Small Scale CO2 Capture: 3 Case Studies

#CraftBrewersCon
Our Vision: Keep the planet cool.

Mission: Avoid 1 Billion metric tons of CO₂ emissions
Small Scale CO2 Recovery Solutions
Advancing Proven Science for Small Craft Brewers

The Standard Method for CO₂ Recovery

1. 1998 US Craft Brewer
   1 MM Lbs CO2 Reduced

2. 2015-17 Chico & NC Facility
   $1 MM / 2 Year Payback

Featured in Brewer’s Association Sustainability Best Practices

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How Much CO2 Do We Use? CO2 / BBL

CO2 Usage Insights
- National Average 4 – 21 lbs / BBL
- Findings of Survey – 100 Breweries
- Primary Areas of Use:
  1. Fermentation Tanks
  2. Canning
  3. Kegging
  4. Pushing Beer
  5. Cleaning Tanks and Pipes

Ways to Reduce CO2 Usage
- Assess usage vs national average
- Assess Usage Points and compare
- Icing on tanks when not in use suggest leaks
- Allowing tanks to purge overnight drains tanks
- Create best practices and monitor personnel

POLL #1: How much CO2 do you use per BBL?

Go to website:
Sli.do
Enter # D165
Small Scale CO₂ Solution
First Plug-n-Play CO2 Recovery Solution

Earthly Labs

CO₂ Unit CiCi™
(Patent-pending)

CO₂ Software
(Patent-pending)

Foam Trap

CO₂ Storage

CO₂ Quality Assurance
The ABGB Case Study

Brewery History Founded in 2013
• “Best Large Brew Pub” (2016, 2017)
• 1,700 BBL in Austin, Texas
• Brew Pub with To-Go Cans
• Committed to Community & Reducing Waste

CO2 Profile
• Produce More CO2 in Fermentation vs Consume

Key Pilot Goals
• Reduce or Eliminate CO2 Costs
• Reduce Greenhouse Gases
• Advance “Hell Yes” Program Goals
Pilot Experience & Next Steps

Pilot Experience
- Easy Installation in Hours
- 3 Phase 208 Connection
- Deliver on a Forklift
- Flex Tubing (Temporary) Plumb to Tanks
- Refrigerator Size Footprint in Limited Space
- Simple Foam Trap
- Use on fermentation and bright tank
- CO2 Storage can replace “rented” systems

R & D Efforts for Small Brewhouse & Tap Room
- Below 2000 BBL
- Address low flow & low pressure
Beer Quality Test & Results

- Carbonated Same Pale Ale with Recovered CO2 & Commercial CO2
- Brewer Blind Taste Tests to Determine Difference & Preference
- Results: 19, Earthly (11), Commercial (7), Neutral (1)
- Quality Insights – Carbonation Head, Aroma, Lacing
Celis Brewery - CO₂ Case Study

Brewery History
- Founded in Belgium in 1966 by Pierre Celis
- First Austin brewery opened July 11, 1992
- Reopened in Austin, TX in 2017
- Christine Celis & daughter Daytona
- 24,000 BBL with expansion planned
- #1 Product Celis White, Belgian wit
- Bottles and cans distributed throughout Texas

CO₂ PROFILE
- CO₂ captured ~85% of CO₂ consumed

Driving Force
- Reduce CO₂ waste and costs
- Be an innovator
- Improve safety of facility through reduced CO₂
- Align brand with doing good
# Third Party CO₂ Quality Test

<table>
<thead>
<tr>
<th>RESULT</th>
<th>PARAMETER, CHEMICAL FORMULA (UNITS)</th>
<th>DL</th>
<th>METHOD</th>
<th>ISBT Guideline Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>99.99+</td>
<td>Purity, CO₂ (% v/v)</td>
<td>5.</td>
<td>ISBT 4.0</td>
<td>99.9% v/v min.</td>
</tr>
<tr>
<td>nd</td>
<td>Moisture, H₂O (ppm v/v)</td>
<td>1.</td>
<td>ISBT 3.0</td>
<td>20 ppm v/v max.</td>
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<tr>
<td>nd</td>
<td>Oxygen, O₂ (ppm v/v)</td>
<td>4.</td>
<td>ISBT 4.0</td>
<td>30 ppm v/v max.</td>
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<tr>
<td>nd</td>
<td>Carbon Monoxide, CO (ppm v/v)</td>
<td>0.5</td>
<td>ISBT 5.0</td>
<td>20 ppm v/v max.</td>
</tr>
<tr>
<td>nd</td>
<td>Ammonia, NH₃ (ppm v/v)</td>
<td>0.5</td>
<td>ISBT 6.0</td>
<td>2.5 ppm v/v max.</td>
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<tr>
<td>nd</td>
<td>Nitrogen Monoxide, NO (ppm v/v)</td>
<td>0.5</td>
<td>ISBT 7.0-1</td>
<td>10 ppm v/v max.</td>
</tr>
<tr>
<td>nd</td>
<td>Nitrogen Dioxide, NO₂ (ppm v/v)</td>
<td>0.5</td>
<td>ISBT 7.0-1</td>
<td>2.5 ppm v/v max.</td>
</tr>
<tr>
<td>nd</td>
<td>Non-volatile Residue, NVR (ppm w/w)</td>
<td>1.</td>
<td>ISBT 8.0</td>
<td>10 ppm w/w max.</td>
</tr>
<tr>
<td>nd</td>
<td>Non-volatile Organic Residue, NVOR (ppm w/w)</td>
<td>1.</td>
<td>ISBT 8.0</td>
<td>5 ppm w/w max.</td>
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<tr>
<td>nd</td>
<td>Methanol, MeOH (ppm v/v)</td>
<td>0.2</td>
<td>ISBT 9.0</td>
<td>10 ppm v/v max.</td>
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<tr>
<td>1.4</td>
<td>Total Volatile Hydrocarbons, THC (ppm v/v as CH₄)</td>
<td>0.1</td>
<td>ISBT 10.0-1</td>
<td>50 ppm v/v max.</td>
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<tr>
<td>nd</td>
<td>Total Non-Methane HC's, TMMHC (ppm v/v as CH₄)</td>
<td>0.1</td>
<td>ISBT 10.0-1</td>
<td>20 ppm v/v max.</td>
</tr>
<tr>
<td>nd</td>
<td>Acetaldehyde, AA (ppm v/v)</td>
<td>0.05</td>
<td>ISBT 11.0</td>
<td>0.2 ppm v/v max.</td>
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<tr>
<td>nd</td>
<td>Aromatic Hydrocarbon, AHC (ppb v/v as C₆H₆)</td>
<td>2.</td>
<td>ISBT 12.0</td>
<td>20 ppb v/v max.</td>
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<tr>
<td>nd</td>
<td>Total Sulfur Content, TSC (ppm v/v as S)</td>
<td>0.02</td>
<td>ISBT 13.0</td>
<td>0.1 ppm v/v max. (excl. SO₂)</td>
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<tr>
<td>nd</td>
<td>Sulfur Dioxide, SO₂ (ppm v/v)</td>
<td>0.02</td>
<td>ISBT 14.0</td>
<td>1 ppm v/v max.</td>
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</tbody>
</table>

**Sensory Tests**

- Odor of Solid CO₂ (Snow Residue)
- Appearance of Solid CO₂ (Snow Residue)

**PASS**

- Odor in Water
- Taste in Water
- Appearance in Water

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CO₂ Sensory Quality Check
Carbonated Water Test for Recovered CO₂

Demonstrate Sensory Quality Checks
- Low levels of VOC going into activated carbon filter
- Low risk of breakthrough of activated carbon filter
- How to test CO₂ for flavor-impacting impurities
- Sensory analysis of carbonated water
- Cheap, easy, little to no additional equipment

Scope Test
- Carbonated with CO₂ in Water over 3 Days
- 2 Corny Kegs in Ice Bath, 30 lbs CO₂
- 11 Taste Testers

Results
- 95% Confidence Level
- Preferred recovered CO₂ Water
- Commercial Tasted like “Metallic” and “Plastic”
**CO₂ Quality Check – Monitoring O₂**

Nondetectable Oxygen limits in CO₂

- Recovered CO₂ show nondetectable limits of O₂ in all third-party ISBT tests
- Earthly system has O₂ sensor on inlet
- Periodically monitor O₂ in recovered CO₂
- O₂ meter (gas) is best solution for quality control
**Brewery History**
Founded in 2009
- 12,000 BBL in Austin, Texas
- Organic Beers, Porters
- Distribute Organic Beer Kegs in Texas
- Committed to Sustainability

**CO2 Profile**
- Fermentation 3X total CO2 needed

**Capture Pilot Tests**
- ISO 10399 Duo Trio Test
- Great carbonation, visual likeness
- Test revealed no discernible difference
- Oxygen readings 11 ppb – 17 ppb

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Hops & Grain: Case Study

Brewery History Founded in 2011
- 8,500 BBL in Austin, Texas, Adding 15,000 BBL in San Marcos
- Tap Room and Distribution in Texas and Colorado
- Committed to Sustainability in all we do

CO2 Profile
- Fermentation blowoff produces 3X total CO2 needed

Key Benefits
- Reduce CO2 Costs, Capture 1.3x What Purchased
- Reduce Greenhouse Gases 44%
- Advance Sustainability Goals
- ROI – 1 -2 Years
- Transparent consumer engagement opportunity
- Brand building opportunity

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CO2 Quality Tests – Internal & Third-party

- Third-party ISBT Recovered CO2 Test Non-detect in all major impurities
- Yields Very Pure CO2 Better than Commercial PPB – 6 – 13 PPB, vs 30 PPB
- Descriptive Analysis results using the Beer Flavor Map shows more flavor attributes detected in recovered CO2 product sample vs. standard CO2 sample
- Shelf Life Test- True to Target Sensory test shows recovered CO2 product sample retains true to brand attributes approximately 30 days longer than standard CO2 product sample

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Commercial Install & Next Steps

Commercial Unit
- 99.99% Pure CO2
- CO2 Capture Rate Improvement
- Digital At-a-glance CO2 monitoring
- Easy to Maintain, Wet Rated

Next Steps
- Market Launch & Storytelling
- Drive Demand and Preference
- Retailer Showcase
Global Climate Goals by 2050
Carbon Capture Solves 13% 60 GT CO₂ Goals

City of Austin Net Zero Example

TO STAY ON TRACK WITH THE NET-ZERO GOAL, WE NEED TO REDUCE EMISSIONS TO:

<table>
<thead>
<tr>
<th>Year</th>
<th>Emissions (Million Metric Tons)</th>
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<tbody>
<tr>
<td>Today</td>
<td>13.7</td>
</tr>
<tr>
<td>2020</td>
<td>11.3</td>
</tr>
<tr>
<td>2030</td>
<td>8</td>
</tr>
<tr>
<td>2040</td>
<td>4.6</td>
</tr>
</tbody>
</table>

Brewers can address ~6%
Small Scale CO₂ Recovery Benefits

- Recovering CO₂ is Possible for Small Brewers
- Brewers Can Reduce or Eliminate CO₂ Costs
- Increase Reliability of CO₂
- Improved CO₂ Purity Can Improve Quality and Shelf Life
- Simple CO₂ Lab Tests Validate CO₂ Quality
- Improve Safety in Brewery
- Recovered CO₂ Can Drive Preference Among Consumers & Retailers
- Achieve Sustainability and Waste Reduction Goals
Q&A

1. What size do I need to be?
2. How big is the unit?
3. What does maintenance look like?
4. What is the energy use per hour?
5. What is the average ROI?
6. Does this reduce my carbon footprint?

Ask your questions
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