**RTI CO₂ Capture R&D**

**Technical Targets**
- > 90% CO₂ capture from flue gas
- > 95 mol% CO₂
- $40/tonne-CO₂ captured by 2025

**Technical Barrier Areas**
- Reduce energy consumption
  - Improve reboiler duty
  - Higher CO₂ working capacity
- Reduce capital cost
  - Simplify process
  - Materials of construction
- Limit operating cost increase

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**PROVEN CO₂ CAPTURE TECHNOLOGY**

**Syngas Cleanup and CO₂ Capture at 50 MW Scale**
(1,000 ton/day CO₂ at a CO₂ >99% purity)

The combination of RTI’s WDP and activated amine CO₂ 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.*

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**RTI’s DEVELOPING CO₂ TECHNOLOGIES**

<table>
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<tr>
<th>Non-Aqueous Solvents</th>
<th>Technical Benefits</th>
<th>Technical Challenges</th>
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<tr>
<td></td>
<td>Faster absorption kinetics than MEA</td>
<td>Solvent cost, capacity, degradation, and emissions</td>
</tr>
<tr>
<td></td>
<td>Chemically and thermally stable, less degradation</td>
<td>Reboiler duty</td>
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<tr>
<td></td>
<td>Non-corrosive, non-toxic, and biodegradable</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Solid Sorbents</th>
<th>Technical Benefits</th>
<th>Technical Challenges</th>
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<tr>
<td></td>
<td>Non-corrosive nature</td>
<td>Sorbent CO₂ capacity and stability</td>
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<td>No vapor emissions</td>
<td>Regeneration energy</td>
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<td>Higher thermal stability</td>
<td>Heat management</td>
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<td>Counter-current flow</td>
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</tbody>
</table>
RTI Non-Aqueous Solvent Based CO₂ 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

**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-CO₂

**Pilot Testing at Tiller Plant**
60 kWeq - 200 lbCO₂/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

**Pre-Commercial Demonstration at TCM ~10 MWeq**
(Norway, 2018+)
Planning and pre-qualification stage

**TRLs and Funding**

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<th>TRL</th>
<th>Stage</th>
<th>Budget</th>
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<tr>
<td>1 – 3</td>
<td>Initial Solvent Discovery</td>
<td>$2.7MM</td>
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<td>4</td>
<td>Large Bench-Scale System</td>
<td>$3.0MM</td>
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<td>5 – 6</td>
<td>Pilot Testing at Tiller Plant</td>
<td>$2.7MM</td>
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<td>7 – 8</td>
<td>Pre-Commercial Demonstration at TCM</td>
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</tr>
</tbody>
</table>

From discovery through large scale (10 MW) demonstration
RTI Solid Sorbent Based CO$_2$ Capture Technology

1$^{\text{st}}$ and 2$^{\text{nd}}$ Generation Sorbents

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

- >25% reduction in cost of CO$_2$ capture, potential for up to 40% cost reduction  
- ~40% energy reduction compared with SOTA MEA based technology  
- Lower CAPEX  
- High CO$_2$ 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)  
$2.1\text{MM}$  
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$_2$ capture rate of 110 kg/day.  
- Commercial design for cement plant application  
- Design, build, and test a prototype of RTI’s solid sorbent CO$_2$ capture technology  
- Evaluate CO$_2$ capture performance  
- Update economics with pilot test data

Demonstrated the technical and economic feasibility of RTI’s solid sorbent CO$_2$ capture process in an operating cement plant

3$^{\text{rd}}$ Generation Sorbents

**3$^{\text{rd}}$ Generation Sorbent Development**  
(1-10 g: TRL 3-4)  
$3\text{MM}$  
2015 – 2017

- Metal organic framework and dendrimer based, fluidizable sorbents  
- Higher CO$_2$ capacity and sorbent stability  
- Attrition resistance  
- Tunable pore sizes  
- Exceptionally high surface areas