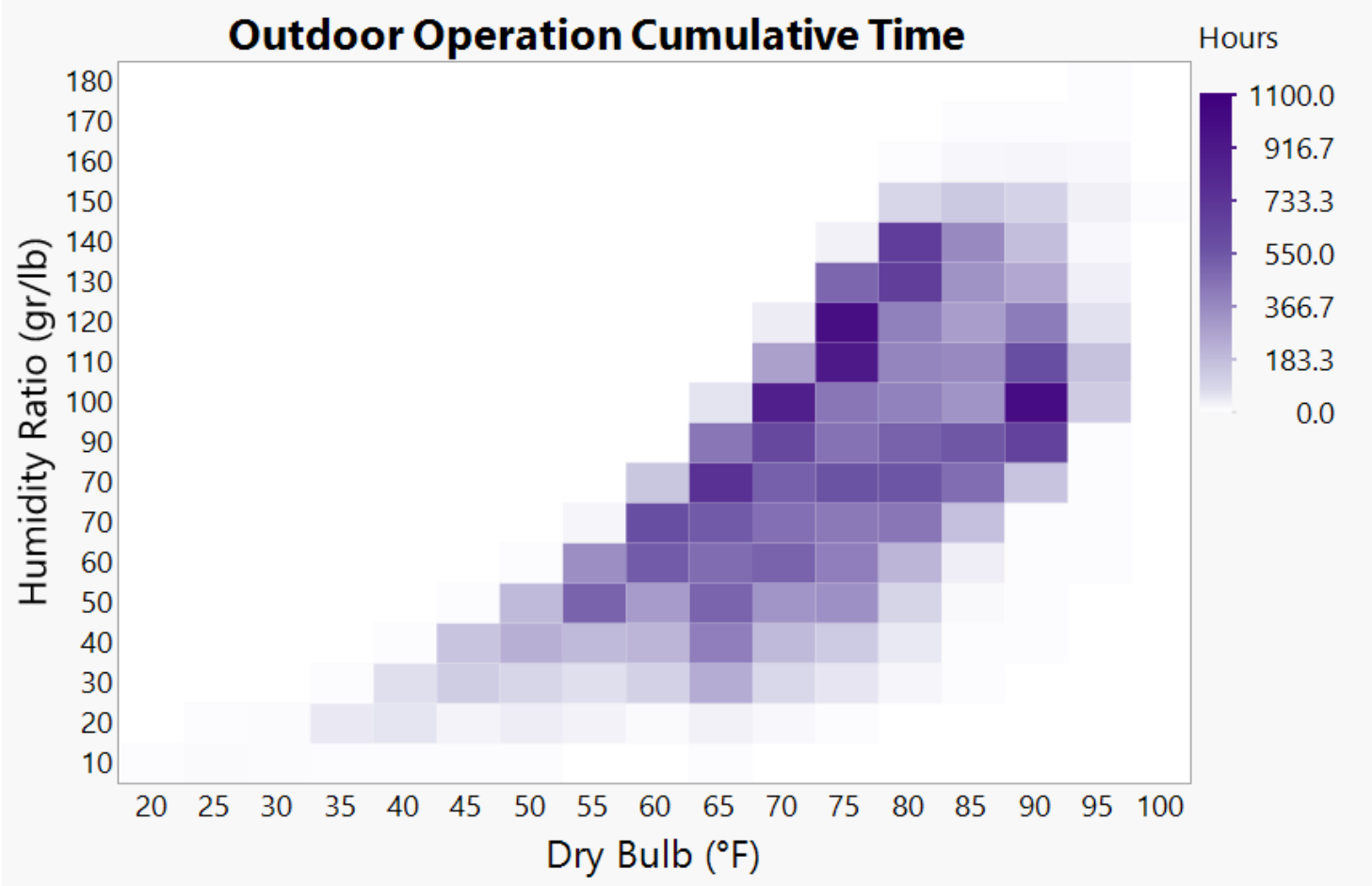
- **Absorber** (11) receives concentrated desiccant: falling film absorbs moisture from pre-cooled air
- **Desorber** (12) receives dilute desiccant: falling film rejects moisture from pre-heated air



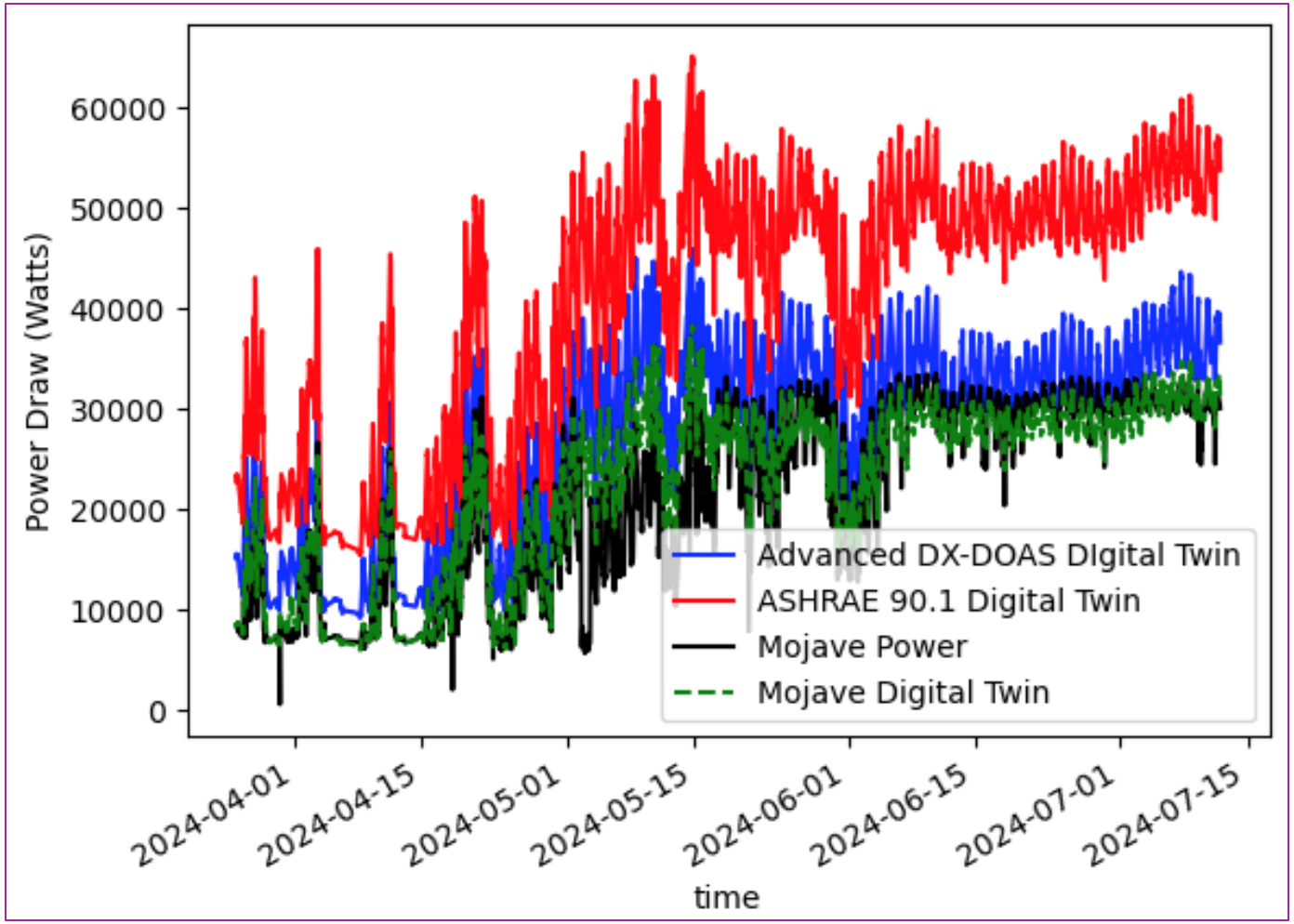
Five sites selected…

Unit Efficiency Ratings and Expected Energy Savings						
	Location	ISMRE2	Total capacity	Moisture removal	Expected energy savings (%) compared to:	
System design:		kg/kWh (Lbs/ kWh**)**	Tons	Lbs./hr (kg/hr)	ASHRAE 90.1	Advanced
EV-1	Tampa, FL	3.8 (8.3)	9	57 (26)	54%	33%
EV-2	Midland, MI	3.8 (8.3)	9	57 (26)	54%	33%
EV-3	Tampa, FL	3.8 (8.3)	9	57 (26)	54%	33%
PV-A	Houston, TX	4.3 (9.5)	25	117 (53)	59%	40%
PV-B, 5000 CFM	Orlando, FL	4.3 (9.5)	40	234 (106)	51%	26%
PV-B,4000 CFM		4.6 (10.7)	40	234 (106)	44%	19%

… to give coverage across psychrometric chart



Energy savings matched expectations!



Energy Savings Estimates from Field Campaign			
Unit	Performance ratio (actual to digital twin)	Energy savings (vs. ASHRAE 90.1 unit)	Energy savings (vs. advanced DX-DOAS)
EV-1	0.97	60%	38%
EV-2	1.04	60%	37%
EV-3	1.02	52%	27%
PV-A	0.97	52%	36%
PV-B	1.04	48%	29%
Average	1.01	54%	33%
Standard deviation	0.04	6%	5%

Measured ISMRE2: 9.5 lbs/kWh (4.3 kg/kWh)

Operating reliability in-line with industry

Overall Reliability Results from Full Field Campaign					
Unit	System Uptime (hours)	Operating (hours)	System Uptime (%) [last 90]	Desiccant Subsystem Uptime (hours)	Desiccant Subsystem Uptime (%) [last 90]
EV-1	7,419	7,602	97.6% [N/A]	7,521	98.9% [N/A]
EV-2	4,945	5,081	97.3% [99.4%]	4,948	97.4% [99.4%]
EV-3	8,273	8,732	94.7% [99.7%]	8,628	98.8% [99.7%]
PV-A	5,972	6,292	94.9% [91.7%]	6,149	97.7% [99.9%]
PV-B	3,919	3,966	98.8% [97.9%]	3,926	99.0% [97.9%]
Total	30,705	31,673	96.9% [97.2%]	31,172	98.4% [99.2%]

Represents 8-10 years of typical operations

Reliability in-line with industry expectations

Desiccant subsystem outperforms vapor compression system at nearly 99% uptime

Conclusion

Five liquid desiccant DOAS systems have been field tested in a variety of climates, accumulating over 30,000 hours of field operation. Prior to deployment each unit had its ISMRE measured, demonstrating ISMREs between 8.3 and 10.7 lbs./kWh (3.8 to 4.6 kg/kWh) with an **average ISMRE of 9.5 lbs./kWh (4.3 kg/kWh)**. Once installed in field locations in Florida, Texas, and Michigan, **the units demonstrated 53% energy savings when compared to ASHRAE 90.1 and 32% energy savings when compared to advanced DX-DOAS units**. Additionally, each unit's performance continues to match its digital twin within 4%. Finally, the units operated reliably, with **97% system uptime and steady state desiccant subsystem uptime of over 99%.** All five units are still in operation, and the performance and reliability of these units continues to be monitored.

In this study, the LD-DOAS systems provided substantial energy savings while supplying neutral dewpoints (48-55°F, 9-13°C). Future work will focus on LD-DOAS's ability to supply lower dewpoint (35-45°F, 2-7°C) air than DX-DOAS. As has been previously characterized (Harriman et al, 2001), further benefits to building-wide efficiency and operability can be realized by using DOAS to provide drier-than-neutral air, which removes the need for all other sensible cooling equipment in the building to dehumidify. Demonstrating this building-wide efficiency benefit from LD-DOAS is the scope of future work.

Acknowledgements

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Questions

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