DALUM
Beverage Equipment

DALUM CO2 Recovery Plant

CO2 recovery solutions tailored for your specific brewery.

Designed by process engineers and veteran brewers.

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It began in Denmark, 2019

Kim, engineer and beverage industry expert, approached several craft brewers and was encouraged to invent an affordable craft-scale CO2 recovery solution.

He partnered with Ørbæk Bryggeri and had the first plant up and running in March of 2020.

The Result:
Serious Technology for Sustainable Brewing

Proven Industrial Technology Scaled & Priced for Craft Breweries

DALUM CO2 Recovery Plant

Svaneke

DALUM Beverage Equipment

First commercial customer installed a plant in November 2020 and has been self-sufficient ever since. They sell their excess CO2 to local businesses on the island of Bornholm.

Svaneke Bryghus and Jan Paul, brewmaster, were a big part of the R&D process from the beginning.

Why Are Breweries Using CO2 Recovery?

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1. Technology available to industrial breweries for a long time, newly available to craft.

2. Protect from increasing CO2 costs and supply chain disruptions

3. Saves a brewery money starting on day 1 of operation.

4. Sustainability benefits of reducing CO2 waste

LERVIG

"It's just like printing money!"

Mike Murphy, Head Brewer
Lervig Bryghus, Norway

DALUM CO2 RECOVERY PLANT OVERVIEW

Our CO2 Recovery Plant promotes a circular utilization of the brewery's own CO2, by recovering the CO2 from the fermentation.

Secures own high-quality supply of CO2

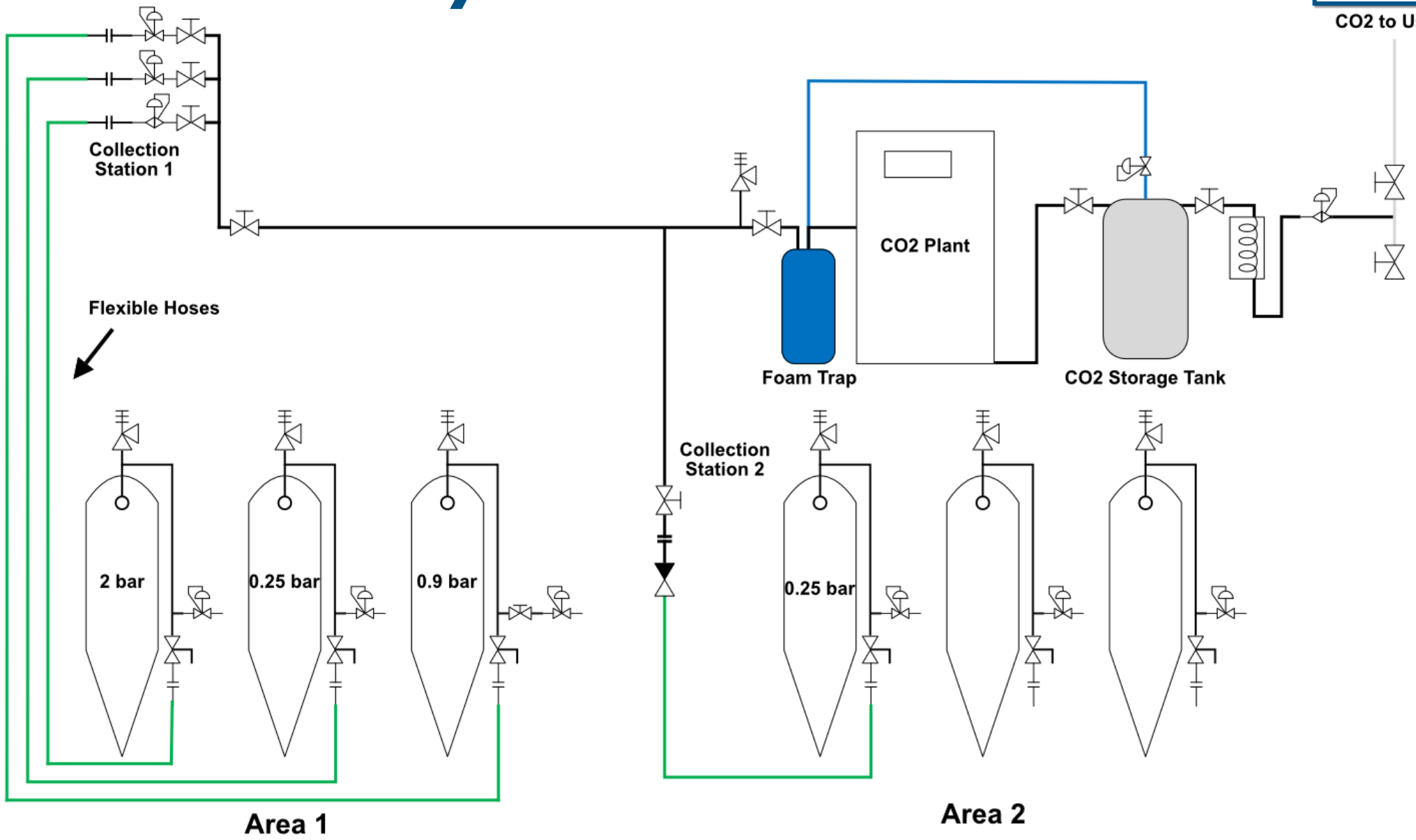
80% of DALUM customers are CO2 self-sufficient

Saves costs from the day it is installed and for the rest of the lifetime of your brewery

Recovery estimate:

- 80% of CO2 from fermentation pending brewery practices
- At 5% alc. content approx. 4 kg per hL / 7-8 lbs. per bbl

System Overview



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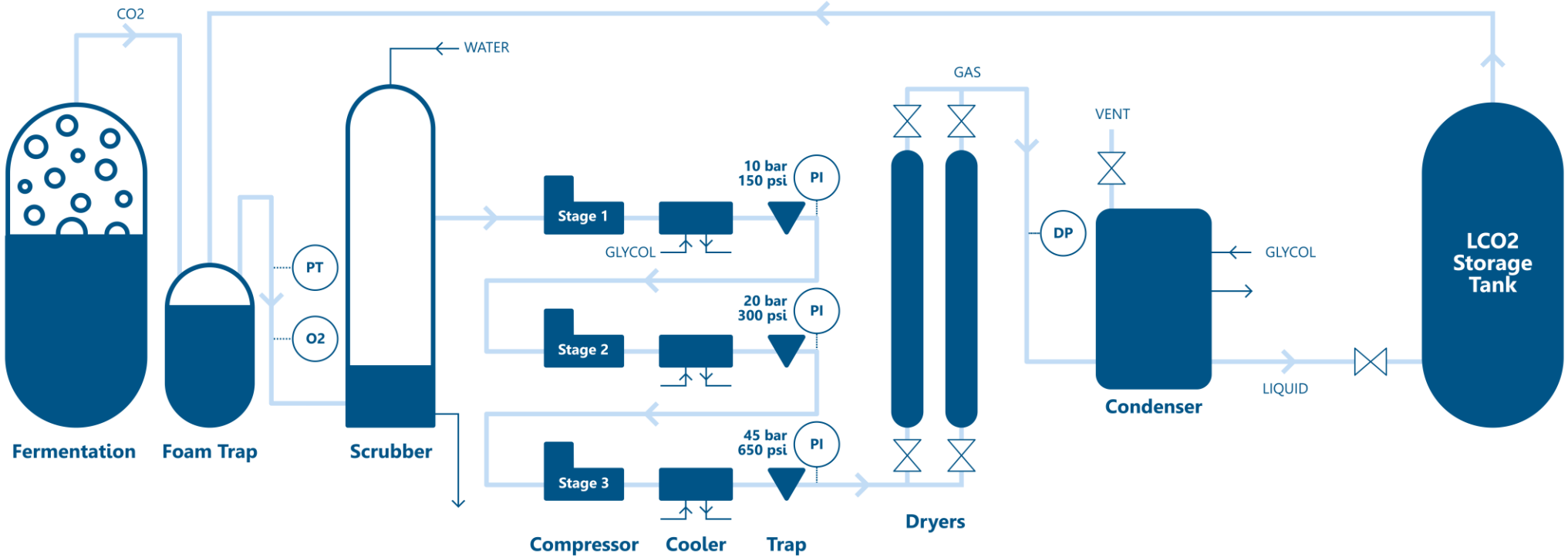
DALUM CO2 Recovery Plant Collection Process



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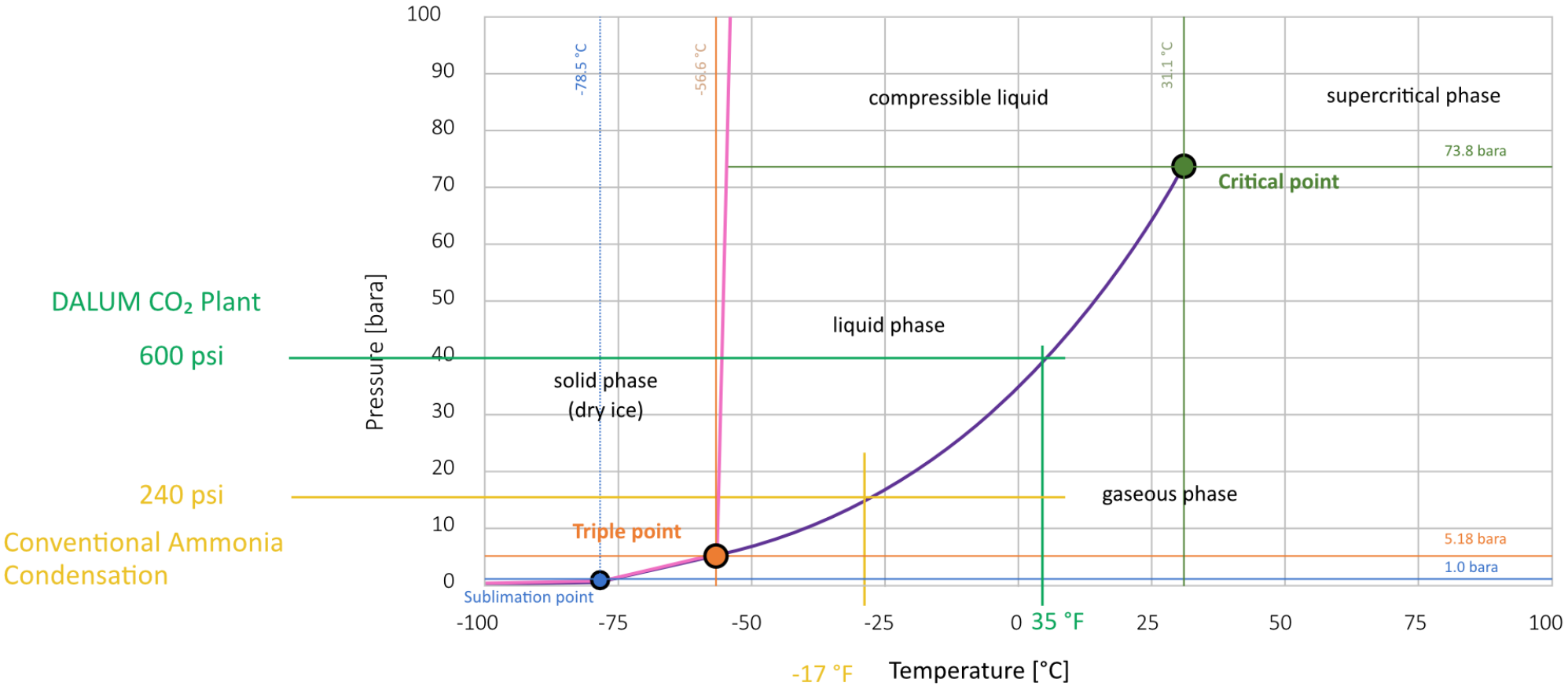

No Refrigerants

Three stage compressor produces 45 bars/650 psi bars condensation pressure. Unnecessary to use separate CFC or ammonia cooling systems. A glycol, ice-water, or alcohol coolant system can be used – even the existing coolant system in the brewery can be utilized.

Simple to Connect to Utilities

DALUM Beverage Equipment

CO2 Gas

Electric

Water

Glycol

Liquid CO2

Other gasses

Drain Water

Glycol Return

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HIGH QUALITY CO2

- No oil, or refrigerants in CO2 Plant.
- Stainless steel and 3-stage variable speed oil-free DALUM Compressor.
- Only food safe materials in contact with CO2.
- ISBT standard - 99.98% purity and no odor

PLUG-AND-PLAY PLANT

- Fully assembled and tested plant ready to plug in.
- Water, electricity, coolant, and drain to be connected.
- No PED or ASME needed for plant.*

*Storage tanks for liquid CO2 need approvals and may need inspections.

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EASY TO USE AND MAINTAIN

- Simple and fully automatic operation with self-diagnosing software.
- Adapts automatically capacity to fermentation cycles.
- No consumables to be replaced regularly.
- Dashboard on smartphone and remote access.

FINANCIALLY FEASIBLE

- Low capex and short ROI
- Protected from CO2 shortages and price increases.
- Reduces cost of CO2 considerably and secures supply.
- increases surplus CO2 value by cylinder filling for beer dispensers for draft beer.

DALUM Beverage Equipment

EASY TO FIT

- Small footprint of plant (1 m2 or 10 sq. ft.)
- Low noise level (65 dB) and can be placed anywhere in the brewery.
- No balloon due to 100% variable speed DALUM Compressor.
- No hazardous ammonia or CFC refrigerants as external cooling source is used.

ENVIRONMENTALLY FRIENDLY

- Low consumption of power and water.
- Better working environment.
- Eliminates breweries largest CO2 emission source (2 tons less emissions per ton recovered).
- Eliminates breweries need for purchase and transport of CO2.

DALUM Customers

Creating collaborative partnerships globally.

"There's no reason every brewery shouldn't have one, it's performing as promised which is kind of unheard of."

Paul Graham, President of Central Waters, WI, USA

"The whole system is extremely reliable and very efficient. Incredibly well-thought-out condenser. First class quality CO2."

Eddie Gadd, President of Ramsgate Brewery, UK

"If you're a craft beer brewery looking to get into it and save any money and help save the environment by letting less CO2 get out of the atmosphere, I couldn't recommend it enough."

Ross Terlick, Head Brewer at Rocky Ridge Brewing, Australia

CO2 Self-Sufficiency

STEWART BREWING

2023
Scotland

CO2 self-sufficient on day one since commissioning two Craft models in February 2023, and are selling excess CO2 in cylinders to local businesses

CROMARTY BREWING CO.

2023
Scotland

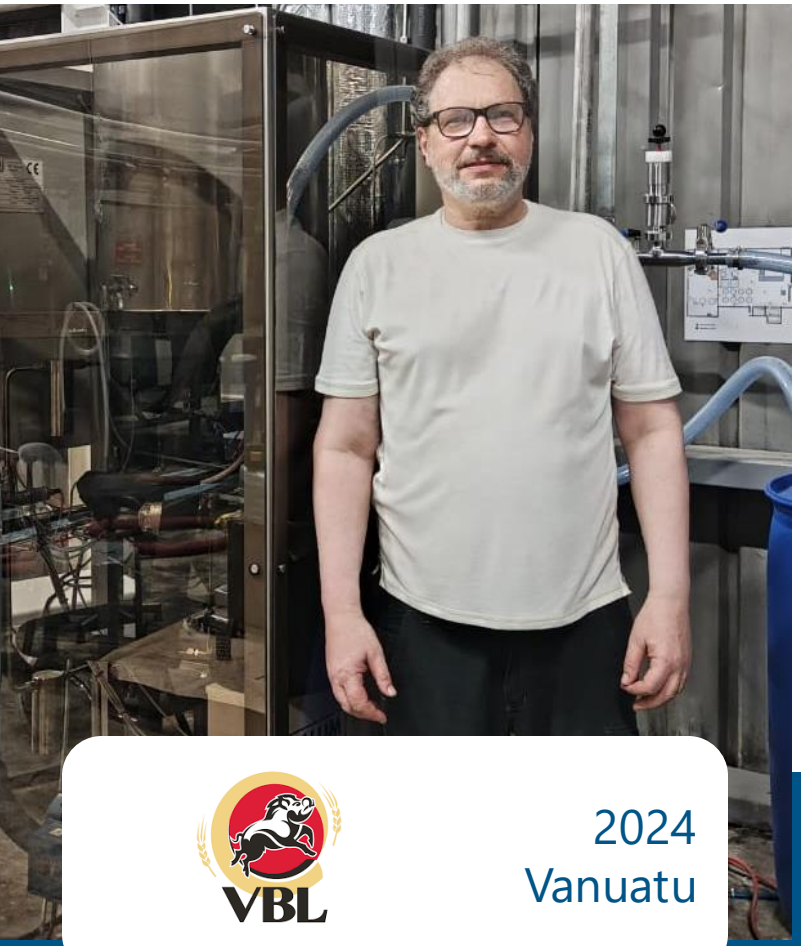
CO2 self-sufficient on day one since commissioning the first Micro model in October 2023

UTOPIAN BREWING

2023
England

CO2 self-sufficient on day one since commissioning a Mini model in April 2023

Cost Reduction and Increased Profits



VBL

2024
Vanuatu

Brewery located on island with volatile CO2 prices and unpredictable disruptions

Thisted BRYGHUS 1902

2023
Denmark

Saving approx. 150 tons of CO2 annually with two Craft models

GOTLANDS BRYGGERI
VISBY S:T HANSG 1995

2024
Sweden

Newly built brewery with built-in piping for CO2 recovery

Simple and Easy Installs by Brewing & Engineering Experts

CENTRAL WATERS BREWING CO.

2023
WI, USA

First US install running after two days and recovering approx. 67,200 lbs. annually

BLACK ISLE BREWING Co.

2023
Scotland

Plant was running and producing CO2 after two days

SEBAGO BREWING CO

2024
Maine, USA

Running and producing CO2 on day one

Financially Feasible for Craft Breweries

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Beer Output in hL	Plant Model	Theoretical Compressor Displacement Size	Plant Price
1,000 - 5,000 hL/yr	Micro	5 kg/hr	€ 32,200
5,000 - 15,000 hL/yr	Mini	10 kg/hr	€ 47,700
15,000 - 25,000 hL/yr	Craft	15 kg/hr	€ 64,000
25,000 - 50,000 hL/yr	Senior	30 kg/hr	€ 99,750
50,000+ hL/yr	Multiple units	30+ kg/hr	-

*Storage tanks for liquid CO2 need approvals and inspections.
Pricing subject to change.

Financially Feasible for Craft Breweries

DALUM Beverage Equipment

Beer Output in bbl	Plant Model	Theoretical Compressor Displacement Size	Plant Price
800 – 4,300 bbl/yr	Micro	10 lbs/hr	$ 44,000
4,300 – 12,800 bbl/yr	Mini	20 lbs/hr	$ 62,000
12,800 – 21,300 bbl/yr	Craft	30 lbs/hr	$ 79,000
21,300 – 42,600 bbl/yr	Senior	60 lbs/hr	$ 115,000
42,600+	Multiple units	60+ lbs/hr	-

*Storage tanks for liquid CO_2 need approvals and inspections.
CRN not included.
USD prices.
Pricing subject to change.

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Total Solution Packages: Storage Tanks, Cylinder Filling Stations, Vaporizers etc.

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Customized Collection Stations




Emission Reduction is 2:1 Relationship

Two tons of emission reduction from each ton of CO_2 recovered.

Producing and transporting one ton of CO_2 to a brewery emits 2 tons of CO_2.*

*University of Winnipeg.

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Beer Output 5% alc. HI	Compressor Displacement Size	CO_2 Recovery (Tons CO_2)	Emission Reduction (Tons CO_2)
7,000	5 kg/hr	22	44
15,000	10 kg/hr	66	132
25,000	15 kg/hr	99	198
50,000	30 kg/hr	198	396

Calculate How Much CO2 is Recovered

Experiment performed at a brewery with a flowtransmitter.

Result: 3.4 kg/7.5 lbs CO2 per hL beer

- 15,600 L fermenter with 128 hL wort, expected 4.8% v/v alcohol, 120 hL beer.
- 4.8% v/v is approx. 3.84% w/w or 3.8 kg/hL beer, meaning 460 kg CO2 is expected.
- 0.4% or 36 kg remain in beer, which means 420 kg leaves the tank. Measured 442 kg.
- First 20 kg is lost with too high oxygen content. Approx. 400 kg goes to plant. Measured 420 kg.
- 420 kg go to plant, but 410 kg are measured in CO2 tank.

Calculations		
Very little loss due to high oxygen	4	%
Yield of the theoretical total CO2 produced	89	%
Yield of CO2 out of the fermenter	93	%
Yield of CO2 sent to the CO2 Plant	97	%

$C_6H_{12}O_6$ = >$2C_2H_5OH + 2CO_2$ + heat or approx.:
2 grams of extract = 1 g alcohol + 1 g CO2

Estimate Recovery Potential

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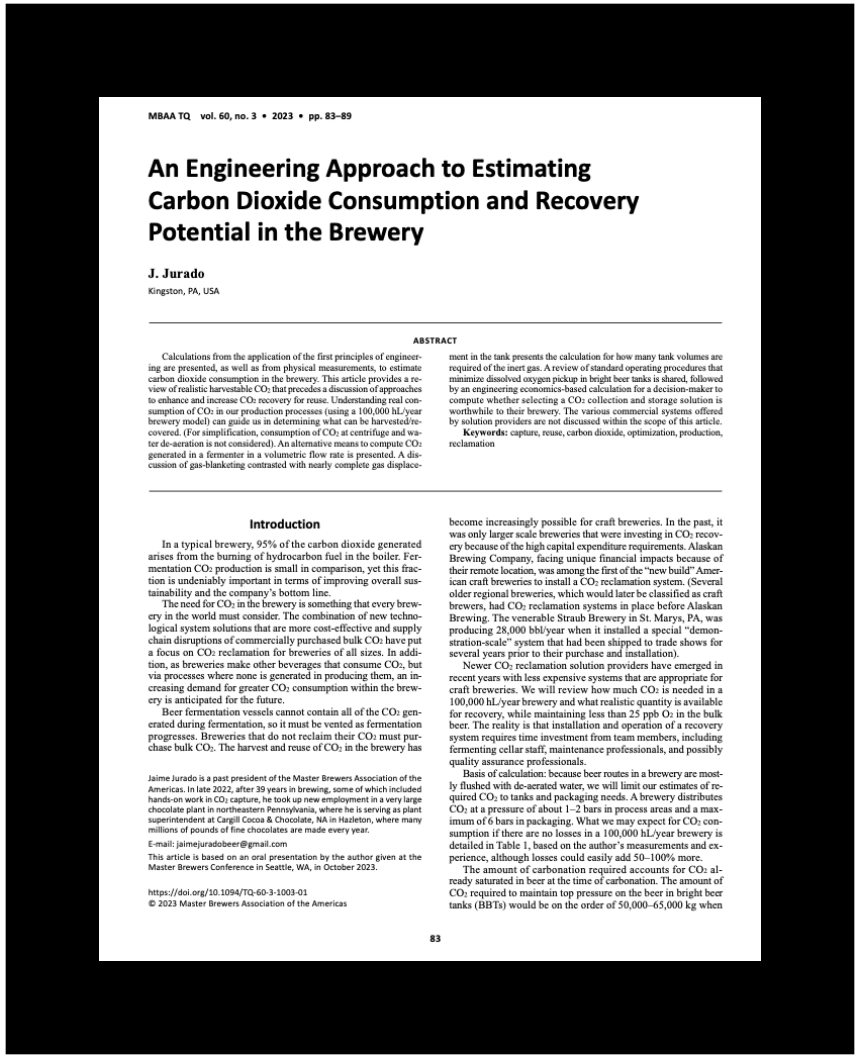
Metrics

- 24 Plato (10% alcohol) produces 10 kg of CO2/hL
- Recovery rate of 80%: 10 x 0.80 = **8 kg/hL**

Convert to imperial system

- Convert to lbs: 10 x 2.2 = 22
- Convert to bbl: 22 / 0.852 = 25.9 (1 hL = 0.852 bbl)
- Recovery rate of 80%: 25.9 x 0.80 = 20 lbs/bbl



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An Engineering Approach to Estimating Carbon Dioxide Consumption and Recovery Potential in the Brewery

J. Jurado
Kingston, PA, USA

ABSTRACT

Calculations from the application of the first principles of engineering are presented, as well as from physical measurements, to estimate carbon dioxide consumption in the brewery. This article provides a review of realistic harvestable CO_2 that precedes a discussion of approaches to enhance and increase CO_2 recovery for reuse. Understanding real consumption of CO_2 in our production processes (using a 100,000 hL/year brewery model) can guide us in determining what can be harvested/recovered. (For simplification, consumption of CO_2 at centrifuge and water de-aeration is not considered). An alternative means to compute CO_2 generated in a fermenter in a volumetric flow rate is presented. A discussion of gas-blanketing contrasted with nearly complete gas displacement in the tank presents the calculation for how many tank volumes are required of the inert gas. A review of standard operating procedures that minimize dissolved oxygen pickup in bright beer tanks is shared, followed by an engineering economics-based calculation for a decision-maker to compute whether selecting a CO_2 collection and storage solution is worthwhile to their brewery. The various commercial systems offered by solution providers are not discussed within the scope of this article.

Keywords: capture, reuse, carbon dioxide, optimization, production, reclamation

Introduction

In a typical brewery, 95% of the carbon dioxide generated arises from the burning of hydrocarbon fuel in the boiler. Fermentation CO_2 production is small in comparison, yet this fraction is undeniably important in terms of improving overall sustainability and the company's bottom line.

The need for CO_2 in the brewery is something that every brewery in the world must consider. The combination of new technological system solutions that are more cost-effective and supply chain disruptions of commercially purchased bulk CO_2 have put a focus on CO_2 reclamation for breweries of all sizes. In addition, as breweries make other beverages that consume CO_2, but via processes where none is generated in producing them, an increasing demand for greater CO_2 consumption within the brewery is anticipated for the future.

Beer fermentation vessels cannot contain all of the CO_2 generated during fermentation, so it must be vented as fermentation progresses. Breweries that do not reclaim their CO_2 must purchase bulk CO_2. The harvest and reuse of CO_2 in the brewery has become increasingly possible for craft breweries. In the past, it was only larger scale breweries that were investing in CO_2 recovery because of the high capital expenditure requirements. Alaskan Brewing Company, facing unique financial impacts because of their remote location, was among the first of the "new build" American craft breweries to install a CO_2 reclamation system. (Several older regional breweries, which would later be classified as craft brewers, had CO_2 reclamation systems in place before Alaskan Brewing. The venerable Straub Brewery in St. Marys, PA, was producing 28,000 bbl/year when it installed a special "demonstration-scale" system that had been shipped to trade shows for several years prior to their purchase and installation).

Newer CO_2 reclamation solution providers have emerged in recent years with less expensive systems that are appropriate for craft breweries. We will review how much CO_2 is needed in a 100,000 hL/year brewery and what realistic quantity is available for recovery, while maintaining less than 25 ppb O_2 in the bulk beer. The reality is that installation and operation of a recovery system requires time investment from team members, including fermenting cellar staff, maintenance professionals, and possibly quality assurance professionals.

Basis of calculation: because beer routes in a brewery are mostly flushed with de-aerated water, we will limit our estimates of required CO_2 to tanks and packaging needs. A brewery distributes CO_2 at a pressure of about 1–2 bars in process areas and a maximum of 6 bars in packaging. What we may expect for CO_2 consumption if there are no losses in a 100,000 hL/year brewery is detailed in Table 1, based on the author's measurements and experience, although losses could easily add 50–100% more.

The amount of carbonation required accounts for CO_2 already saturated in beer at the time of carbonation. The amount of CO_2 required to maintain top pressure on the beer in bright beer tanks (BBTs) would be on the order of 50,000–65,000 kg when

Jaime Jurado is a past president of the Master Brewers Association of the Americas. In late 2022, after 39 years in brewing, some of which included hands-on work in CO_2 capture, he took up new employment in a very large chocolate plant in northeastern Pennsylvania, where he is serving as plant superintendent at Cargill Cocoa & Chocolate, NA in Hazleton, where many millions of pounds of fine chocolates are made every year.

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This article is based on an oral presentation by the author given at the Master Brewers Conference in Seattle, WA, in October 2023.

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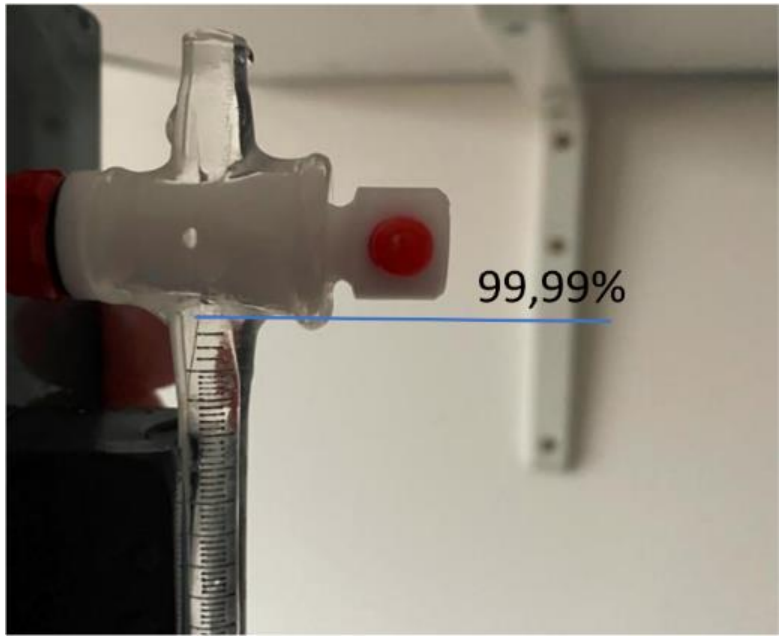
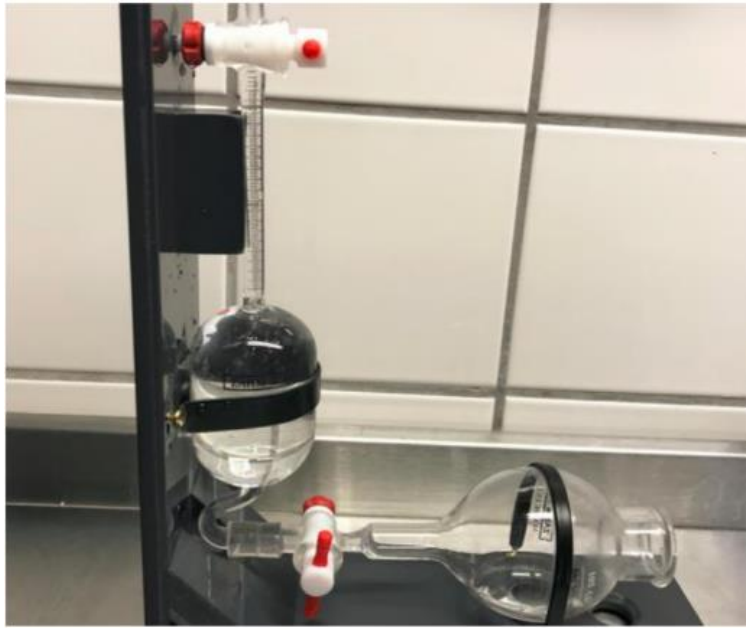
Detailed calculations - MBAA Technical Quarterly, Number 3, 2023
Jaime Jurado

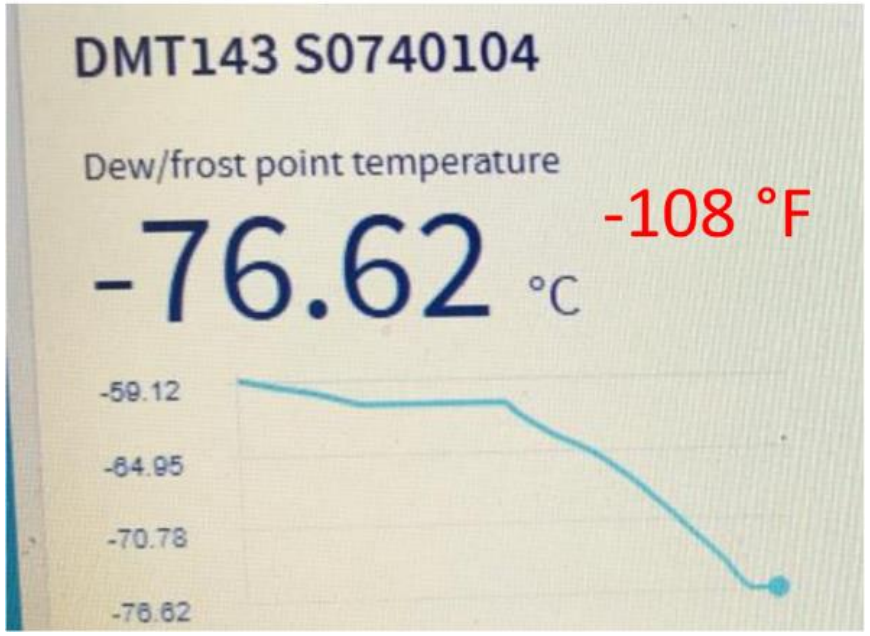
High Purity and Low Oxygen Content

Eddie Gadd, Managing Director, Ramsgate Brewery:

Collection system (generally 16 hours from yeast pitching). Some CO2 is lost through the initial stage of fermentation, due to high O2 content, and some remains in the beer at the end. With good management, 75% yields can be achieved, with an oxygen content of <6 ppb, measured with an Orbisphere (wholesale liquid CO2 at the bottling site measures 16 ppb O2). A burette is used to demonstrate purity >99.99%.







Typical Chemical Profile in CO2 Output

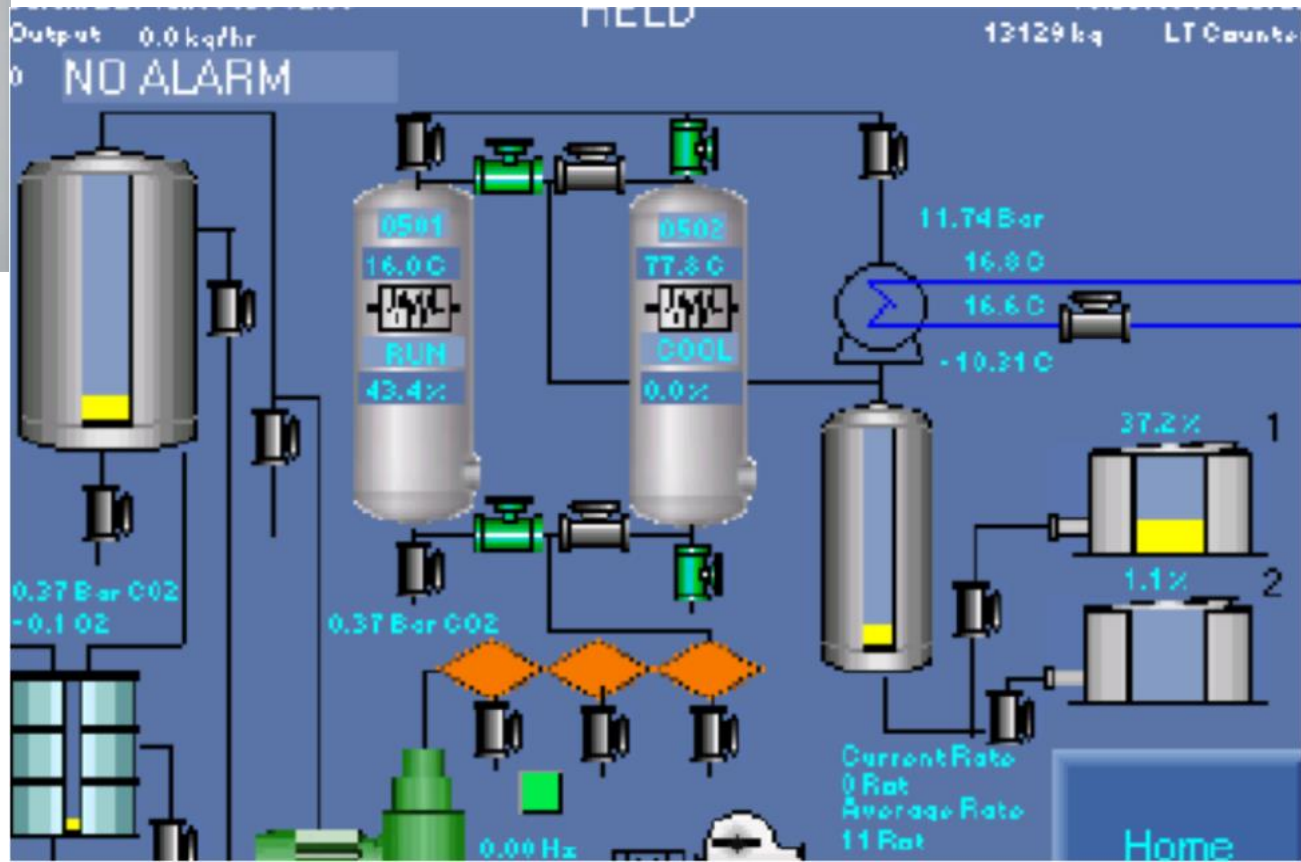
Typical chemical profile in DALUM CO2 Recovery					
Component	Presence in feed, ppm	After water scrubber, ppm	After compressor,ppm	After dehydrator and condenser, ppm	ISBT ppm
Acetaldehyde	20	0	0	**0.02**	0.2
Ethyl acetate	200	10	8	**0.0**	
Mercaptans	5	1	0.7	**0.0**	0.1
Dimethyl sulfide	35	3	2	**0.05***	0.1
Ethanol	2500	5	0	**0.0**	
Carbon disulfide, CS_2	0	0	0	**<0.05**	0.1
Hydrogen sulfide, H_2S	0	0	0	**<0.01**	0.1
Carbonyl sulfide COS	0	0	0	**<0.05**	0.1
Oxygen O_2	1000	1000	1000	**0.005-0.1***	30
Moist H_2O	>10000	>10000	1000	**1**	20
Carbon dioxide %	**96**	**97**	**99**	**99.985-99.995**	**99.900**
Nitrogen	4000	4000	4000	**0.1**	na
Ammonia	na	na	na	**<1**	2.5
Oil & grease	na	na	na	**<1**	5
Hydrocarbon	na	na	na	**1.5**	50
Benzene	na	na	na	**<0.01**	2.5
Methanol	na	na	na	**0.06**	10

ISBT: International Society of Beverage Technologists

DALUM Beverage Equipment

Control System With Vision Combi PLC Remote Operator

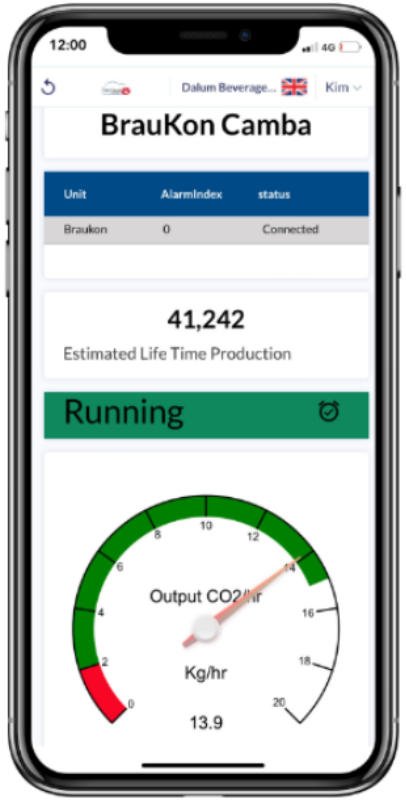
Simple and fully automatic operation with self-diagnosing software



User Interface

Easy to monitor and control

Remote Operator and Smartphone Dashboard



Partner with Brewery on Feasibility

Questionnaire
- Brewery inputs information
- Size, schedule, cost of CO2 etc.

Size & price recovery system
- Recovery plant
- Piping, tank etc.

Feasibility Study results
- ROI
- Includes savings & anticipated costs

Year	2022	2023	2024
Production Hl Beer	10.000,00	11.500,00	12.650,00
CO2 Usage Brewery, Kg	33.000,00	37.950,00	41.745,00
Recovery, Kg	34.900,00	40.135,00	44.148,50
Saving	159.011,02	182.171,47	199.927,81
kg/h, 47 weeks/y	4,42	5,08	5,59
No inflation			
Cash Flow of operations		182.171,47	199.927,81
Working Capital		0,00	0,00
Increase in working capital		0,00	0,00
Capital investment		**81.700,00**	
Sale of plant			
Net cash flow	0,00	100.471,47	199.927,81
PV 2018 at 2,5%	0,00	98.020,94	190.294,17
Cost of capital rate	1,0250		
NPV(at 2,5%)	**2.265.510,71**		
PV 2021 at IIR%	11.370,00	91.337,70	165.229,60
IRR =10%	**1,10**		
NPV(IRR= 10.0%)	1.477.386,03		

EXAMPLE

Continues (10 yr analysis)

Resources

- Quotes, feasibility study, info on government grants
  - Denmark office (All countries outside of North America): Frederik@dalumequipment.com
  - Wisconsin, USA office (USA, Canada, Caribbean): ashley@dalumequipment.com
- How much CO2 does my fermenter produce? Article here
- Technical Brauwelt article here
- Brewer's Journal article here
- Brewery case studies here
- CO2 systems and importance of quality - MBAA podcast here
- Dalum Newsletter HERE