

Brewery Case Studies of Carbon Capture and Nitrogen Dosing

Presenters

Christina Marrick – Business Development Manager
Alex Calkins – Technical Solutions Manager



NEXUS OF CLEAN™

We developed an all-encompassing approach to support sustainability and ESG goals

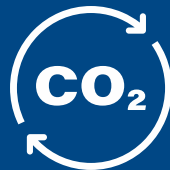
High Recovery | Low-Waste | Minimal-Emission



Water
Treatment
Optimization



Wastewater
Treatment



Carbon
Capture



Cryogenic Gas
Dissolution



Green
H2



More of Chart: New Markets, New Geographies

Africa, South America, Middle East, and expansion of existing geographies



Expanding Exposure to Additional Markets



☐ Howden additions

 Industrial Gas	 Over the Road	 CCUS	 Molecules by Rail	 Water	 Nuclear	 Energy Recovery
 Energy & Chemical	 Hydrogen	 Space	 Cannabis	 Lasers	 Biomass	 Tunnel & Metro
 LNG	 Food & Beverage	 Biofuels	 Marine Systems	 Critical Care	 Metal	 Mining



Chart Industries completes the acquisition of Howden

Friday, 17 March 2023

Share



Chart's Global Team Helps World Leaders Grow



Courtesy of Shell, 2019



It all adds up



64

The number of manufacturing sites globally



50

The number of countries we operate in



169

The number of countries our products are installed in



50

The number of repair and service sites globally



1500+

Engineers on our team



1000+

Trademarks and patents held

Operational Challenges, Anyone?

- Cost effective operation
- Effective packaging
- Product shelf life
- Carbon footprint
- CO₂ shortage
- Water ratio (water / beer)
- Increasing water & power rates
- Meeting WW discharge permit
- Public opinion & perception
- Expectation to commit to sustainability goals



Nitrogen Dosers

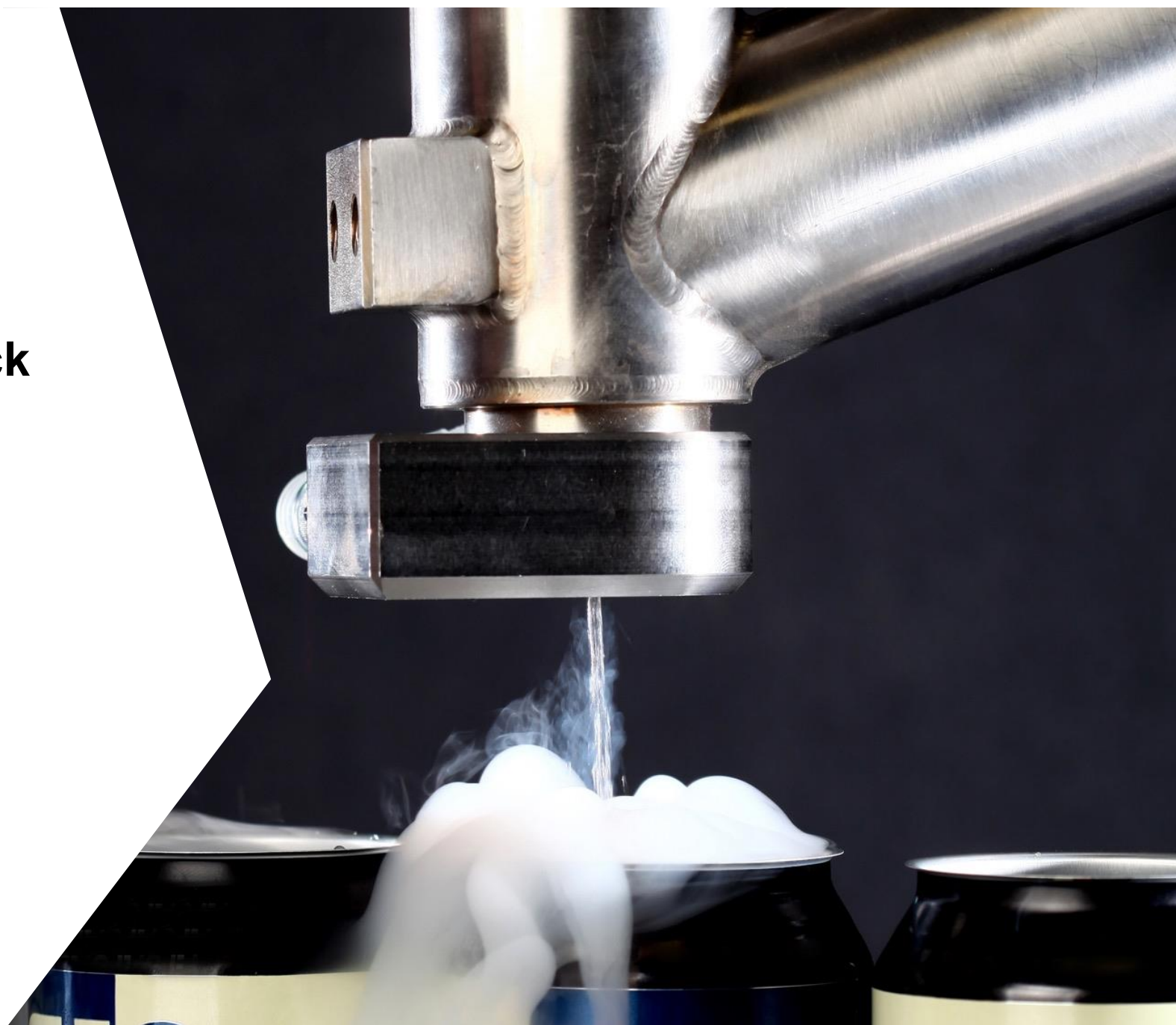
Precise Dosing for Pressurization, TPO reduction for Extended Shelf Life, and Nitrogenation

Carbon Capture

Reduce CO₂ costs and Supply Independence

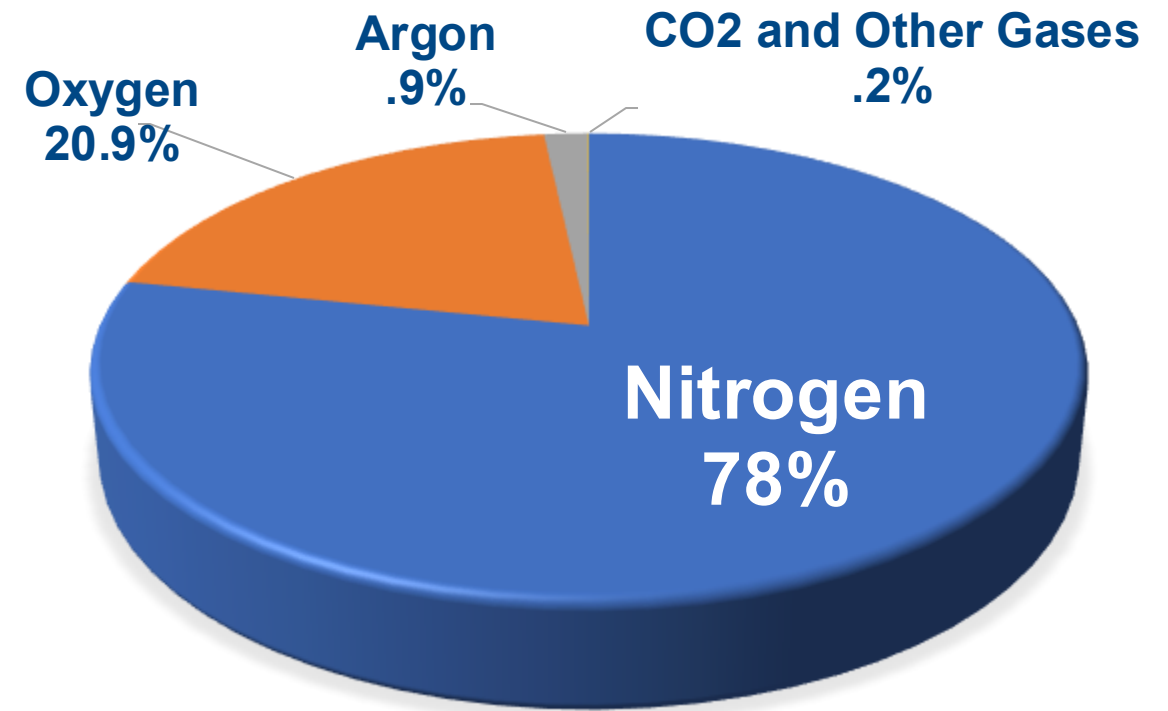
Fundamentals of Nitrogen Dosing

Presented by Christina Marrick

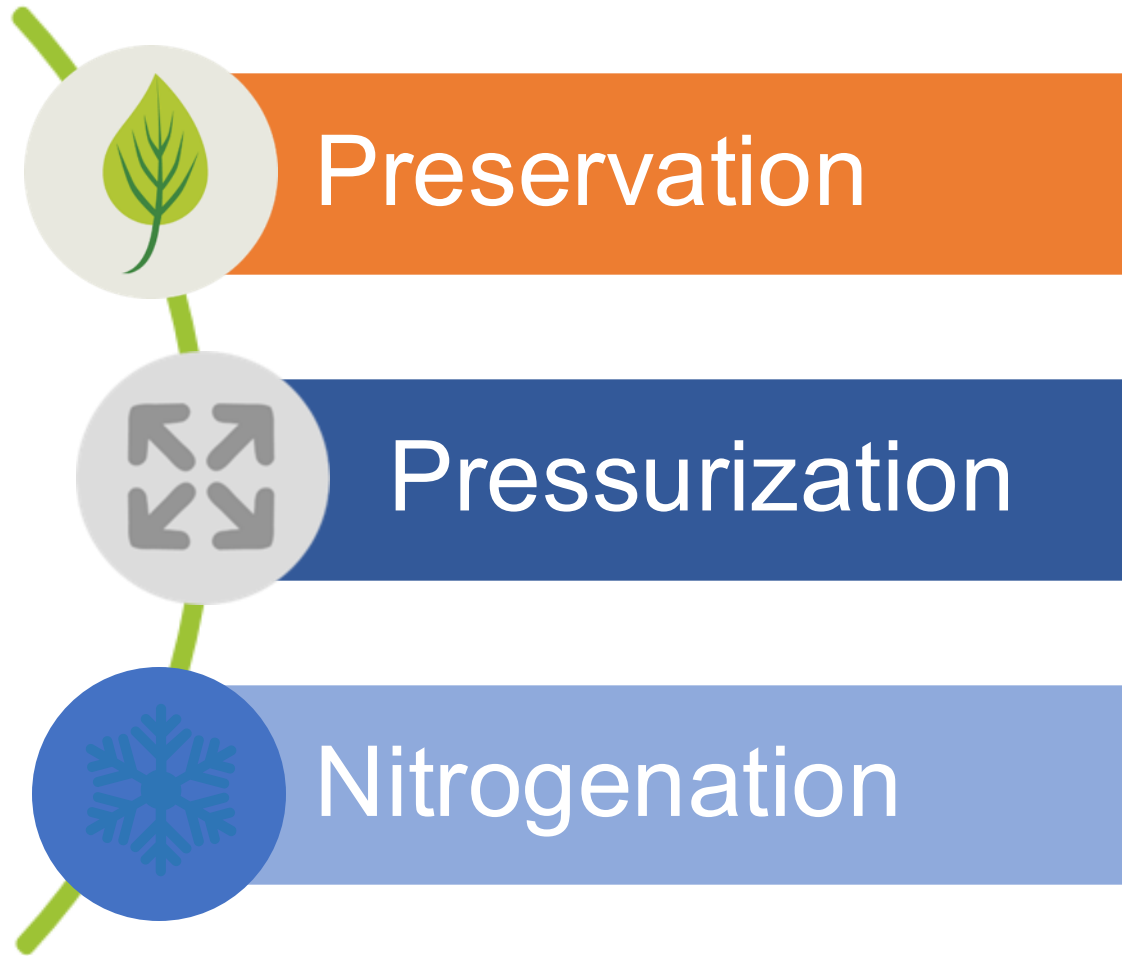


**Nitrogen is the
most Common Gas
Found in the Air...**

**...but it can only exist as
a liquid at temperatures
below -320F**



Three Primary Benefits of LN₂ Dosing



- Beverage Sector

- Still Water
- Juice
- Tea
- Beer
- Coffee
- Wine
- RTD
- Soft Drinks

- Packaging Sector

- Nuts / Trail Mix
- Powdered Products
- Soups & Syrups
- Spices
- Cannabis
- Pet Food
- Detergents and Disinfectant Fluids
- Vitamins and Pharmaceuticals
- Oils and Lubricants

Liquid Nitrogen Expansion

- Expands rapidly from a liquid to a gas
- 1 : 694 volumetric expansion
- 0.5g dose equates to 430ml after accounting for density
- Visual “fog” characteristic of cold-water vapor is being pushed out of the head space as the nitrogen expands





CryoDoser Flex Craft Custom

- Specifically designed for the craft beverage industry
- Compact and easy to operate
- Works easily with most fillers
- Dynamic Dose Duration for In-Line Fillers
- Integrated Purge
- Grow from introductory canning line to 750cpm
- Removable arm for custom heads



CD FleX Craft Custom Nozzle Flow Test

Item no.	Nozzle size	Actual size	Flow g/min.	Flow L/min.	Flow L/sec.	mL/sec.	Duration mS)	grams/dose
1	0.020"	0.020"	11.5	0.0142	0.0002	0.2370	20	0.0038
2	0.030"	0.031"	30.2	0.0373	0.0006	0.6224	60	0.0302
3	0.040"	0.037"	63.1	0.0780	0.0013	1.2994	45	0.0473
4	0.050"	0.051"	127.5	0.1577	0.0026	2.6277	80	0.1700
5	0.060"	0.058"	188.9	0.2336	0.0039	3.8931	50	0.1574
6	0.070"	0.069"	251.2	0.3106	0.0052	5.1771	40	0.1675
7	0.080"	0.08"	323.4	0.3999	0.0067	6.6651	60	0.3234
8	0.090"	0.089"	386.4	0.4778	0.0080	7.9635	100	0.6440
9	0.100"	0.100"	493.7	0.6105	0.0102	10.1748	70	0.5760
10	Ventilator	3 hole	145.7	0.1802	0.0030	3.0028	75	0.1821
11	Ventilator2	6 hole	293.0	0.3623	0.0060	6.0385	45	0.2198
12	Ventilator3	4 large hole	506.3	0.6261	0.0104	10.4345	25	0.2110
13	Regar	No insert	415.9	0.5143	0.0086	8.5714	60	0.4159
14	Regar	0.050" insert	144.9	0.1792	0.0030	2.9863	60	0.1449
15	Regar	0.060" insert	169.9	0.2101	0.0035	3.5015	50	0.1416
16	Regar	0.065" insert	199.3	0.2464	0.0041	4.1074	45	0.1495
17	Regar	0.070" insert	218.9	0.2707	0.0045	4.5114	90	0.3284



Nitrogen Consumption

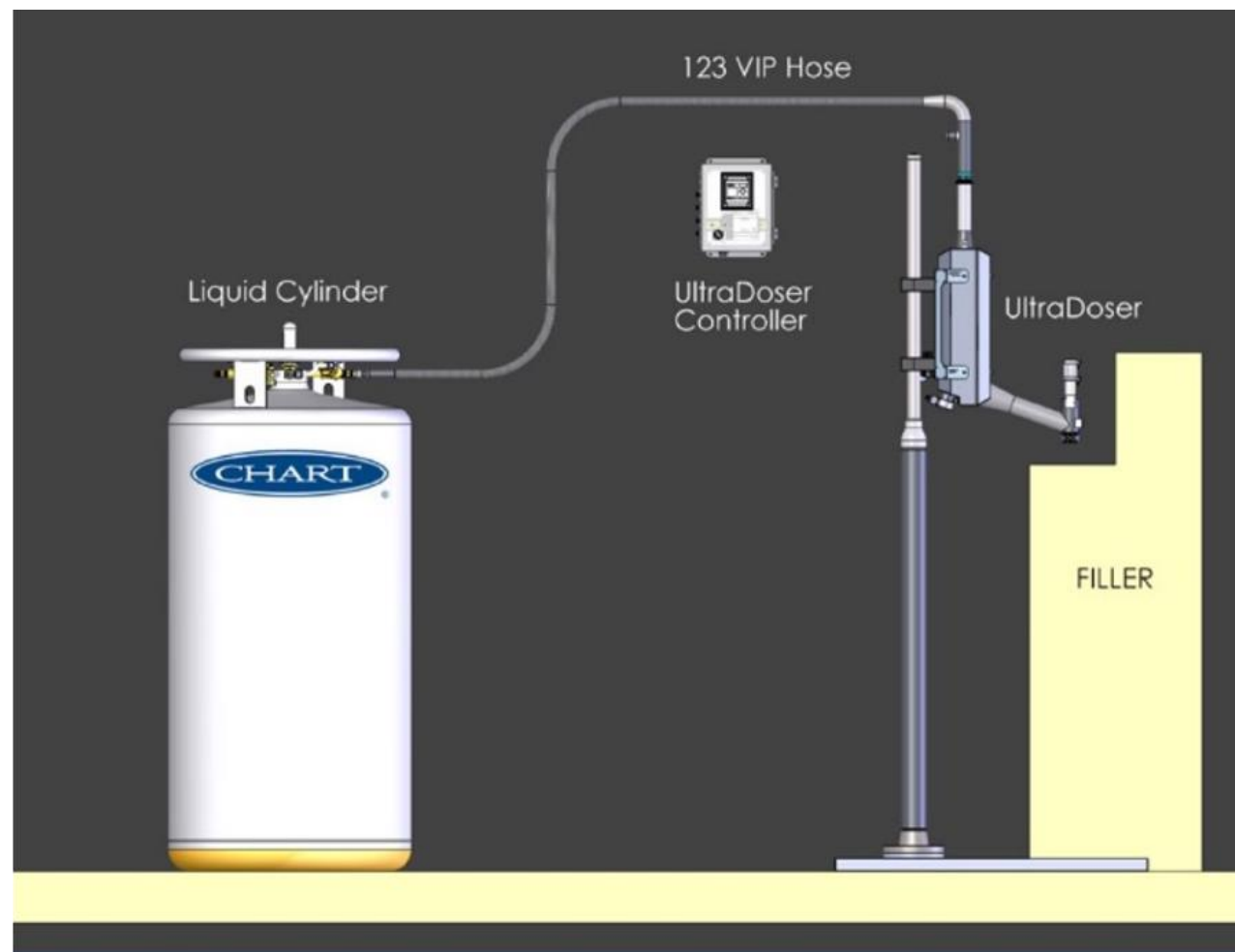
Variables	Qty	Units	
Length of Pipe (Dewar to Doser)		3Metres	
Bayonets		1Quantity	
Dose per container (calculated on another sheet)		0.25g/dose	
Containers per Hour		6000CPH	
Hours per shift		8hours	
Shifts per week		5shifts	
Cool downs per week		0cool downs	
Weekly Consumption		Total	
Cool down		0Kg's	
Steady state		9Kg's	
Dosing operations		60Kg's	
		69Kgs	
	or	85Litres	
So per bottle		0.29grams	
		0.35millilitres	





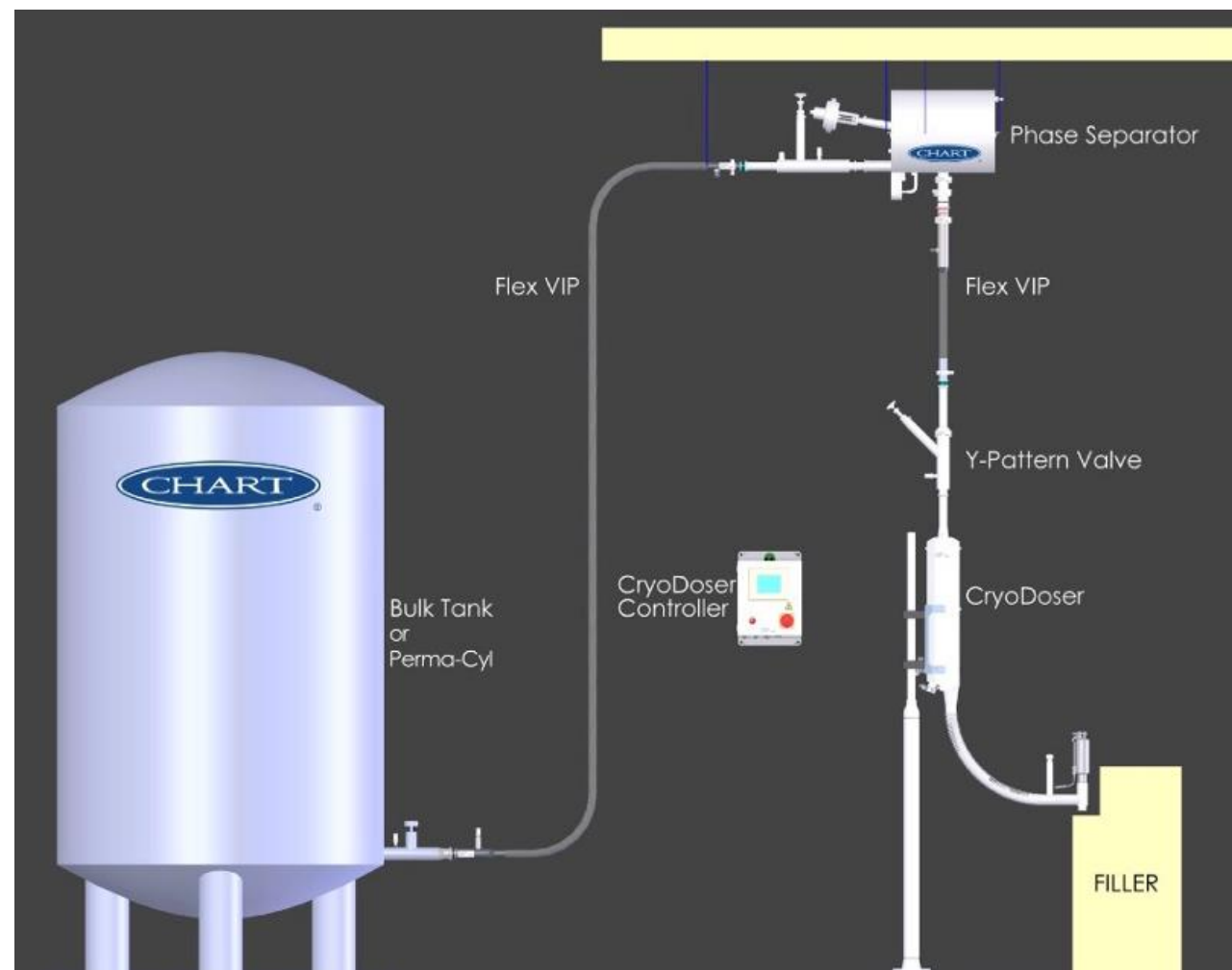
Typical Dewar Installation

- LN₂ Dewar
- Vacuum Insulated Hose
- Chart Doser
- Stand/Base



Typical Tank Installation

- ▶ Bulk LN₂ Tank (Low Pressure)
- ▶ Fixed Pipe Installation
- ▶ Isolation Valves
- ▶ Phase Separator
- ▶ Chart Doser
- ▶ Stand/Base/Mount





Nitrogen Solubility

- Low solubility in liquid
- Requires 3 environmental conditions for beer
- A beer carbonated to 2.5 vol CO₂ = 5000ppm
- Far less nitrogen is necessary for a liquid to be “nitrogenated”
- At 1.2 vol CO₂, add 50ppm nitrogen
- At 1.8 vol CO₂, add 20ppm nitrogen



Pressure

30-45psi in can



Temperature

40F or colder



Time

5 days stored cold



Dissecting a Nitro Head

- The cascade effect is caused by a combination of protein hydrophobicity and super small nitrogen bubbles
- The head has two parts: smaller, compact bubbles on the bottom and larger, airier bubbles on top



Brewery TPO Reduction Case Study



October 2021 – 300-450 PPB

New Canning System Installed

November 2021 – 93.9 PPB

Nitrogen Doser Installed



Late November 2021 – 74.6 PPB

Nitrogen Doser Optimization

March 2022 – 42.64 PPB

Nitrogen Doser, Filler Maintenance, Fobber Device Positioning, and Foam Shaver Blade all working in harmony

Nitrogen Doser itself reduced overall TPO by around **400 points**





Carbon Capture Case Studies in Craft Beer

Presented by Alex Calkins

Technical Solutions Manager: Earthly Labs

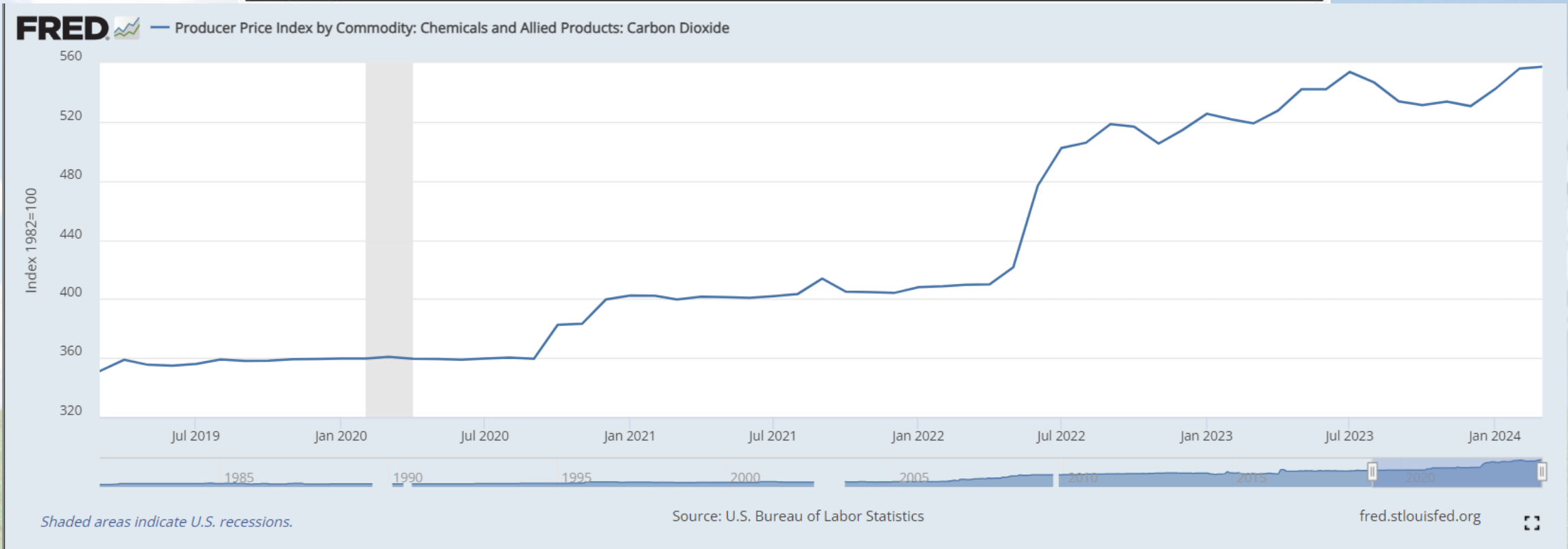
N E X U S O F C L E A N™



BREW BETTER BEER.

CO₂ Commodity Prices Continue to Increase

Per the PPI (US bureau of labor statistics) Increase in CO₂ cost from 2019 to present
16% per year



CO₂ Market Trends

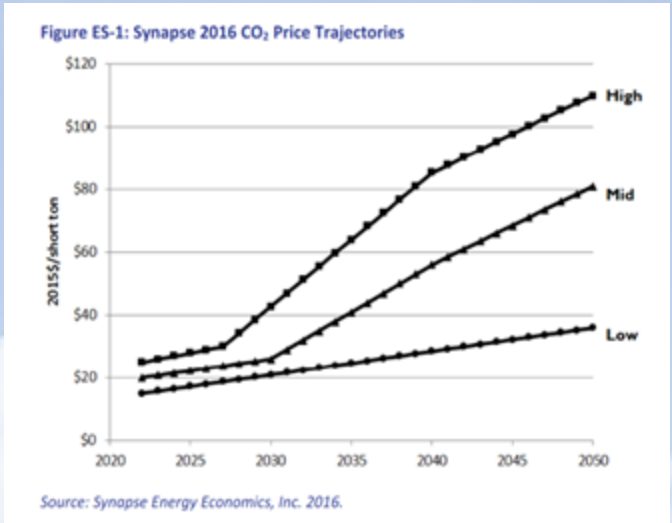
CO₂ Volatility, Value & Incentives to Capture Growing

CO₂ MARKET TRENDS

- › Supply Constraints, Outages, Shutdowns, Allocations Continue
- › Price Volatility and Force Majeure Pricing (Worldwide)
- › Inflation Reduction Act, Earmarks Billions for CO₂ Capture

OPPORTUNITY FOR CO₂ CAPTURE

- › New State-Based Grant Money Available Now; Talking About You Michigan, Connecticut, Colorado, New York, California
- › Supplement Project Cost with an R&D Tax Credit
- › Innovations in Voluntary CO₂ Market Driving New Opportunities
- › CO₂ Exchange Proven Allowing Opportunity to Sell Excess CO₂



Carbon Capture Drives Value

Advances Sustainability & Business Goals



Reduce CO₂ Supply Chain Volatility and Mitigates Revenue Loss



Reduce CO₂ Emissions and Advance Sustainability Goals



Reduce Total CO₂ Costs (ROI in 2-3 Years)



Improve Worker Safety with Reduced CO₂



Elevate Brand Among Consumers



Real Ale: The Right Fit

Quality, resilience, and credible sustainability

ISBT

Purified to beverage-grade standards

Reuse

CO₂ used for carbonation + production

Uptime

Remote monitoring + performance tracking

“We’re proud to expand our sustainability program with a solution that helps us reduce our carbon footprint while ensuring our production is more efficient and more resilient.”

— Brad Farbstein, President, Real Ale Brewing



Real Ale: The Challenge

Make sustainability tangible while protecting production

What was at stake

Fermentation CO₂ was being vented; beverage-grade CO₂ still had to be sourced from a gas distributor

Supply volatility + delivery logistics create risk for carbonation and packaging schedules.

Brand commitment to Texas Hill Country stewardship called for visible, credible action.

Need to ensure recovered CO₂ meets quality expectations (taste + sensory).

The Chart Difference

We're closing the loop on CO₂ — capturing fermentation CO₂, cleaning it to beverage-grade standards, and reusing it to carbonate and package our beer.

The Right Fit: Real Ale Brewing

Proven CiCi® CO₂ Capture Platform Scales to Deliver Customer Value

CiCi (Teak)



- Capacity
 - 2-10 lb/hr
- Capture, Purify, Liquify CO₂
- Achieve Beverage Grade
- Compact 4x5x7' footprint
- Standard One Size
- Turnkey Solution Installs in 1 Week
- Dozens of References in food and beverage, ethanol, R&D environments
- Manufactured in Chart Ball Ground, GA

CiCi (Oak)



- Capacity
 - 5 - 25 lb/hr
 - **0.16 TPD**
- Capture, Purify, Liquify CO₂
- Achieve Beverage Grade
- Compact 4x5x7' footprint
- Standard One Size
- Turnkey Solution Installs in 1 Week
- Dozens of References in food and beverage, ethanol, R&D environments
- Manufactured in Chart Ball Ground, GA

CiCi (Elm)



- Capacity
 - 90 – 3900 lb/hr
 - 1.0 – 42 TPD
- Standard 6- Skid Modular Plant Design
- Engineered for Inlet/Outlet Gas Comp
- Capture, Purify and Liquify CO₂
- Indoor and Outdoor Rated
- Turnkey Solution includes Chart storage tanks
- Applications in food and beverage, fuel cell, biogas, direct air capture and dry ice recovery
- Manufactured in Chart Tulsa OK

CiCi® (Elm) CO₂ Capture Solution

Large Scale System Made in USA

KEY FEATURES

- **6-Skid Modular Design**
- **Rated for Indoor or Outdoor**
- **Scaled to meet CO₂ Capture Needs**
- **Easy retrofit – inside or outside facility**
- **Made in Chart Tulsa OK Facility**
- **Containerized solution available**



Industry Leading CO₂ Capture Projects – Food & Beverage

Capture and Reuse CO₂ in Breweries

Maine Beer Captures CO₂ to reduce emissions and Increase Resilience



- Maine Beer installed CO₂ Capture solution to harness waste CO₂ from fermentation process to reduce emissions, reduce costs and increase resilience in the face of CO₂ shortages
- Maine Beer installed the CiCi (Oak) solution in 1 week, including a manifold, Chart vaporizer, and 2 Chart Carbomax 1000 CO₂ storage tanks
- Exhaust CO₂ is purified to ISBT beverage standards for reuse to carbonate the beer. Quality processes by Maine Beer's demonstrates it meets or exceeds CO₂ sensory standards
- Maine Beer uses the Howden Uptime software to monitor key performance indicators, CO₂ capture volume and interfaces with Earthly Labs team .

Maine Beer Company



CO₂ Capture from Wine Production

One of the world's leading wineries utilizes recovered CO₂ in production process



- Opus One is one of the world's leading wineries, producing coveted cabernet sauvignon from its Napa Valley vineyards.
- As part of its commitment to invest in sustainable processes that reduce its environmental impact, Opus One implemented Chart's carbon capture technology expanding the capture over 3 consecutive harvests
- Opus One implemented the CiCi (Oak) + system and purification skids for wineries including multiple 500 lb CO₂ tanks to enable dry ice production used in the wine-making process
- Opus One also used the Uptime remote monitoring dashboard to help monitor operations and ensure attainment of CO₂ capture goals

"We have continued to expand Chart's Earthly Labs carbon capture solution, reducing our climate impact and ensuring the enjoyment of each new vintage for generations to come."

Michael Silacci, Winemaker - Opus One



Project Installation

Key Insights

- ✓ Installation Earthly Labs team took a week – piping, training team, capturing CO₂
- ✓ Capturing CO₂ Weekly at Maine Beer Co
- ✓ Team installed the two Chart Carbo-Max 1000 storage Dewars outside and mounted the displays on the unit.
- ✓ Supplements commercial CO₂ needs weekly, providing more natural alternative and insurance policy.



Maine Beer Company



"One of Maine Beer Company's core values is to 'Take care of the Earth and encourage others to do the same.'"

**Steve Mills
CEO**

CO₂ Capture Configuration & Use

CO₂ Capture Case Study

Maine Beer Company



Do what's right.



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Maine Beer Elm Upgrade

Troeg's

CO₂ – Trends, Supply, Demand, Pricing Insights

Supply Side

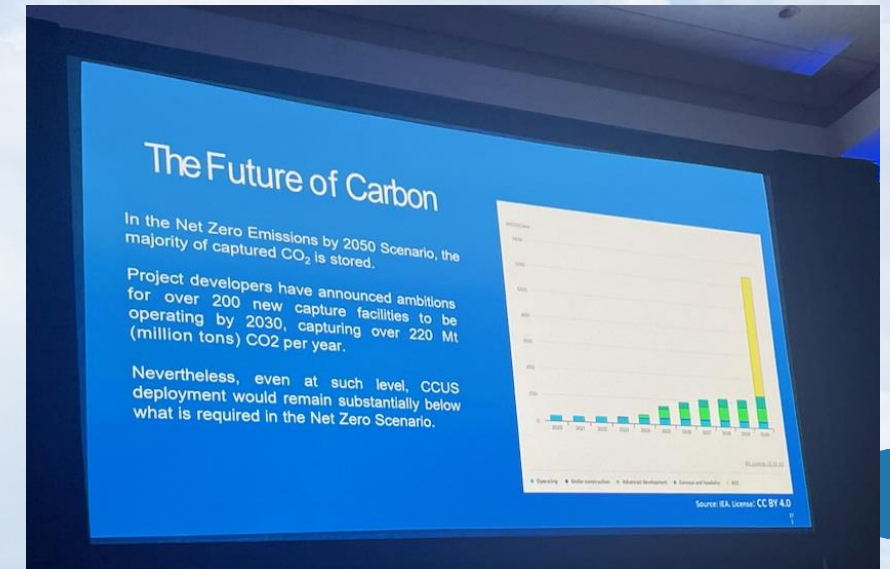
- 25% Supply are natural well sources
 - Natural decline in reservoir production
 - New wells have lower purity, higher production cost
 - Producers of CO₂ have lost fast access to capital, driven by desire to avoid CO₂ production
- Ethanol sources could go to pipelines
- Ammonia / refineries could go green
- Existing sources will close
- New smaller sources could help reduce cost increases (biogas, fuel cell)
- US incentives to reduce carbon emissions will impact future Merchant CO₂ supply

Demand Side

Dry ice market growing, driving new demand for CO₂

Allocations are happening from major suppliers for end users and distributors

Modest growth in demand 2% (11.4 MTPY) – *Intelligas Consulting*





Speakers:



Alex Calkins

Technical Solutions Manager
Earthly Labs Carbon Capture



Christina Marrick

Business Development Manager
Nitrogen Dosing Systems

Craft Brewers Conference

April 20th - 22nd, 2026

Pennsylvania Convention Center, Philadelphia, PA

Booth #1507

Join us for a presentation on **Brewery Case Studies of Carbon Capture & Nitrogen Dosing**

Tuesday, April 21st 10:00am - 11:00am

Location: Room 107-AB