Electrostatic Dehumidification

Electric Power Research Institute (EPRI)
Ron Domitrovic, Program Manager
865-218-8061

Project Summary

Timeline:

Start date: April 1, 2020

Planned end date: March 31, 2023

Key Milestones (insert 2-3 key milestones and dates)

1. Successful Modeling and Analysis; April 2021
2. Initial Prototype Design and Creation; June 2021
3. Test Stand Construction; July 2021

Budget:

Total Project $ to Date:
(through 6/30/21)

- **DOE:** $523,280.84
- **Cost Share:** $142,681.34

Total Project $:
(Includes BP3 Funds Not Yet Released)

- **DOE:** $1,300,000
- **Cost Share:** $400,000

Key Partners:

Electric Power Research Institute
ORNL Center for Nanophase Materials Science
Optimized Thermal Systems
Southern Company
Tennessee Valley Authority

Project Outcome:

The targeted outcome of this project is to design, construct, and test the concept of using electrostatics to enable non-condensing air dehumidification through molecular sorting for application in heating, ventilation, and air conditioning (HVAC) and related industries.

Team

Ron Domitrovic - EPRI

- Principal investigator

Joseph Jansen - EPRI

- Analysis of field physics and electrode geometry
- Prototype design and fabrication

Matt Robinson - EPRI

- Thermodynamic analysis
- Test stand design and instrumentation

Nick Lavrik – ORNL CNMS

- Field physics
- Nano-scale design and fabrication

Andrea Mammoli - EPRI

- Thermodynamic analysis
- Instrumentation design

Kelsey Palko - EPRI

- Project coordination and reporting

John Jansen - EPRI

- Analysis of field physics and molecular dynamics
- Electrical systems and measurement

Reinhard Radermacher - UMD

- Thermodynamic analysis
- Test stand and instrumentation design
- Commercialization

Cara Martin - OTS

- Market and commercialization research

Chase Cortner – Southern Company

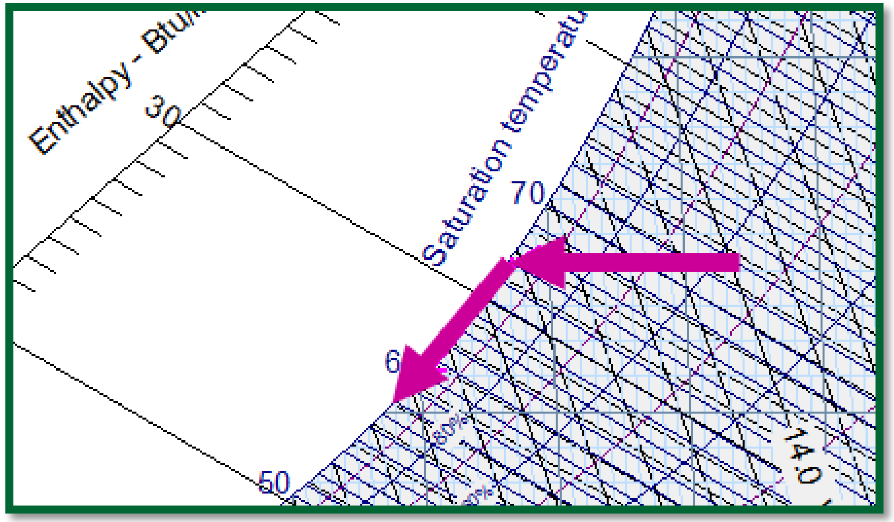
- Commercialization, application and customer perspective

Sam DeLay – TVA

- Commercialization, application and customer perspective

Challenge

- **Dehumidification consumes over 1 Quad per year in the U.S.**
- **~1/3 of cooling energy is expended for dehumidification**
  - $90 for an average U.S. household per year (~$270 for air conditioning)
  - 200M tons of CO_2 results
  - Requires 970Btu/lb (2,260kJ/kg) for phase change of water

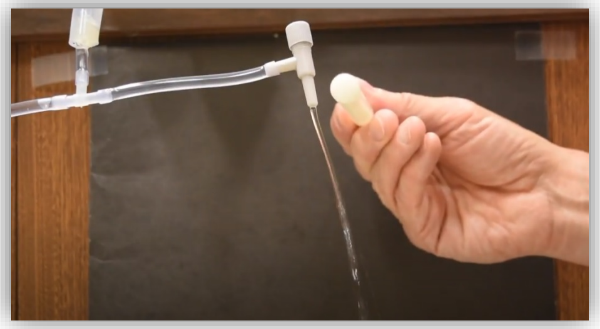


Δh Sensible: ~5 Btu/lb
Δh Latent: ~4 Btu/lb

- **What if water could be removed without phase change?**

Approach

- **Sort water molecules out of an air stream**
  - In the vapor phase
  - Avoid the need for phase change
- **Create a concentration gradient, dehumidifying one air mass, humidifying the other**
  - Create electrostatic force on water molecules (only)
  - Cause flow of water molecules via the force
  - Minimal energy requirement with no phase change
- **Objective is to test the concept**
  - Design, construct and test an electrostatic dehumidifier (benchtop)
  - Gain understanding of underlying physics

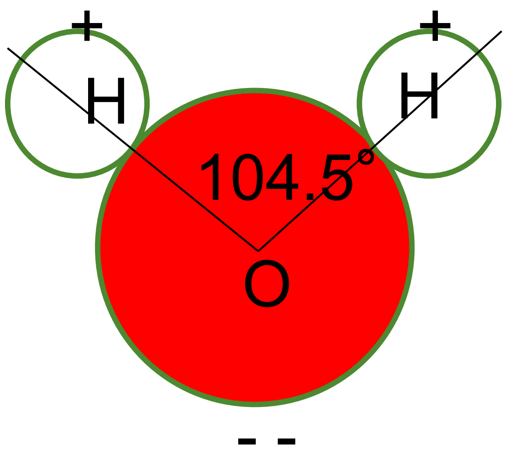


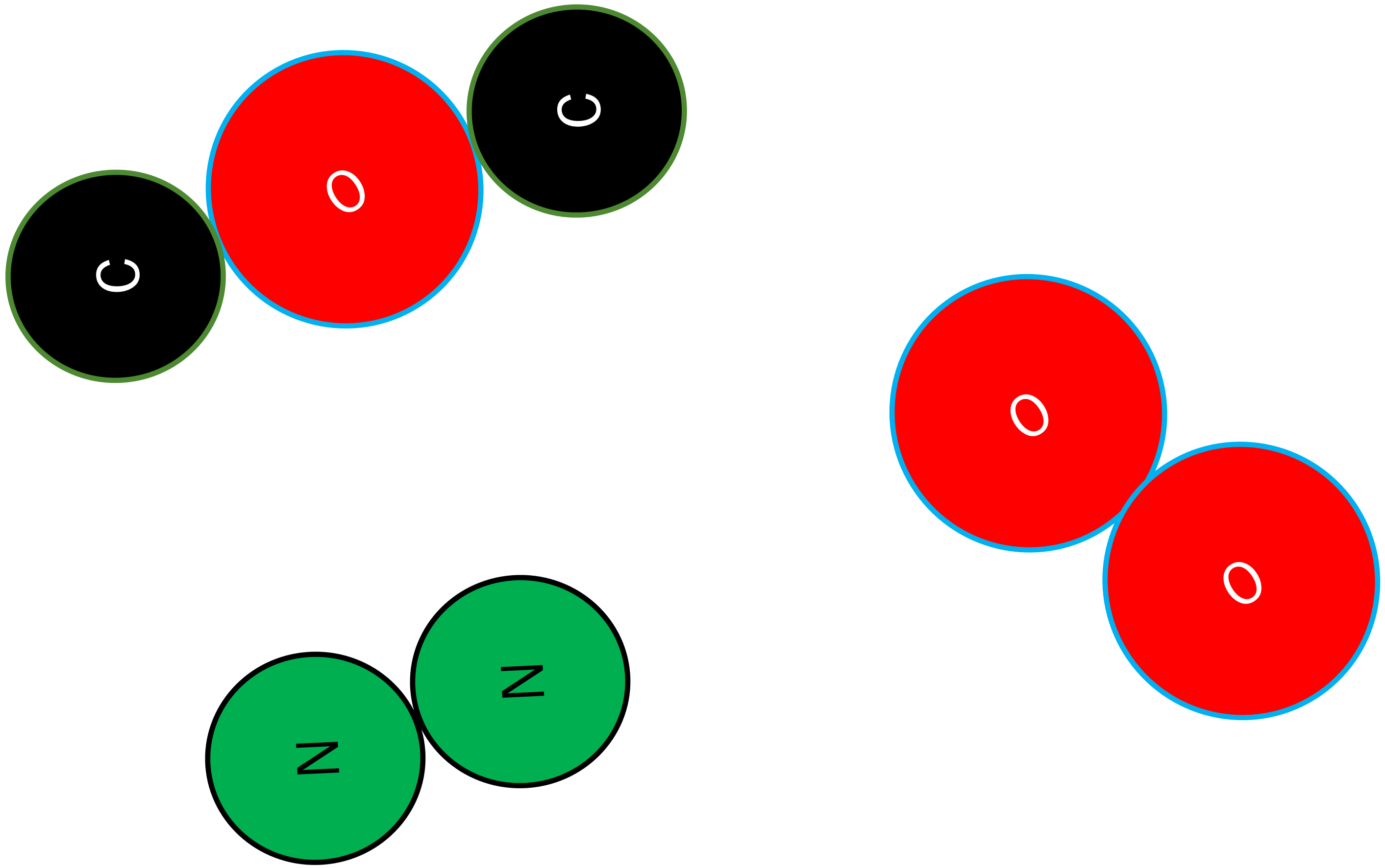
<u>Key points about water in air</u>

- ~1% concentration (by mole) in summer air
- Water molecules are naturally polar
- Mean free path ~100nm
- 1.85D dipole moment

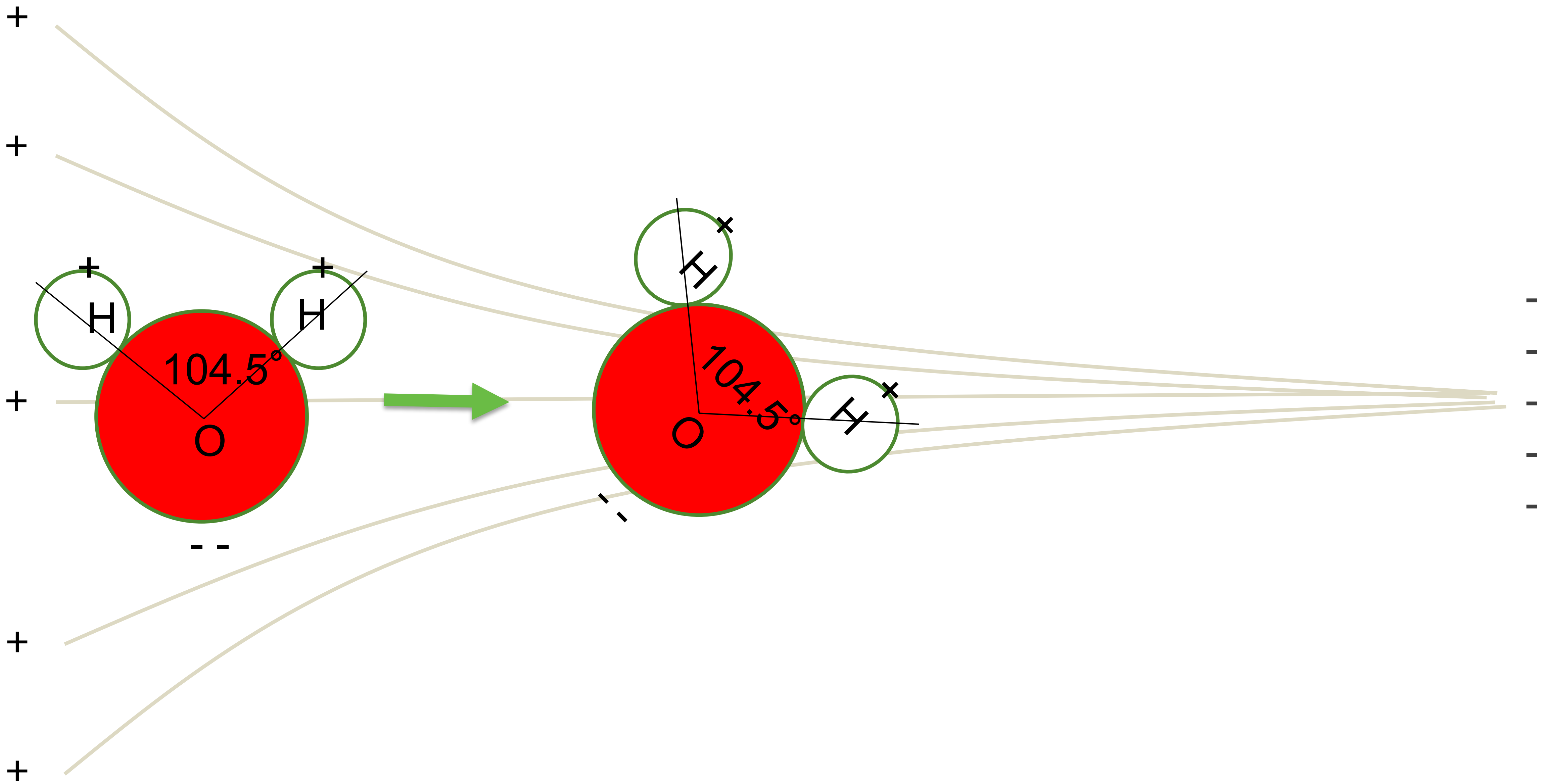
Primary challenge

Uniqueness of a Water Molecule

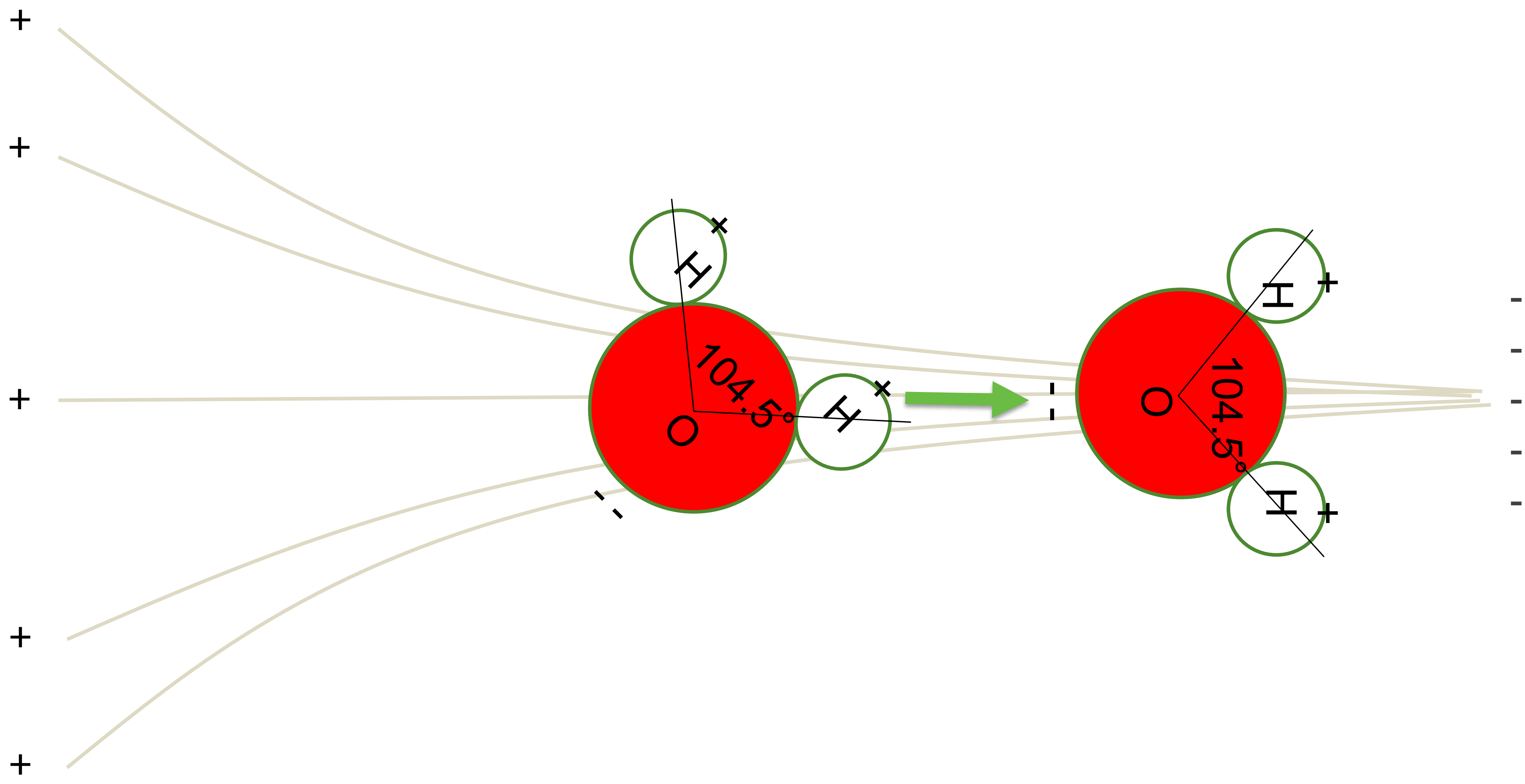




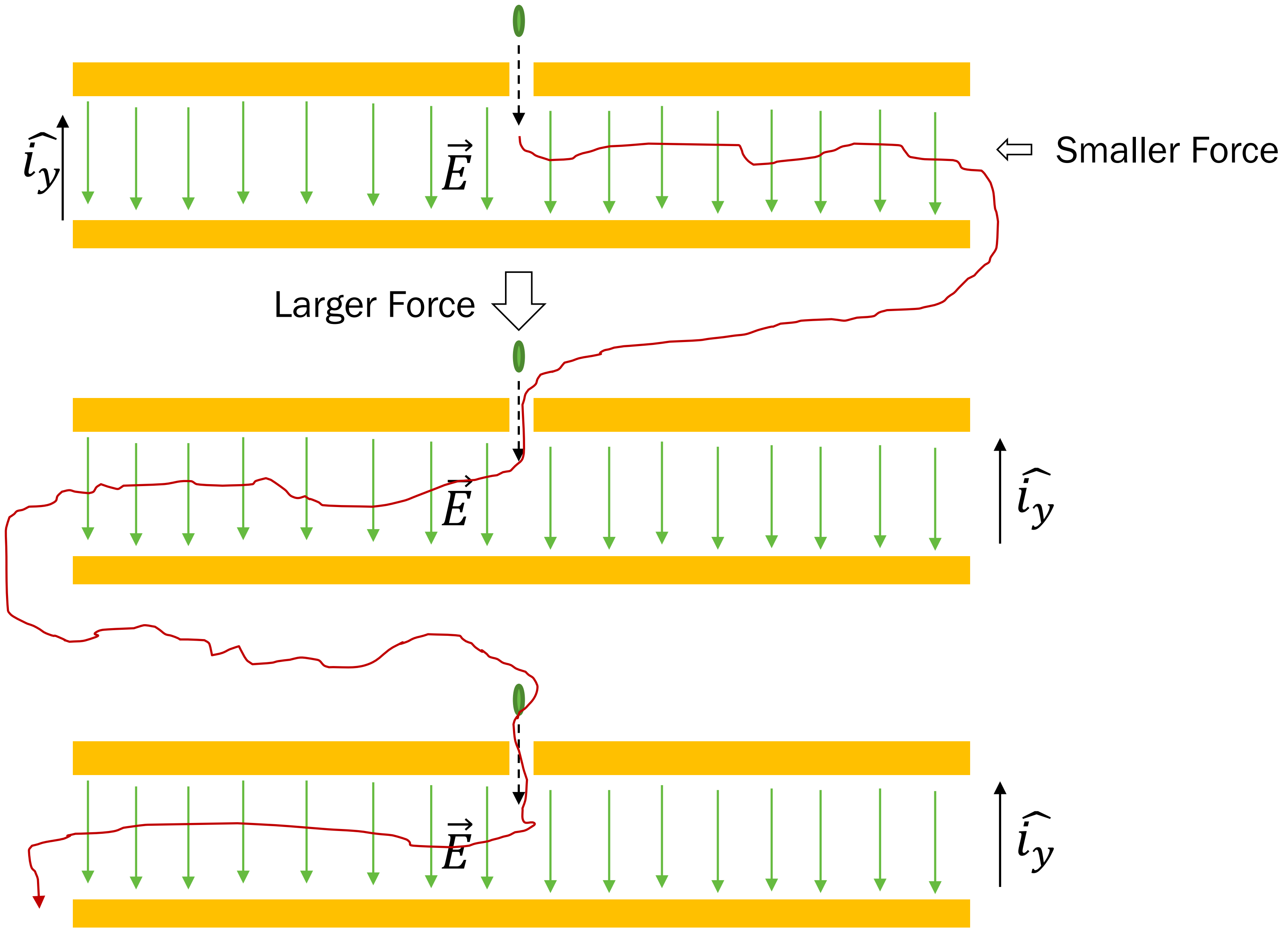
Uniqueness of a Water Molecule



Uniqueness of a Water Molecule



Step - Change Electric Field

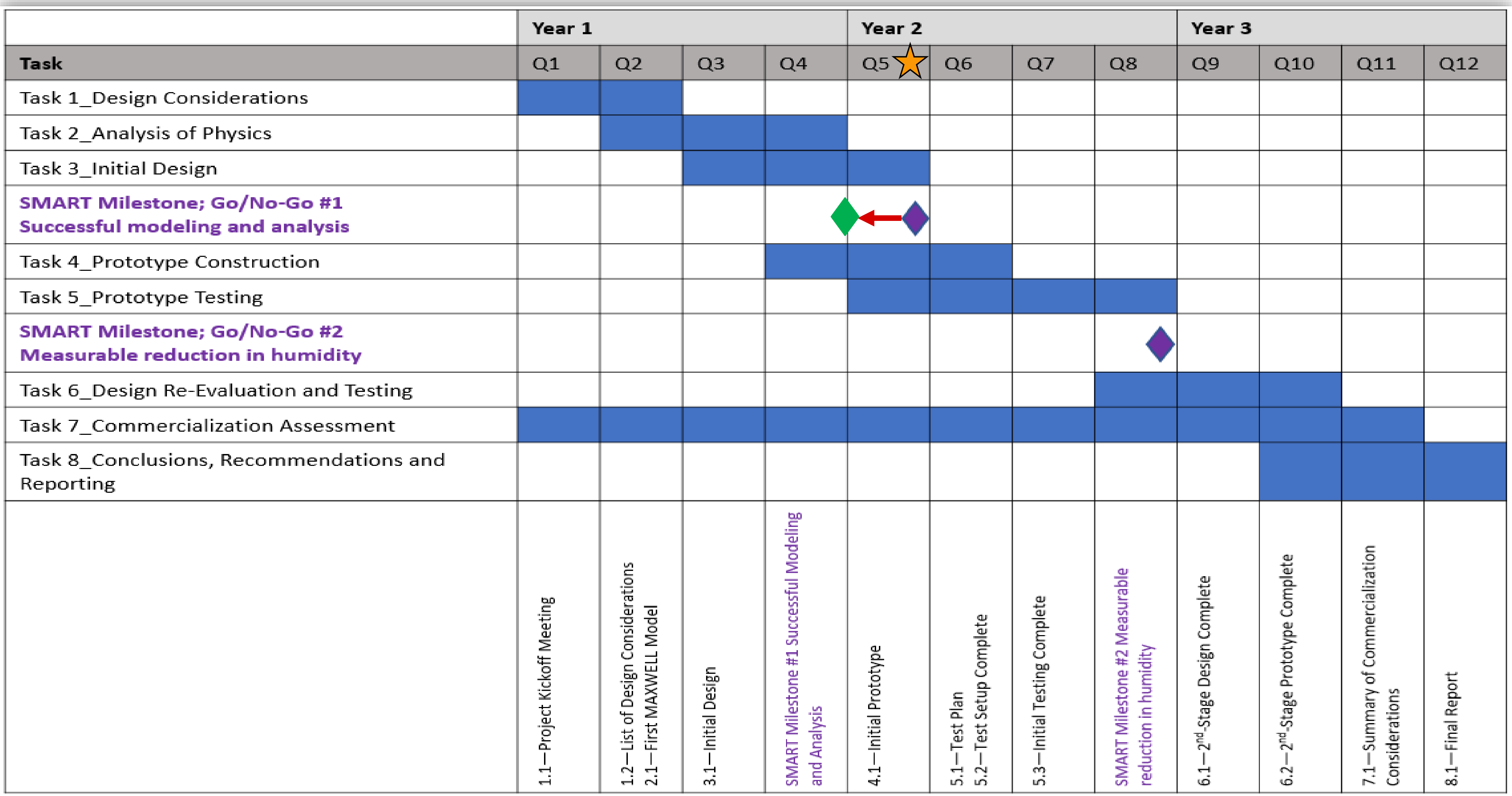


Impact — Molecular Sorting vs. Condensation

- **Theoretical advantage**
  - Condensation 500x energy compared to sorting (assuming 3.0 COP for vapor-compression condensation)
    - 2,260 kJ/kg vs ~1.5 kJ/kg
- **Our target is 10x reduction** (90% lower energy)
  - 0.9 Quad energy savings
  - $81 savings for average U.S. household
  - 180 M Tons CO_2 reduction
- **Creates new industry**
  - Expansion for existing HVAC manufacturers
  - Expanded use of nanomanufacturing industry
- **Creates potential new applications**
  - Separation of latent/sensible cooling

Impact (cont.)

- **Target of project**
  - Demonstrate concept
  - Quantify the effect
  - Identify paths for commercialization
    - HVAC, semiconductor, micro-fabrication industries
  - Identify engineering path for commercial product
    - Continuous flow and operation in buildings

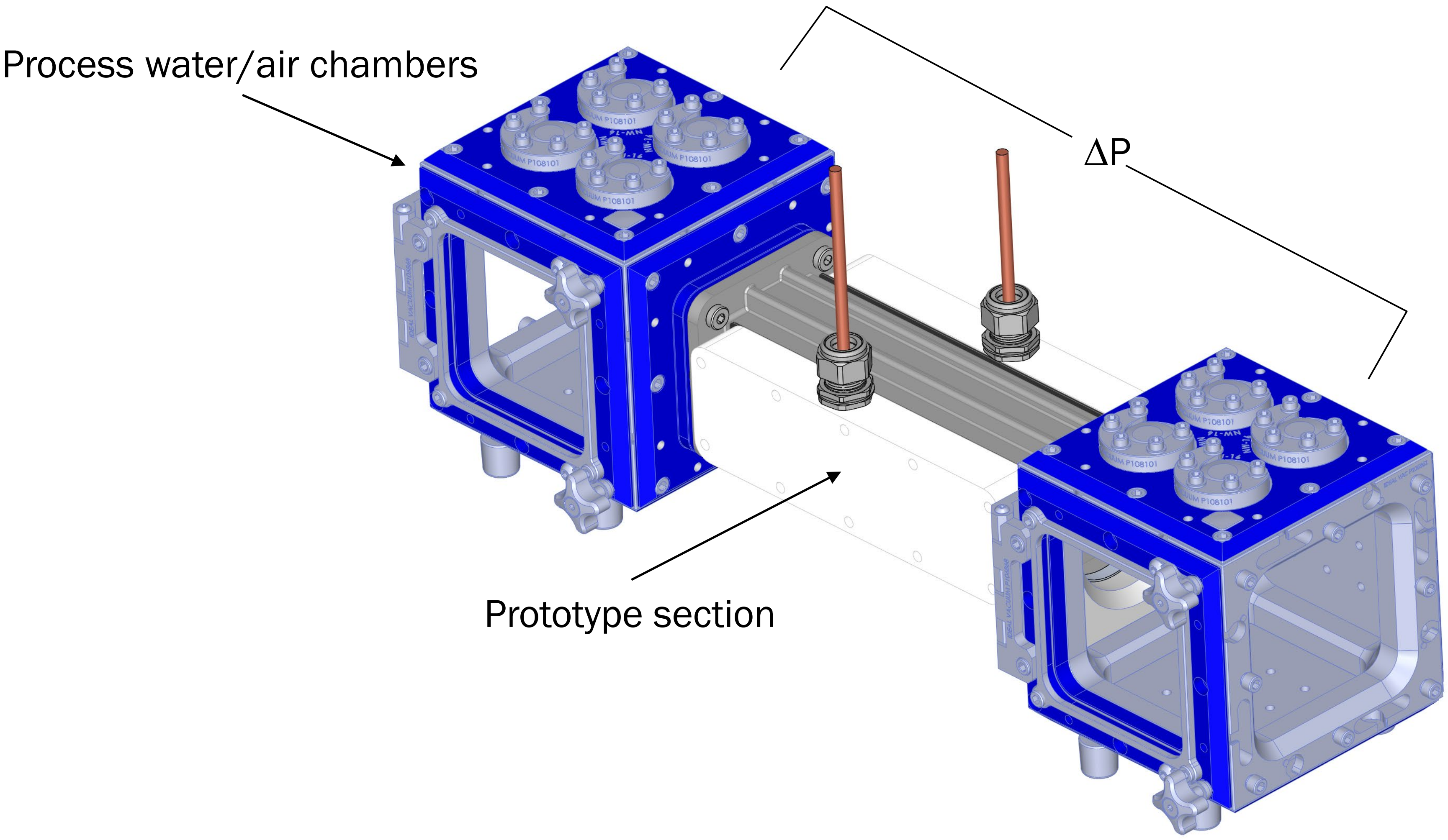

Year 1
Year 2
Year 3
Task
Q1
Q2
Q3
Q4
Q5
Q6
Q7
Q8
Q9
Q10
Q11
Q12
Task 1_Design Considerations
Task 2_Analysis of Physics
Task 3_Initial Design
SMART Milestone; Go/No-Go #1 Successful modeling and analysis
Task 4_Prototype Construction
Task 5_Prototype Testing
SMART Milestone; Go/No-Go #2 Measurable reduction in humidity
Task 6_Design Re-Evaluation and Testing
Task 7_Commercialization Assessment
Task 8_Conclusions, Recommendations and Reporting
1.1—Project Kickoff Meeting
1.2—List of Design Considerations
2.1—First MAXWELL Model
3.1—Initial Design
SMART Milestone #1 Successful Modeling and Analysis
4.1—Initial Prototype
5.1—Test Plan
5.2—Test Setup Complete
5.3—Initial Testing Complete
SMART Milestone #2 Measurable reduction in humidity
6.1—2nd-Stage Design Complete
6.2—2nd-Stage Prototype Complete
7.1—Summary of Commercialization Considerations
8.1—Final Report

Progress

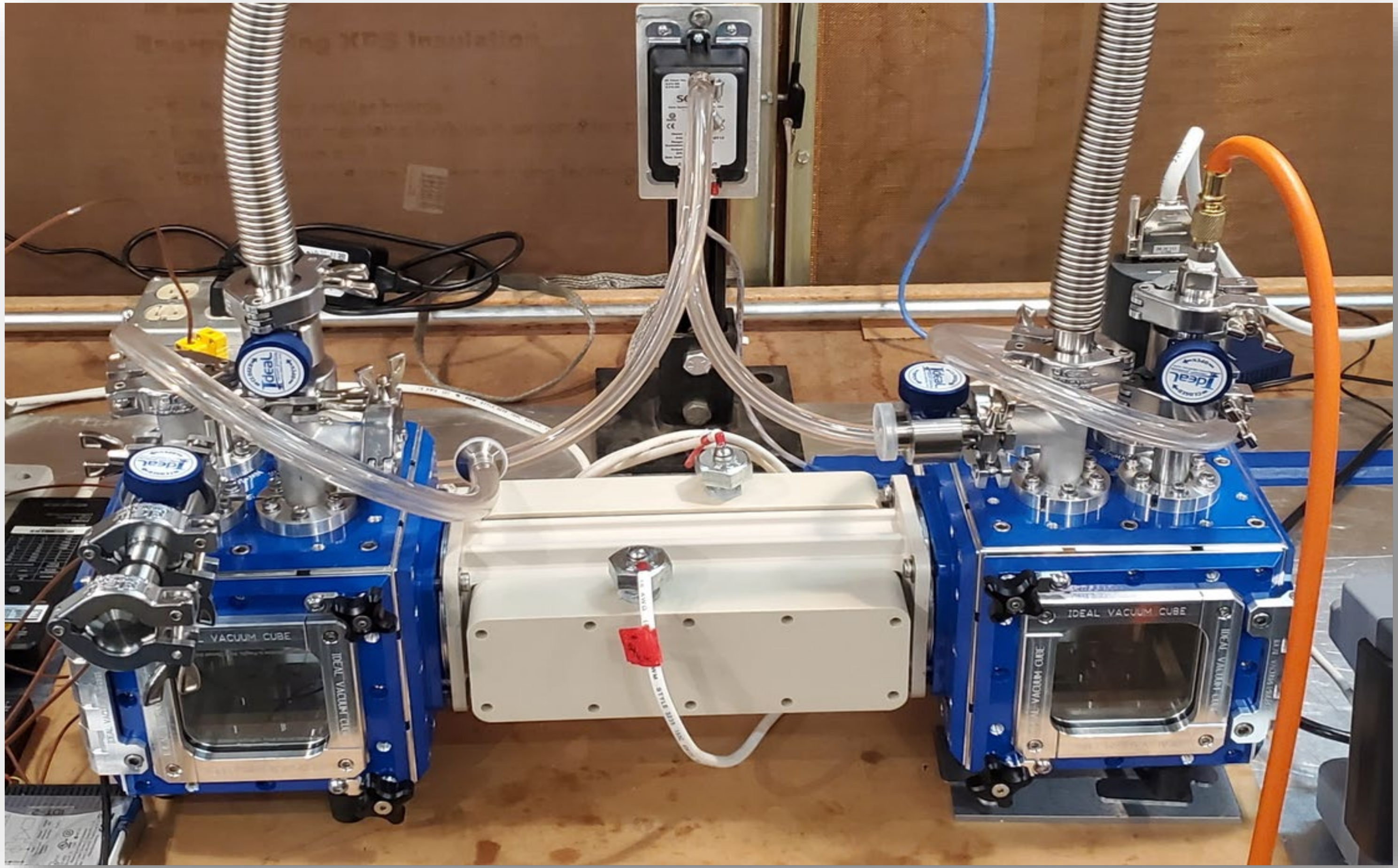
- ~5 quarters into a 3-year project
- Conceptual agreement on approach by project team
  - Electrostatic and thermodynamic analysis
- Prototype design
- Testing approach and test stand design
- Test stand construction
- Prototype construction
- Assembly fully constructed
- Have begun a 2nd approach in parallel (nano-scale)
- All tasks to date completed on schedule and within budget

- Challenges:
  - All discussions meetings have been virtual
  - Unpredictable lead times for procurement of materials
  - Inflating prices for certain components and materials

Experimental Design



Experimental Design



Stakeholder Engagement

- **Currently in early stage of technology (~TRL 1-2)**
- **~40% into project period (5 quarters into 3 years)**
- **Engaged with U.S. utility industry**
  - Southern Company and TVA are both directly involved in the project
- **Engaged with other related technologies**
  - PARC membrane technology
  - Separation of latent & sensible cooling techniques
- **Strong relationships with many U.S. HVAC manufacturers**
- **OTS leading commercialization assessment activities**
- **Activity would dramatically increase upon successful testing**

Remaining Project Work

- **On track or ahead of schedule on all tasks presently**
- **Testing is a current major activity**
- **Design and testing improvements will happen in parallel**
  - Currently exploring a nano-fabricated option
  - Considerations for transition from bench-top to engineered system
- **Commercialization assessment will ramp, pending testing**
- **2^{nd} prototype design and testing**
  - Targeting future commercialization
- **Tech transfer**
  - Reporting, etc.

Thank You

Electric Power Research Institute (EPRI)
Ron Domitrovic, Program Manager
865-218-8061, rdomitrovic@epri.com

REFERENCE SLIDES

Project Budget

Project Budget: See charts below.
Cost to Date: *(As of 6/30/21)* DOE: $523,280.84 | Cost Share: $142,681.34

Budget					
BP 1 (4/20 – 3/21)		BP2 (4/21 – 3/22)		BP3 (4/22 – 3/23)	
DOE	*Cost Share*	*DOE*	*Cost Share*	*DOE*	*Cost Share*
$452,398	$138,099	$439,760	$134,940	$407,842	$126,961
$590,497		$574,700		$534,803	

Expenditures			
BP 1 (Total)		BP2 (Apr-Jun 2021)	
DOE	*Cost Share*	*DOE*	*Cost Share*
$389,831	$124,852	$133,450	$17,829
$514,683		$151,279	

Project Plan and Schedule

Project Start Date: April 1, 2020
Planned Completion Date: March 31, 2023