



# RTI International

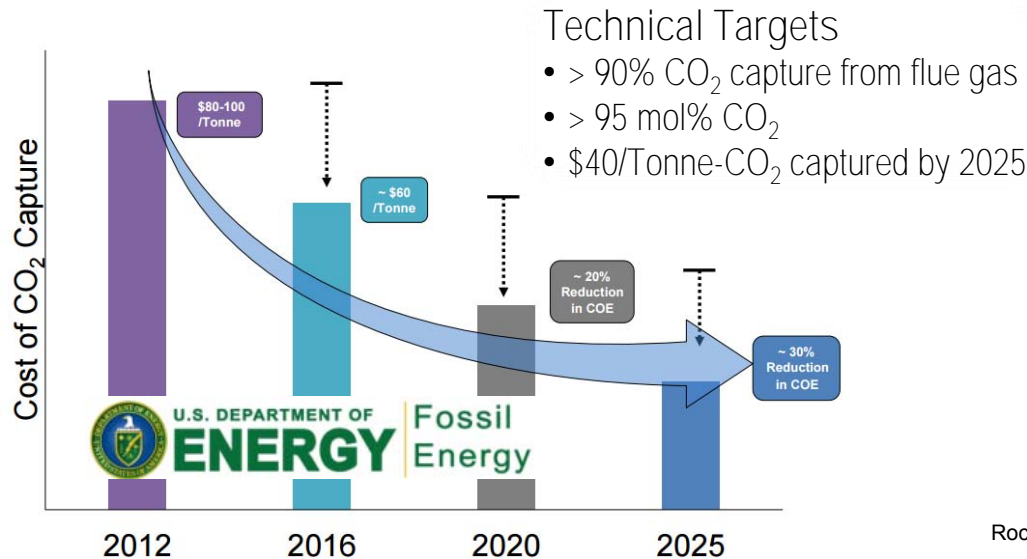
## CO<sub>2</sub> Capture and Utilization Technology Development

DOE/BETO Algae Cultivation for Carbon Capture and Utilization Workshop  
May 23, 2017

David C. Dayton, Fellow and Director of Biofuels  
Shaojun (Jim) Zhou, Director of Gas Separations

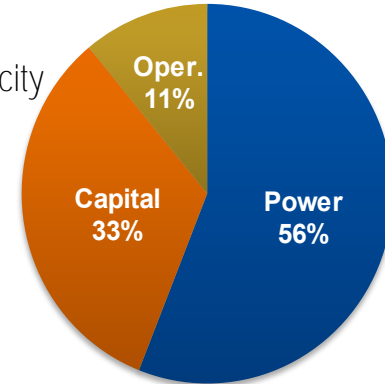


# RTI CO<sub>2</sub> Capture R&D



## Technical Barrier Areas

- Reduce energy consumption
  - Improve reboiler duty
  - Higher CO<sub>2</sub> working capacity
- Reduce capital cost
  - Simplify process
  - Materials of construction
- Limit operating cost increase



Rochelle, G. T. Amine Scrubbing for CO<sub>2</sub> Capture. *Science* **2009**, 325, 1652-1654.

## PROVEN CO<sub>2</sub> CAPTURE TECHNOLOGY

Syngas Cleanup and CO<sub>2</sub> Capture at 50 MW Scale  
(1,000 ton/day CO<sub>2</sub> at a CO<sub>2</sub> >99% purity)

The combination of RTI's WDP and activated amine CO<sub>2</sub> capture (90% capture) results in:

- Reduced levelized cost of electricity (LCOE),
- Reduced overall IGCC capex/kW,
- Reduced overall IGCC opex/MWh
- ~75% reduction in overall sulfur emissions compared to a base case IGCC with dual-stage Selexol™

The WDP+ activated amine process commercially available from Casale S.A.



TECO's Polk Power Station

## RTI's DEVELOPING CO<sub>2</sub> TECHNOLOGIES

	Technical Benefits	Technical Challenges
Non-Aqueous Solvents	<ul style="list-style-type: none"> <li>• Faster absorption kinetics than MEA</li> <li>• Chemically and thermally stable, less degradation</li> <li>• Non-corrosive, non-toxic, and biodegradable</li> </ul>	<ul style="list-style-type: none"> <li>• Solvent cost, capacity, degradation, and emissions</li> <li>• Reboiler duty</li> </ul>
Solid Sorbents	<ul style="list-style-type: none"> <li>• Non-corrosive nature</li> <li>• No vapor emissions</li> <li>• Higher thermal stability</li> </ul>	<ul style="list-style-type: none"> <li>• Sorbent CO<sub>2</sub> capacity and stability</li> <li>• Regeneration energy</li> <li>• Heat management</li> <li>• Counter-current flow</li> </ul>

# RTI Non-Aqueous Solvent Based CO<sub>2</sub> Capture Technology



## Initial Solvent Discovery (2010-2013)

- Solvent formulations developed and tested at the lab (6 L) and large bench scale (300 L/hr)
- Substantial IP estate in materials and process technology

TRL 1 – 3

**\$2.7MM**



## Large Bench-Scale System (RTI facility, 2014-2016)

- Regeneration energy reduced by ~40-50% compared to commercial aMEA solvents
- Lower CAPEX
  - Lower increase cost of electricity
  - Clear pathway to reach DOE goal of \$40/T-CO<sub>2</sub>

TRL 4

**\$3.0MM**



## Pilot Testing at Tiller Plant 60 kWeq - 200 lbCO<sub>2</sub>/day (Norway, 2015-2018)

- 400 hours of baseline testing (propane and coal flue gas)
- Verified reduced regeneration energy
- Additional long-term testing with coal flue gas scheduled for this year

TRL 5 – 6

**2.7MM**



## Pre-Commercial Demonstration at TCM ~10 MWeq (Norway, 2018+)

Planning and pre-qualification stage

TRL 7 – 8



From discovery through large scale (10 MW) demonstration

# RTI Solid Sorbent Based CO<sub>2</sub> Capture Technology

## 1<sup>st</sup> and 2<sup>nd</sup> Generation Sorbents

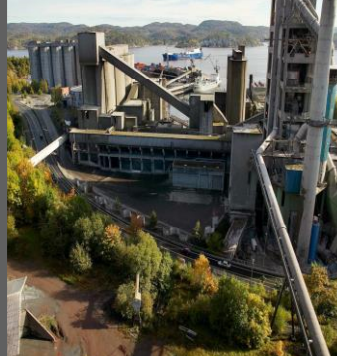
Initial Sorbent  
Discovery  
(10 – 200 g: TRL 2-4 )  
**\$3.8MM**  
2011 – 2015



- >25% reduction in cost of CO<sub>2</sub> capture, potential for up to 40% cost reduction
- ~ 40% energy reduction compared with SOTA MEA based technology
- Lower CAPEX
- High CO<sub>2</sub> loading capacity (~10 wt%)
- Relatively low heat of absorption; no heat of vaporization penalty
- No evaporative emissions
- Sorbent production scaled up to 1,000 kg scale



NORCEM Cement  
Plant Pilot Testing  
(150 kg : TRL 5)  
**\$2.1MM**  
2013 – 2016



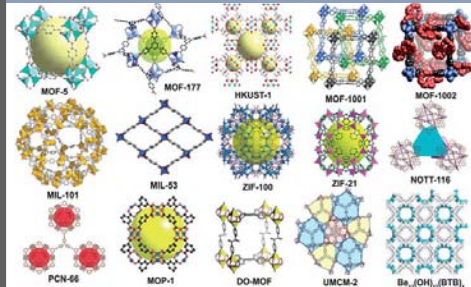
- Fluidized bed adsorption/desorption process testing with actual cement plant flue gas at a sorbent circulation rate of 100 kg/hr and CO<sub>2</sub> capture rate of 110 kg/day.
- Commercial design for cement plant application
- Design, build, and test a prototype of RTI's solid sorbent CO<sub>2</sub> capture technology
- Evaluate CO<sub>2</sub> capture performance
- Update economics with pilot test data



Demonstrated the technical and economic **feasibility of RTI's solid sorbent CO<sub>2</sub>** capture process in an operating cement plant

## 3<sup>rd</sup> Generation Sorbents

3<sup>rd</sup> Generation Sorbent  
Development (1-10 g: TRL 3-4)  
**\$3MM**  
2015 – 2017



- Metal organic framework and dendrimer based, fluidizable sorbents
- Higher CO<sub>2</sub> capacity and sorbent stability
- Attrition resistance
- Tunable pore sizes
- Exceptionally high surface areas