NETL-RUA’s Carbon Capture Solutions

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NETL-RUA: Strength in Collaboration
Integrated Technology Development

Material Synthesis & Fabrication

Molecular Design & Optimization

Process Synthesis & Techno-economic assessment

Characterization

Material Processing & Device Development

Accelerating Discovery, Development & Deployment

Performance Assessment In Real Environments

COE Sensitivity to Module Separation Efficiency

Case 6 1% Efficiency:
COE = $291/MWh
Membrane ~77% of TPC

3.5% COE increase (Case 6)

Case 6 100% Efficiency:
COE = $88.3/MWh
Membrane ~3% of TPC

7% COE increase (Case 6)
Integrated Technology Development

**Technology Pathway**

<p>| Stage 0: Materials Design: Modeling, Synthesis, and Characterization |</p>
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<tr>
<th>FY 12</th>
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<tr>
<td>Stage 1: Performance Testing (Ideal)</td>
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<td>Stage 2: Performance Testing (Realistic)</td>
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<td>Stage 3: Bench Scale Slipstream</td>
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<td>Stage 4: Scale-up &amp; Module Development</td>
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<td>Stage 5: Pilot Scale Slipstream</td>
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**Technology Transfer**

Industry
Technologies
Supported Amine Sorbents
Miller/Fisher: 10:30 a.m. Monday

John Kitchin, CMU
Angela Goodman, DOE
Damodaran Krishnan, Pitt

Larry Shadle, DOE
David Miller, DOE (CCSI)
Supported Amine Sorbents
Miller/Fisher: 10:30 a.m. Monday

McMahan Gray, DOE
Bingyun Li, WVU

Larry Shadle, DOE
David Miller, DOE (CCSI)

Silica
MOF-based Mixed Matrix Membranes

Albenze: 11:15 a.m. Wednesday

Brian Adzima, ORISE
Hunaid Nulwala, CMU

David Hopkinson, DOE
Surendar Venna, ORISE

Polymer Membrane

MOF

Particle Bypass

“True” MMM Transport

Brain Kail, URS
Nathaniel Rosi, Pitt

CO₂

N₂
PDMS

Chemical Modification

Hunaid Nulwala, CMU
Robert Thompson, URS

Phase Behavior

Bob Enick, Pitt

CSTR Scale-up

Fan Shi, URS
Dave Luebke, DOE
Ionic Liquids

Estimated $10^{18}$ possible ionic liquids

~1000 ionic liquids commercially available

- Highly Tailorable Liquid Salts
  - Negligible Vapor Pressure
  - Good Thermal Stability
  - High CO$_2$ solubility relative to CH$_4$, N$_2$, and H$_2$
Ionic Liquids
Chemical Informatics

Hunaid Nulwala, CMU
Robert Thompson, URS
Michael Lartey, ORISE

1,000,000 ILs Screened

Experiment

Molecular Simulation

Chemical Informatics

Select Best Candidates for Experimental Validation

Screen Huge Library of ILs/ Suggest Candidates

Initial IL

Suggest and Validate Simulation

Provide Force Field, Structure and Solubility

Optimal IL

Berend Smit, Berkeley
Maciej Haranczyk, Berkeley
Jeff Kortright, LBNL
Supported Ionic Liquid Membranes

\[ \text{Permeability} = \text{Solubility} \times \text{Diffusivity} \]

IL Development

Dissolution → Diffusion → Evolution

\[ D_{\text{H}_2} \quad D_{\text{CO}_2} \]
Supported Ionic Liquid Membranes

IL Development
- Dissolution
- Complexing
- Decomplexing
- Diffusion
- Evolution

Polymer Support

Michael Lartey, ORISE

Victor Kusuma, ORISE
Membrane Development
Fiber Modules and High Throughput Testing

Fiber Fabrication

- Core Fluid
- Dope
- Spinneret – cross section
- Air Gap
- Quench Bath
- Take-Up Drum
Membrane Development
Fiber Modules and High Throughput Testing

Fiber Fabrication

Erik Albenze, URS

SILM Fiber Development

Still Too Thick (~20 micron)

Much Too Thick (~200 micron)

Practical Membrane Thickness (~1 micron)

Shan Wickramanayake, URS
Dave Hopkinson, DOE

Lie Hong, URS
Dave Luebke, DOE
Structurally Dynamic MOFs

Christopher Matranga, DOE
Jeff Culp, URS

Andrew Allen, NIST

Mixed Gas Testing

Tom Brown, DOE
Fan Shi, URS

Neutron Scattering
Advanced Research Projects

Phase Change
Amino Acids

Comparison between 30 wt% MEA and 20 AA-K⁺ salts

Bingyun Li, WVU
Fan Shi, URS

N-rich Carbon

Hunaid Nulwala, CMU
Tomasz Kowalewski, CMU
Sittichai Natesakhawat, Pitt
Advanced Research Projects

Layered Double Hydroxides

Jonathan Lekse, URS
Yuhua Duan, DOE

Structured Polymer Membranes

Brian Adzima, ORISE
Krzysztof Matyjaszewski, CMU
NETL-RUA: Creating Technology Solutions

- Unrivaled Understanding of Energy Applications
- Results-based Technology Development Approach
- Vast Array of Expertise and Facilities within NETL-RUA
- Collaborations with World Class Research Organizations
- Proven Record of Achieving Technology Solutions