Demonstration Results of Enzyme-Accelerated CO₂ Capture

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GHGT-13

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Forward Looking Statements

All statements in this presentation that are other than statements of historical facts are forward-looking statements which contain our current expectations about our future results. Forward-looking statements involve numerous risks and uncertainties. We have attempted to identify any forward-looking statements by using words such as “anticipates”, “believes”, “could”, “expects”, “intends”, “may”, “should” and other similar expressions.

Although we believe that the expectations reflected in all of our forward-looking statements are reasonable, we can give no assurance that such expectations will prove to be correct. A number of factors may affect our future results and may cause those results to differ materially from those indicated in any forward-looking statements made by us or on our behalf. Such factors include our early stage of technology development; our need for capital to finance necessary research and product development; our ability to attract and retain key employees and strategic partners; our ability to achieve and maintain profitability; fluctuations in the trading price and volume of our stock; competition from other providers of similar products and services; and other unanticipated future events and conditions.

For further information concerning risks and uncertainties that may affect our future results, please review the disclosures as may be contained from time to time in our filings with SEDAR. Other than as required by applicable securities laws, we undertake no obligation to publicly update or revise any of our forward-looking statements, whether as a result of changed circumstances, new information, future events, or for any other reason occurring after the date of this presentation. This presentation does not constitute an offer to sell or solicitation of an offer to buy securities in any jurisdiction.
About CO$_2$ Solutions Inc.

- Leader in the field of enzyme-based CO$_2$ capture
- >$50$ million invested to date
- $22$ employees, including $7$ PhDs
- $46$ issued and $37$ pending patents
- Entering commercial phase
- Publicly traded on TSX Venture Exchange (Symbol: CST)
• High-temperature stripping (>120°C) requires use of high-grade steam
CO₂ Solutions’ Process – An ‘Industrial Lung’

LOW COST, NON-TOXIC CARBONATE SOLVENT

USES STANDARD GAS TREATMENT EQUIPMENT

USES LOW-GRADE HEAT (~80°C) FOR REGENERATION ENERGY
CO₂ Solutions’ Process – An ‘Industrial Lung’

- **NO AEROSOLS**
- **No waterwash**
- **No filter**
- **No solvent makeup**
- **No reclaimers**
- **No toxic wastes**
Robust Patent Portfolio

BROAD PATENT PORTFOLIO FOR USE OF CARBONIC ANHYDRASE IN CANADA, U.S., EU, CHINA, AUSTRALIA AND OTHER MARKETS

46 ISSUED 37 PENDING

SOLVENTS
Amines
Carbonates
Amino Acids
Combinations

INDUSTRIAL SECTORS
Power
Steam
‘Drop-in’ Applications

PROCESSES
Packed Tower
Spray Scrubber
Bubble Column
Universal

ENZYME UTILIZATION
Soluble
Particle-Based
Analogs

Areas of Carbonic Anhydrase CO₂ Capture Application
Scale-Up Progress

<2014 Lab and Bench-Scale: 0.5tpd

2014-2015 Pilot: 1tpd

2015 Demonstration: 10tpd

2016+ Commercial

tpd = metric tonnes CO₂ captured per day
10 tpd Demo Overview

- >2,500 operating hours completed near Montreal in summer and fall of 2015
- \( \text{CO}_2 \) capture from flue gases of natural gas fired boiler
- Used \( \text{CO}_2 \) Solutions’ proprietary ‘1T1’ enzyme
- Built on schedule in 1 year from engineering to commissioning and on budget
Demo – Design Basis

- Built in cooperation with Seneca Experts Conseils Inc.
- Flue gas properties
  - Burning of natural gas
  - Temperature: 30°C (after quench)
  - Pressure: 102 kPa(a)
  - Composition (mol%):
    - $\text{CO}_2$: 9.7
    - $\text{H}_2\text{O}$: 4.2
    - $\text{N}_2$: 83.2
    - $\text{O}_2$: 2.9
- $\text{CO}_2$ absorption was between 30°C and 40°C
- Enzyme was added via mixing tank and homogeneously dissolved in solvent flowing freely throughout the absorber and stripper
- Stripping used hot water produced by boiler at between 80°C to 85°C, simulating low-grade, nil value heat
- Stripping was at ~0.3 bara using single stage liquid ring vacuum blower
- $\text{CO}_2$ produced saturated
- Power needed for equipment was supplied by on-site diesel generator
Demo – Solvents

- Operation was divided into three phases according to solvents tested:

<table>
<thead>
<tr>
<th>Run</th>
<th>Period</th>
<th>Solvent Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>June-August, 2015</td>
<td>1.45 M K₂CO₃ 0-0.5 g/l enzyme</td>
</tr>
<tr>
<td>2</td>
<td>August-September, 2015</td>
<td>1.45 M K₂CO₃ 0-0.5 g/l enzyme 0-0.18 M additive</td>
</tr>
<tr>
<td>3</td>
<td>October, 2015</td>
<td>1.45 M K₂CO₃ 0-0.5 g/l enzyme</td>
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</tbody>
</table>

- Solvent additive (Run 2) was tested with potential to improve its VLE properties, but did not bring expected benefits

- Solvents were benchmarked against carbonates without enzyme
Demo – Enzyme Program

- Use of industrially stable carbonic anhydrase is key; Enzyme must remain active despite high surface to volume ratio, high temperature, high ionic strength, high pH and high shear stress

- Two pronged program:
  - Use of natural enzymes that can withstand process conditions (at least partially)
  - Improving these natural enzymes using directed evolution

- In-house development

- Start with thermophilic enzymes (stable to >75°C) and then create mutants with resistance to the other stresses

Enzyme stability improvements of various CA mutants by exposure to constant temperature (60°C) in 20 wt% $\text{K}_2\text{CO}_3$/KHCO$_3$
• **CO₂** capture rates of between 65% and 95% were attained; ability to achieve a range of performance objectives

• Capture rate can be adjusted and controlled

• Design capacity of the plant was reached with enzyme concentration of ¼ of planned amount

Percentage of CO₂ capture vs. lean solvent loading
Demo – Enzyme Stability

- In-Process, free enzyme stability
  - No enzyme deactivation observed over operation period
Demo – Energy Consumption

- ProTreat® rate-based simulator from Optimized Gas Treating Inc. (OGT) used to perform mass and energy balances, and to size absorber and stripper
  - CO₂ Solutions collaboration with OGT developed kinetic module to represent the catalytic effect enzyme in a K₂CO₃/KHCO₃ solvent
- Comparison of the plant data vs ProTreat® simulation results (Solvent composition: 1.45M K₂CO₃ & 0.5 g/l enzyme)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Pilot</th>
<th>Simulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>L/G</td>
<td>Kg/kg</td>
<td>10.8</td>
<td>11.0</td>
</tr>
<tr>
<td>Lean Solvent Loading</td>
<td>-</td>
<td>0.506</td>
<td>0.506</td>
</tr>
<tr>
<td>Rich Solvent Loading</td>
<td>-</td>
<td>0.708</td>
<td>0.708</td>
</tr>
<tr>
<td>CO₂ captured</td>
<td>%</td>
<td>83</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>Ton/day</td>
<td>7.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Reboiler Duty</td>
<td>GJ/tonCO₂</td>
<td>3.6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

- 3.6 GJ/tonne consumption (low-grade (>80°C), nil value heat)
Demo – Environmental Performance

- No solvent degradation observed
- No solvent make-up was required
- Entire solvent volume was sent to municipal sewer at end of campaign without treatment
- NOx in the flue gas is absorbed in the solvent and is converted into nitrates and nitrites which accumulate slowly over time
  - Solvent can be bled conventionally
  - SOx in flue gas (i.e. for coal) handled in same manner
Demo – CO₂ Purity and Operation

• Produced CO₂ Purity
  • Analysis performed by Airborne Labs International
  • Purity was 99.5% after accounting for presence of O₂ and N₂ due to small amounts of air infiltration
  • Only simple post-treatment needed for food and beverage use

• Autonomous operation
  • Beyond first 11 weeks of operation, operators were only needed during the day, mainly for sampling
  • Unit controlled remotely
Larger Scale Application

- Performance data from demo validated by Tetratech Inc. for larger scale costing
- Base case
  - Full-size once-through steam generator (OTSG); Natural gas combustion
  - 1250 tonnes CO$_2$/day captured
- Cost of capture (before compression and ROC)

<table>
<thead>
<tr>
<th></th>
<th>($/t CO$_2$)</th>
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<tbody>
<tr>
<td>Fixed Costs</td>
<td>6.9</td>
</tr>
<tr>
<td>Variable costs</td>
<td>12.6</td>
</tr>
<tr>
<td>Total Capital Req. (30 year amort.)</td>
<td>8.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$28.0</strong></td>
</tr>
</tbody>
</table>

- Further cost reduction initiatives based on 10tpd demo learnings
  - Absorber sizing optimization
  - Non-steel materials
  - Heat circuit optimization
  - Modularization and containerization
Commercial Greenhouse Project

- Saint-Félicien, QC

- Capture of up to 30tpd CO₂ from Resolute Forest Products’ pulp mill
  - Utilize mill’s low-grade / waste heat for process

- Pipelining of CO₂ to neighbouring Serres Toundra vegetable greenhouse

- Full CO₂ value chain enabled by CO₂ Solutions’ technology
Alberta Project

- $15 million from CCEMC towards $30M first commercial scale deployment of CO$_2$ Solutions’ process in Alberta; up to 300 tonnes-CO$_2$/day
- Capture CO$_2$ from flue gases and utilize and/or sequester for GHG reductions
- Long-term operation following techno-economic reporting period
- Generates Alberta credit of ~$24/tonne-CO$_2$ captured and utilized/sequestered
- Positions technology for broad Alberta deployment to reduce GHG from oil and gas industry
- Seeking consortium partners
CO\textsubscript{2} Solutions’ Process for EOR/Sequestration

- Larger net GHG reduction than amine technology through use of low-grade / waste heat
- Generates Alberta credit of ~$24/tonne-CO\textsubscript{2} captured and utilized/sequestered
Capture and New CO₂ Reuse Processes - Closing the CO₂ Loop

- Renewable, Value-Added Products

Industry

3-30%

CO₂ Capture

99%+

CO₂ Conversion/Reuse

$15M from Government of Quebec for development and demonstration
THANK YOU

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