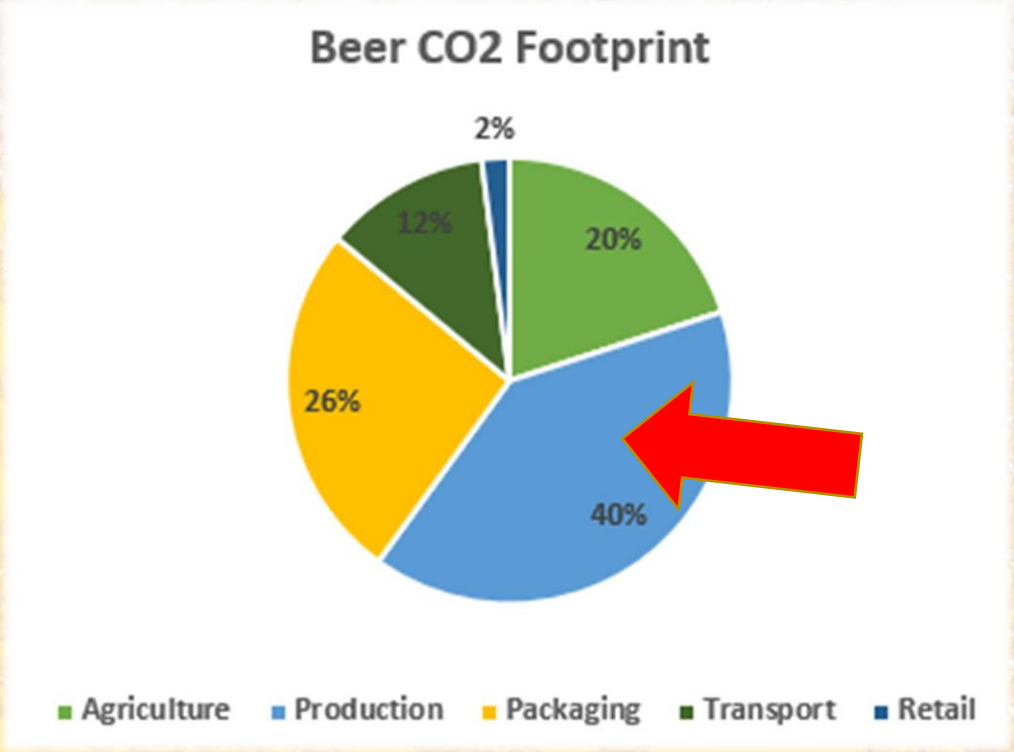
# Verified Sustainable Brewing: A case study from Denmark




Source: Concito

Since January 2021 Svaneke Bryghus, based on the Danish island of Bornholm, is verified for being carbon neutral in its beer production process

# Who am I?

- Jan Paul
- 47 years old
- Raised bilingually in the Danish Minority of Germany
- Brewing Engineer from  theTechnical University of Munich (Weihenstephan)
- Self-employed Brewing Consultant
- 2005 – 2023: Brewmaster at Svaneke Bryghus, Denmark
- Since 2018: Lecturer at the University of Copenhagen
- 2006 – 2018: Lecturer at the Scandinavian School of Brewing, Copenhagen
- 2016 – 17: Adjunct Faculty at Sterling College, USA
- Lecturing and consultancy in Iceland, Norway, Indonesia, Moldova, Georgia and Armenia
- Talks, tastings and collabs all over the world

# Svaneke Bryghus

- Founded in 2000 as a 10 hl pub brewery
- Mainly Lagers  in the start
- Rapid expansion
  - Malt warehouse
  - Packaging line in former fish factory
  - From 15 to 50 tanks
- Greenfield brewery in 2007
  - Five vessel brewhouse, 50 hl system
  - 50, 100 and 200 hl unitanks
  - 8.000 uph bottling line
  - 60 uph kegging line (commissioned in 2016)
  - 10.000 uph Canning line (commissioned in 2019)
  - Possible annual output 30.000 hl
- Portfolio of roughly 50 beers
  - 5 Non-alcoholic beers
  - 500 generations with own Lager yeast
  - Ales, Stouts, Porters, wild-fermented beers, fruit beer etc.
- 100 % organic
- Output 2022: 16.100 hl

# Focus on climate change and the environment – from the very start

- **2007**: Green field brewery
  - Installation of a Propane-based cooling plant with a non-toxic alcohol-water-brine
  - Nitrogen generator
  - Three steam generators rather than one big kettle
  - Vapor condenser for wort boiler
  - Pre-cooling of brewing water
- **2014**: Installation of solar panels on the brewery roof
- **2015**: Change from oil to gas burners for steam production
- **2018**: 100 % organic
- **2019**: Commissioning of waste water treatment plant
- **2019**: Commissioning of canning line
- **2019**: 100 % oil-free on the production site
- **2019**: Purchase of green electricity only
- **2020**: Purchase of biogas only
- **2021**: Commissioning of $CO_2$-recovery plant
- **2021**: Svaneke Bryghus is verified for $CO_2$-neutral beer production
- **2022**: All delivery/service vans and company cars electrically powered
- **2023:** All waste water from beer production is turned into biogas

# Key Performance Indicators

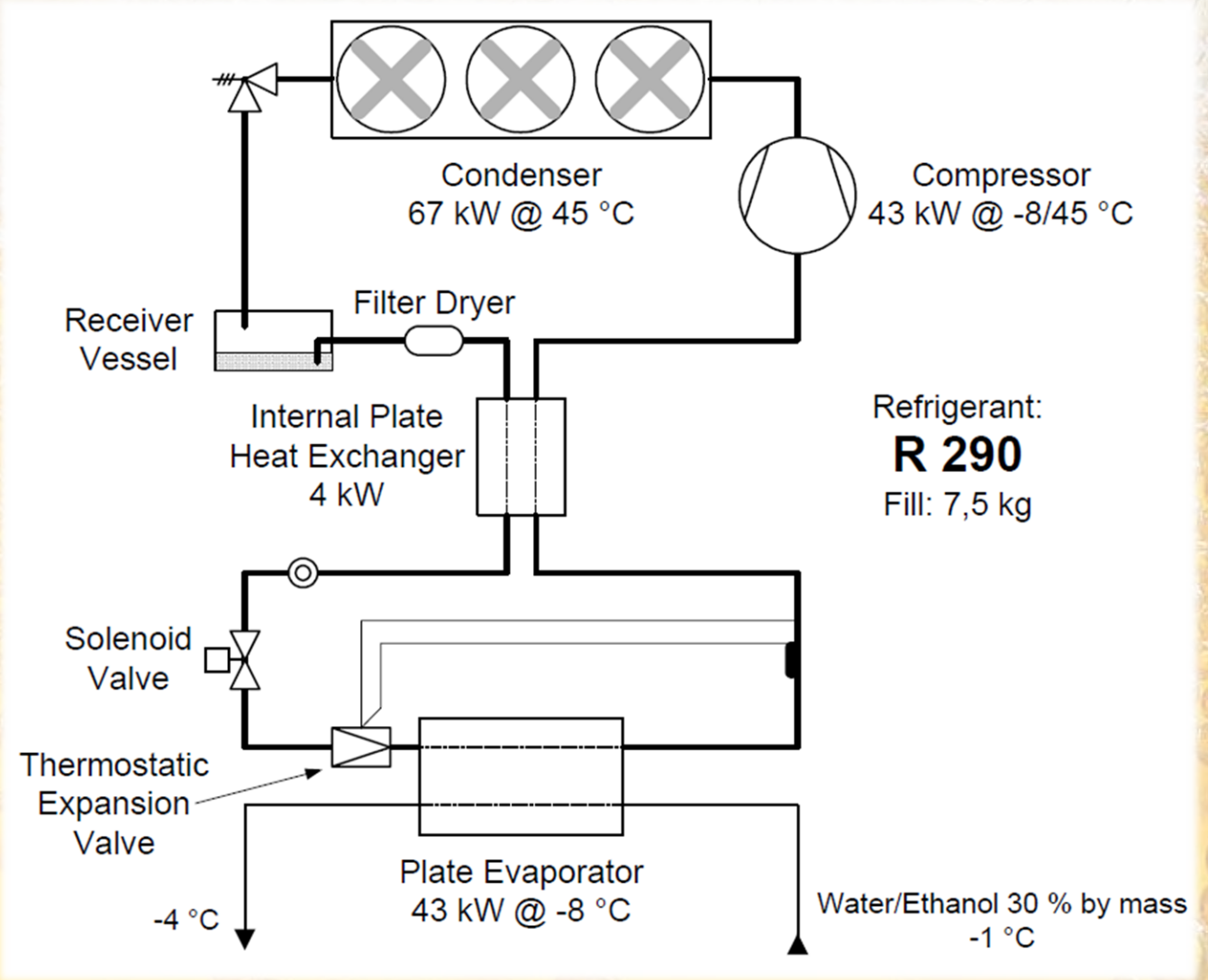

| Indicator | 2022 | 2021 | 2020 | Comment |
|---|---|---|---|---|
| Annual Beer Output [hl] | 16.100 | 17.100 | 16.500 | |
| Annual wort production [hl] | 18.400 | | | → Without wort for N.A. beer: 16.000 hl |
| Annual Water Consumption [hl/hl] | 5,1 | 4,8 | 4,8 | → Average for Danish breweries in 2011: 6 hl/hl<br>→ Key figures for medium sized to small breweries: 4 – 8 hl/hl<br>→ 23 % increase in keg sales |
| Annual Electrical Energy Demand [kWh/hl] | 16,1 | 15,2 | 20,5 | → Average for Danish breweries in 2011: 24 kWh/hl<br>→ Key figures for medium sized to small breweries 10 – 50 kWh/hl<br>→ 57 % covered by own solar panels<br>→ Packaging line down time |
| Annual Thermal Energy Demand [kWh/hl] | 42,0 | 39,6 | 43,5 | → Average for Danish breweries in 2011: 45 kWh/hl<br>→ Key figures for medium sized to small breweries: 24 – 56 kWh/hl<br>→ 23 % increase in keg sales<br>→ Packaging line down time |
| Annual $CO_2$-consumption [kg/hl] | 1,6 | 1,5 | 2 | → Average for Danish breweries 2 kg/hl<br>→ 25 tons consumed in total |
| Annual $CO_2$-production [kg/hl] | 2,2 | 2,5 | N.A. | → 35 tons produced in total<br>→ 7,5 % increase in non-alcoholic beer production |
| Annual Electric Power production [kWh/hl] | 9,2 | 7,2 | 7,7 | → 147.379 kWh produced in total |

| Sales | 2022 | 2021 |
|---|---|---|
| Kegs [%] | 35,1 | 28,5 |
| Cans [%] | 12 | 10,2 |
| Bottles [%] | 52,9 | 61,3 |
| Non-alcoholic beer as of total [%] | 5,3 | 4,6 |

# The Chiller

- Two independent circuits with natural hydrocarbon Propane (R 290)
- Propane is explosive, therefore:
  - Outdoor placement
  - Propane-sensor and fan inside machine housing
  - Switchboard placed outside machine housing

| Refrigerant | COP | GWP | Comment |
|---|---|---|---|
| R 717 ($NH_3$) | 3,8 | 0 | High cost |
| R 744 ($CO_2$) | - | 1 | N.A. |
| R 410A | 2,9 | 1.800 | Original offer from contractor |
| R 404A | 2,6 | 3.900 | |
| R 290 ($C_3H_8$) | 3,6 | 3 | Propane |
| R 134A | 3,1 | 1.600 | Common refrigerant found in AC's |



# The Chiller

- The brine storage vessel and the brine pumps are placed indoor
- The ethanol-water mix is non-toxic → No risk for environment or product

| Brine for – 20 °C | Conc. [%-mas] | Spec. Heat Capacity [KJ/Kg·K] | Thermal Conductivity [W/m·K] | Dynamic Viscosity [mPa·s] |
|---|---|---|---|---|
| Monoethylene-Glycol (1,2-Ethanediol) | 36,2 | 3,45 | 0,4 | ≈ 9 |
| Ethanol-water | 29,5 | 3,7 | 0,39 | ≈ 12 |
| Bio-Glycol (1,3-Propanediol) → N.A. in 2007 | | 3,73 | 0,46 | ≈ 12 |

- Future increase of capacity can be obtained by changing the existing evaporator to a binary ice generator (DWT = Double Wall Tube) and a lower concentration of ethanol in the brine
  - → Liquid ice will be pumped to the consumers and the melting enthalpy increase the capacity of the total refrigeration system, even though compressor performance will sink from 85 kW to roughly 55 kW
  - → Agitator in brine storage vessel needed
  - → Specific heat capacity of brine will increase to 4,1 KJ/kg·K

# The Nitrogen Generator

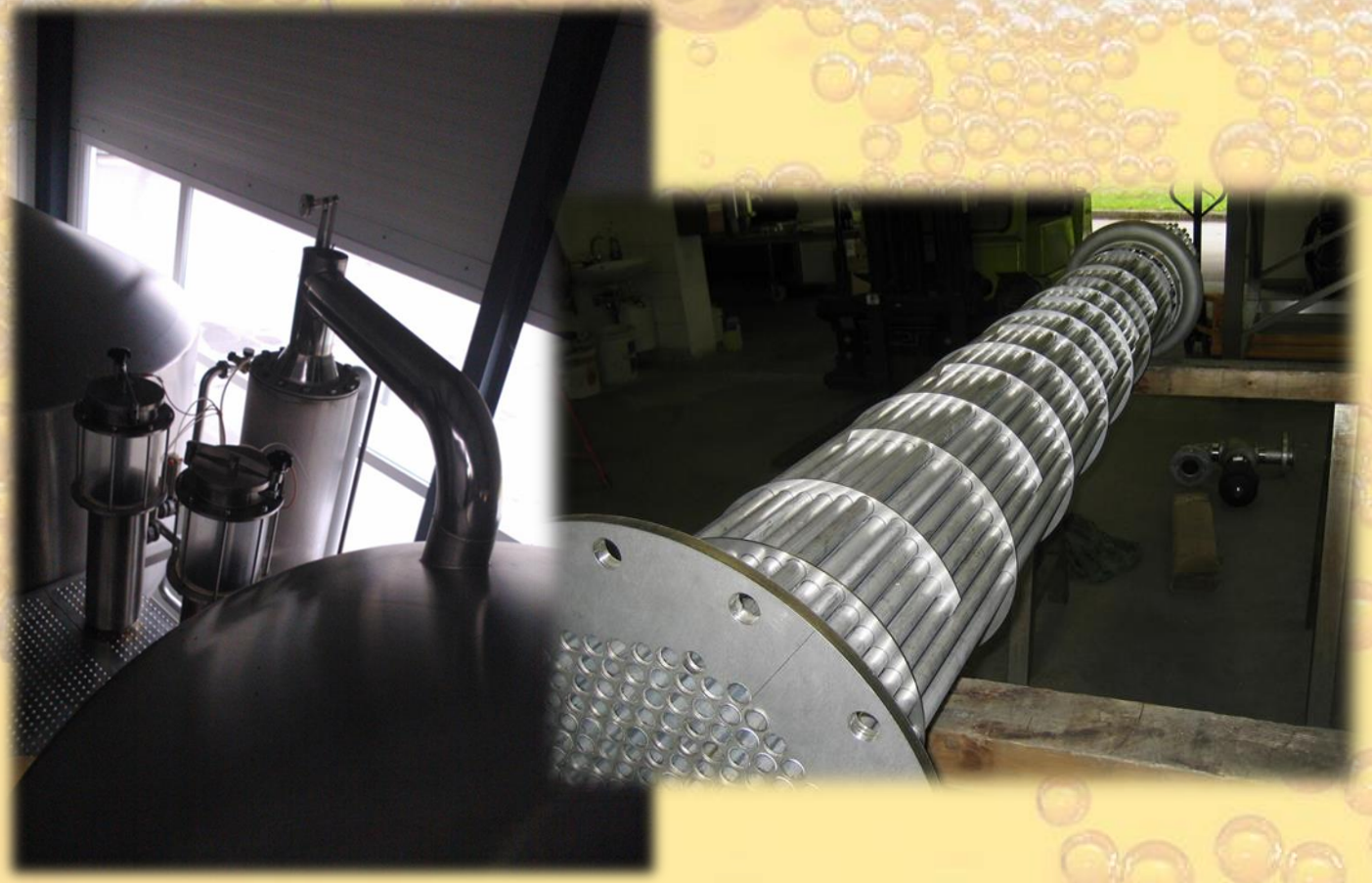
- Used to produce inertgas for keeping unitanks pressurized during packaging
- $N_2$-purity: 99,99 %

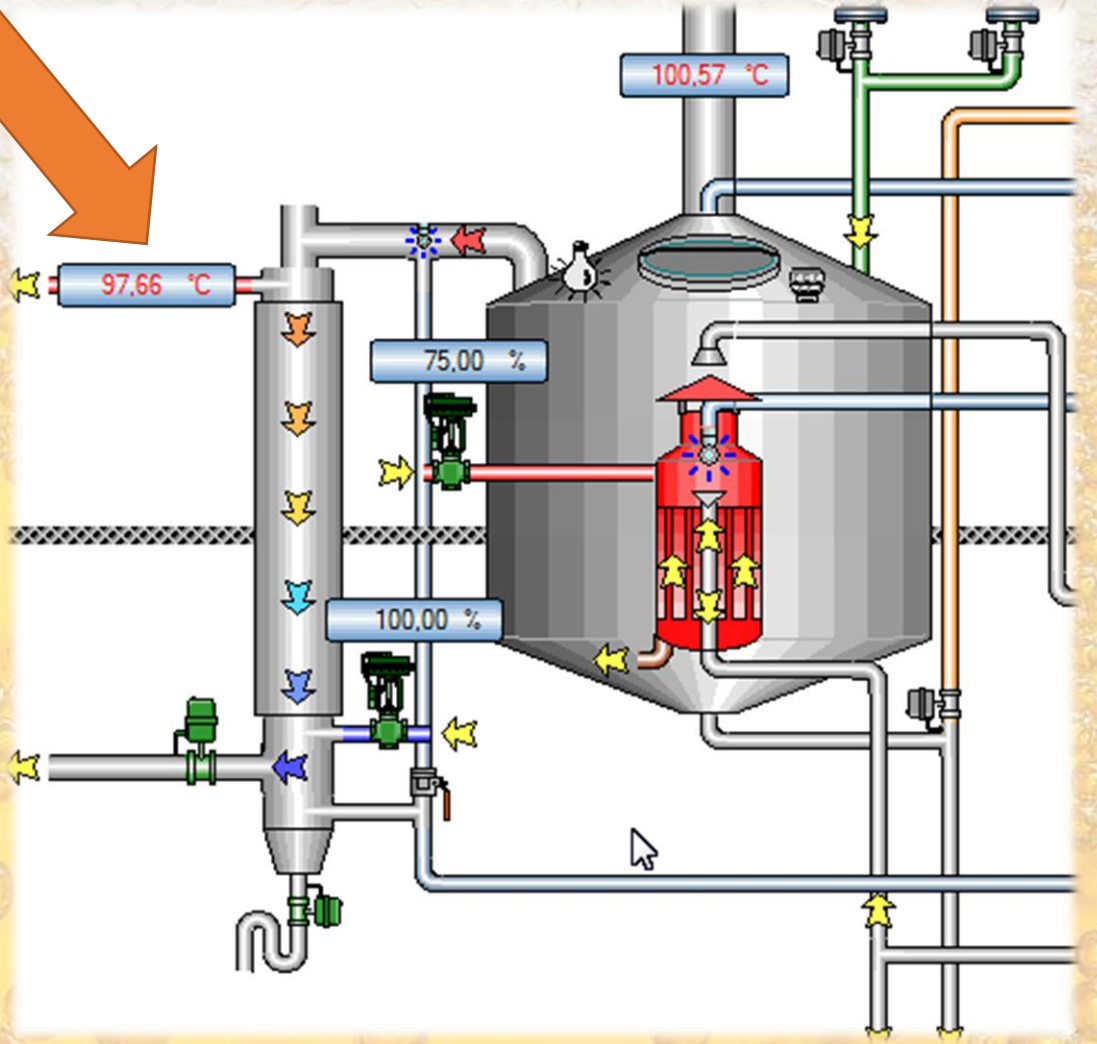

# The Steam Generators

- Three generators (each 460 kg/h) rather than one big kettle
- $P_{steam}$= 8 bar(g)
- Change from oil to gas burners in 2017

# The Vapor Condenser

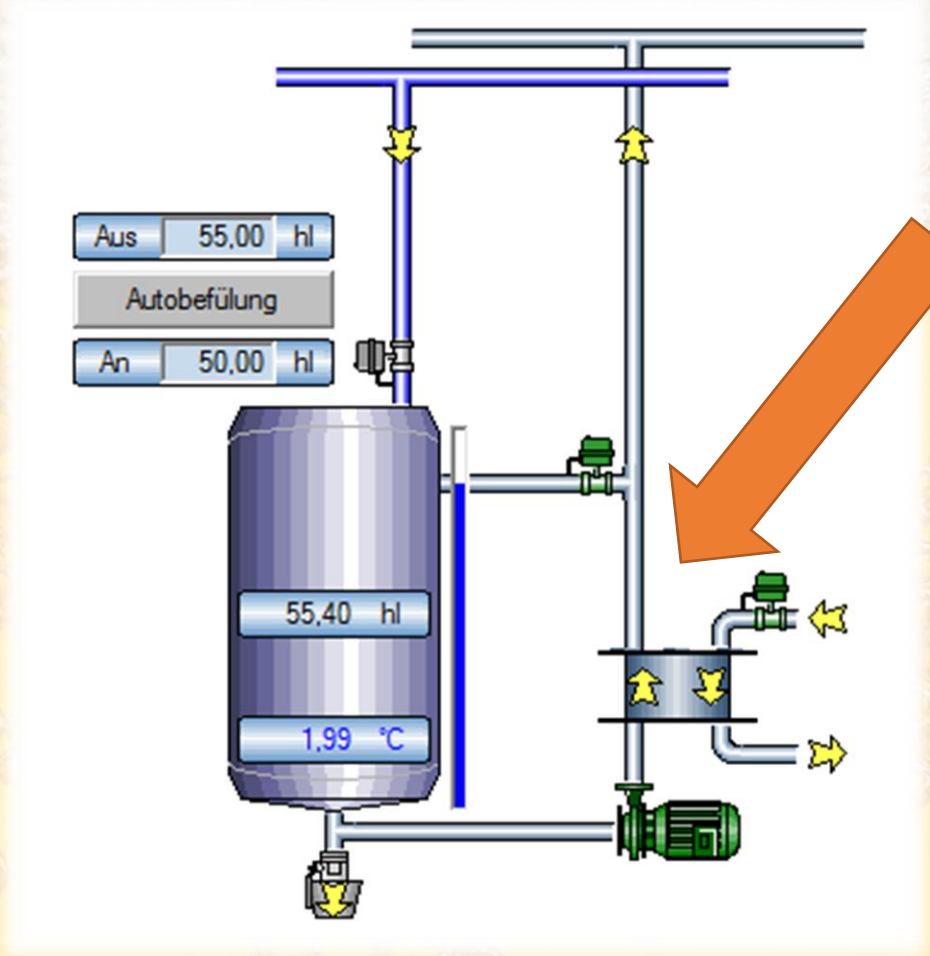
- Condensing vapor from wort boiling → Production of hot liquor
- Energy recovery > 90 %
- Tube bundle heat exchanger





# Pre-cooling of brewing water

- Single stage wort cooler
- Water is cooled down to 2 °C with brine through an external heat exchanger and accumulated in an insulated tank
- Peaks are smoothened so the performance of the cooling plant could be scaled down



# Solar Panels

- Comissioned in **2014**
- $\dot{Q}$ = 110 kW
- 2022:
  - 147.379 kWh produced
  - 57 % of electrical energy covered
  - Break-even obtained after 8 years

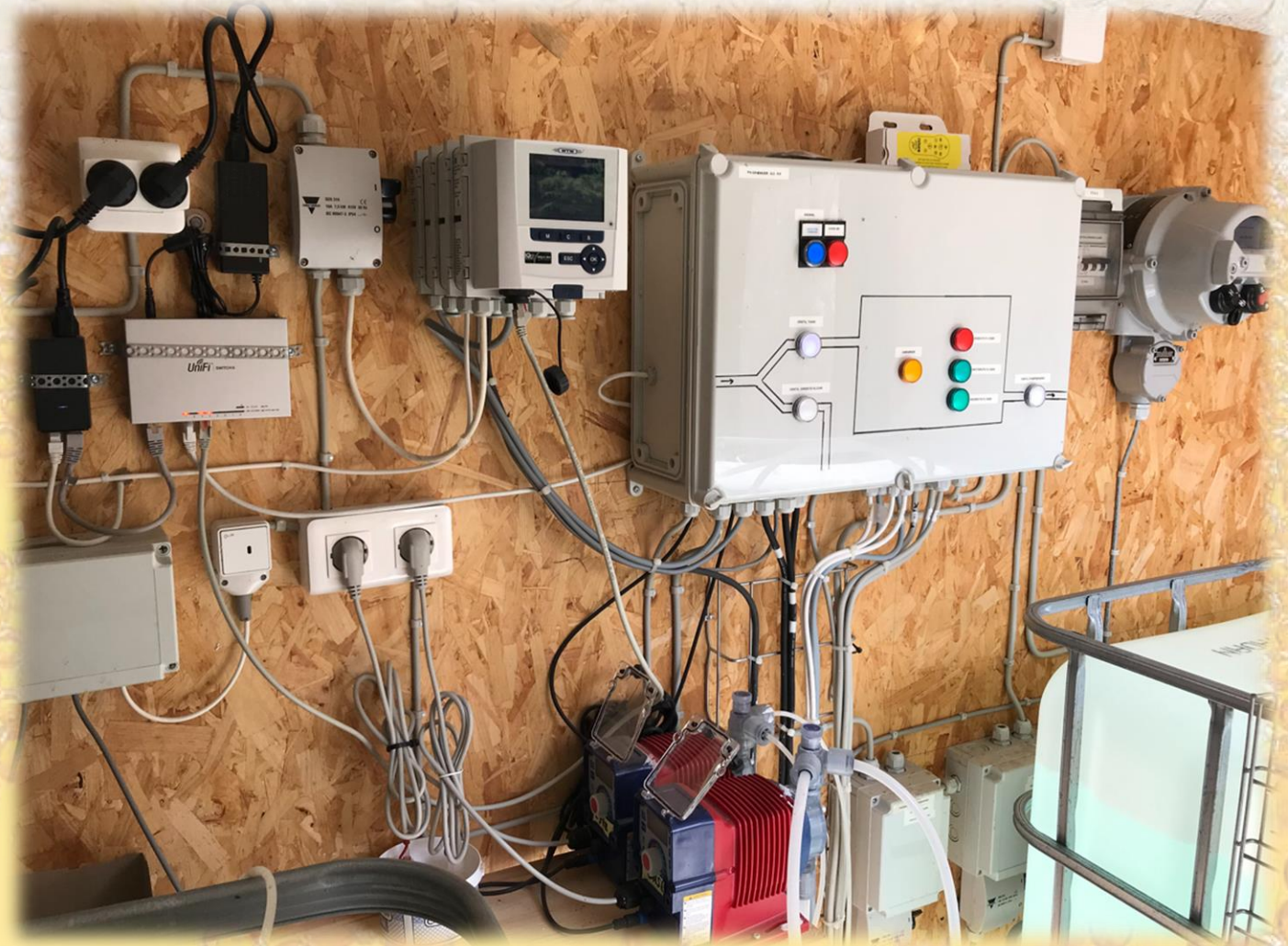
# 100 % Organic

- 100 % organic from **January 1st 2018**
- Being organic means not to pour poison into the soil and crop, but also 50 % less $CO_2$ emissions from agriculture (→ Synthetic fertilizers are energy-intensive to produce)
- Long-term contracts on raw materials mandatory, particularly hops!
- Flexibility in the mashing process cardinal as for varying qualities of malt batches → step mash

Stats-
kontrolleret
økologisk

# Waste Water Treatment Plant

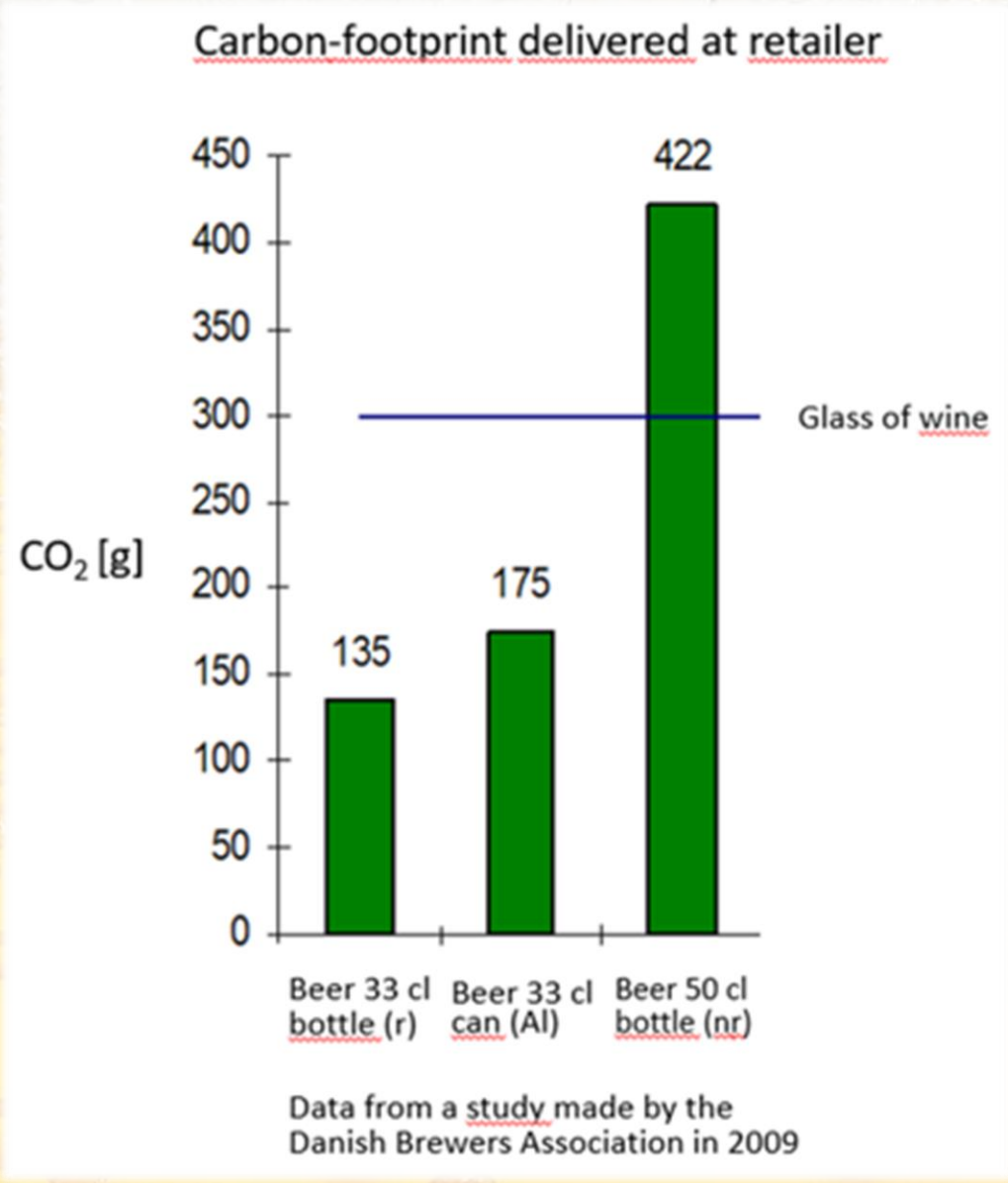
- Comissioned in **2019**
- 300 hl dug-down tank for neutralization of wastewater
- pH-meter, controller and dosage pumps for NaOH or $H_2SO_4$
- pH-range: 6,5 – 9
- Solids like yeast and spent grains are turned into biogas at a Bornholm-based plant → electrical energy and heat



# Canning Line

- Initial thoughts:
  - Carbon footprint (DK)
  - Product quality


vs.

# The project:

Integrating a canning line into an existing bottle packaging line

| Existing: |
| --- |
| Packaging line for one-way bottles from 2007 |
| 8.000 bph |
| Bottle depalletizer |
| 30 valve Electropneumatic Triblock filler |
| Bottle dryer |
| Labelling machine (self adhesive) |
| Packer (cardboard boxes) |
| Palletizer |

## Wanted!

- Automatic can depalletizer
- Ionized air rinser
- 8.000 cph filler-seamer block
- Fill level inspector (X-ray)
- Modification of existing labelling machine to also handle cans
- Later: New machine for labelling

# Canning Line

- Comissioned in **2019**


# Canning Line

The Result:

- Aluminum cans over steel cans
  - Despite the high energy demand during aluminum production, an aluminum can has a lower carbon footprint than a steel can because of the highly efficient recycling system in Denmark
  - In countries with insufficient or no recycling systems steel cans are better, as they disintegrate over time
- Sales: Cans in relation to bottles
  - 2019 → 13,6 %
  - 2020 → 16,8 %
  - 2021 → 20,1 %
  - 2022 → 23,3 %

# Green electricity and Biogas

- Since **2020**:
  - 100 % ”green” electricity i.e. wind and sun

    → Mass balance principle based on certified amounts of wind and solar power
  - 100 % ISCC-certified LPG (92 %Propane, 8 % Butane)

    → Mass balance principle, delivered in bulk


BORNHOLMS ENERGI & FORSYNING

Foto: Bornholms Energi og Forsyning. © Bornholms Energi og Forsyning 2021

## Certifikat

Det bekræftes hermed at elforbrug for virksomheden
Svaneke Bryghus A/S
I perioden 1/1 - 31/12 -2023
Dækkes 100% af certificeret grøn strøm fra bornholmske vindmøller af Bornholms Energi A/S.

Garantien oppebærer en certificering på ét blad i forbrugerombudsmandens mærkningsordning for vedvarende energi. For yderligere information om ordningen henvises til https://www.forbrugerombudsmanden.dk

**Proof of Sustainability (PoS) for Biofuels and Bioliquids** V4.5

For biofuels and bioliquids according to the Renewable Energy Directive (RED) and the Fuel Quality Directive (FQD), both amended through Directive (EU) 2015/1513

| | |
|---|---|
| Unique Number of Sustainability Declaration: | 67442019/84822-1 |
| Place and date of dispatch: | Odense, 05-08-2020 |
| Date of Issuance: | 31-08-2020 |

ISCC International Sustainability & Carbon Certification

www.iscc-system.org

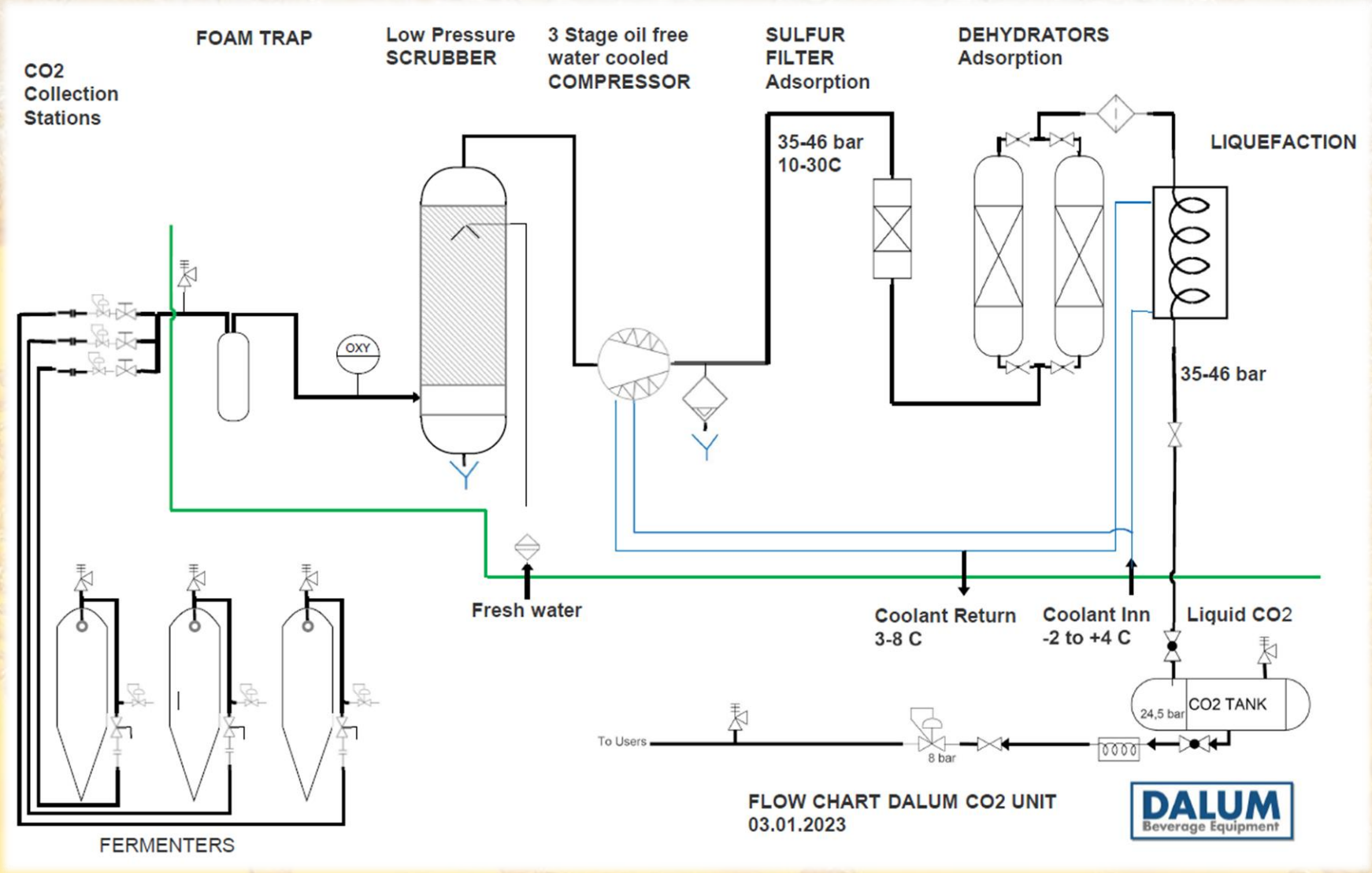
# $CO_2$-recovery plant

- Comissioned **January 2021**
- Compact size: 1 x 1 x 3 m
- In:
  - Raw gas: Approx. 96 % $CO_2$ , max. 1 % $O_2$
  - Electric power: 3 x 400 V, 50 Hz, 10 A fuses
  - Power consumption: 0,25 kW/kg
  - Water: 1 – 15 l/min, 5 – 15 ˚C
  - Cooling: -4 to 1 ˚C, 20 l/min, 0,15 - 0,2 kW/kg
- Out:
  - 99,99 % liquified $CO_2$ , 1 – 14 kg/h, 0 – 5 °C
  - Cooling return
  - Drain water 20 ˚C
  - Incondensable gasses
- $CO_2$-consumption: < 15 g $CO_2$/kg $CO_2$produced

# $CO_2$-recovery plant

- Working principle:

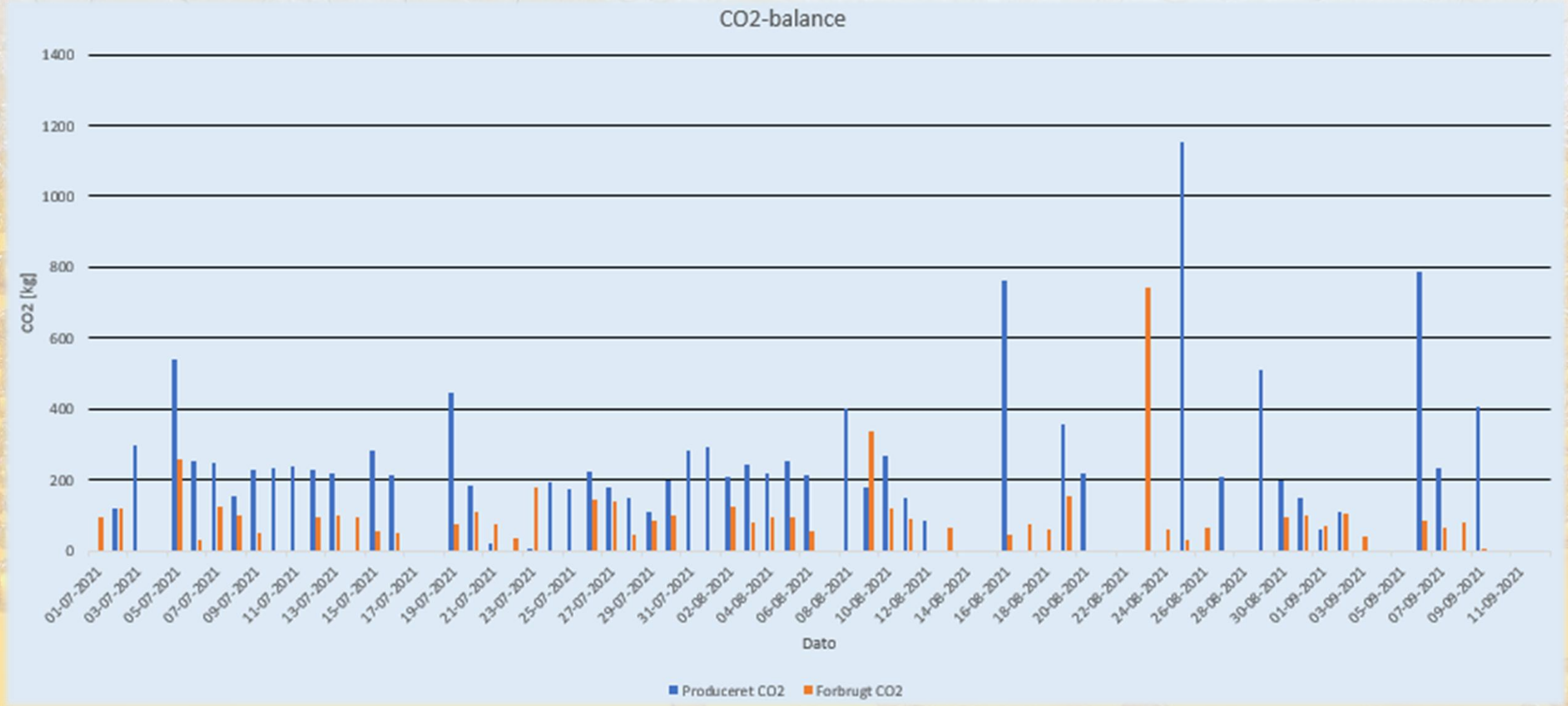
  - Low pressure scrubber removes Alcohols, Acetaldehyde and Esters
  - Frequency controlled three stage compressor increases pressure from 0,2 bar to 35 - 45 bar → No $CO_2$-balloon needed
  - Activated carbon filter removes sulfuric components e.g. $H_2S$
  - The Dehydrator dries the $CO_2$ to a dewpoint of below – 60 ˚C and removes residual DMS
  - The condenser liquefies the $CO_2$ and removes traces of incondensable gasses like $O_2$ and $N_2$ to under 0,05 % (500 ppm) with brewery glycol (-4 ˚C to 1 ˚C)



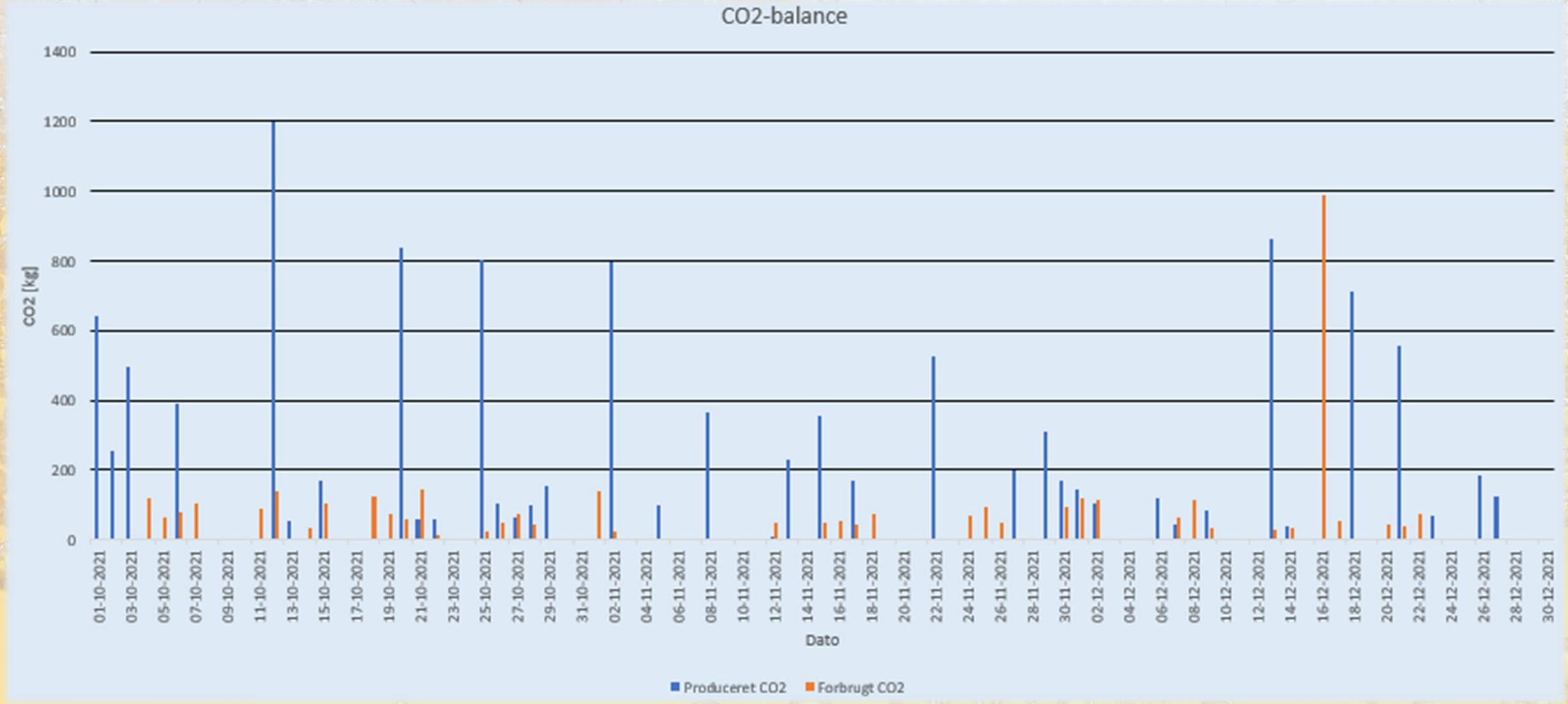
# $CO_2$-recovery plant

- $CO_2$-consumption for processing 2022: 25 tons
- $CO_2$-production 2022: 35 tons
- $CO_2$ recovered from wort (excl. non-alcoholic): 2,2 kg/hl
- Excess $CO_2$ is filled into steel cylinders and distributed to draft beer customers
- The purity of the $CO_2$ also makes it applicable for us in soda pops and sparkling water
- By every kilogram $CO_2$ recovered a total of 2 kg $CO_2$–emissions are reduced, as 1 kg $CO_2$ produced by an industrial gas company generates 1 kg $CO_2$ emissions for production and transport
- Investment of 160.000 EURO
  - $CO_2$–recovery unit
  - Cylinder filler
  - Purchase and modification of existing $CO_2$-tank
  - Regulatory approval
- Break-even obtained after 4 ½ years due to savings on $CO_2$–purchase and sales of $CO_2$ in gas cylinders to draft beer customers

# $CO_2$-recovery plant
# 3. quarter of 2021

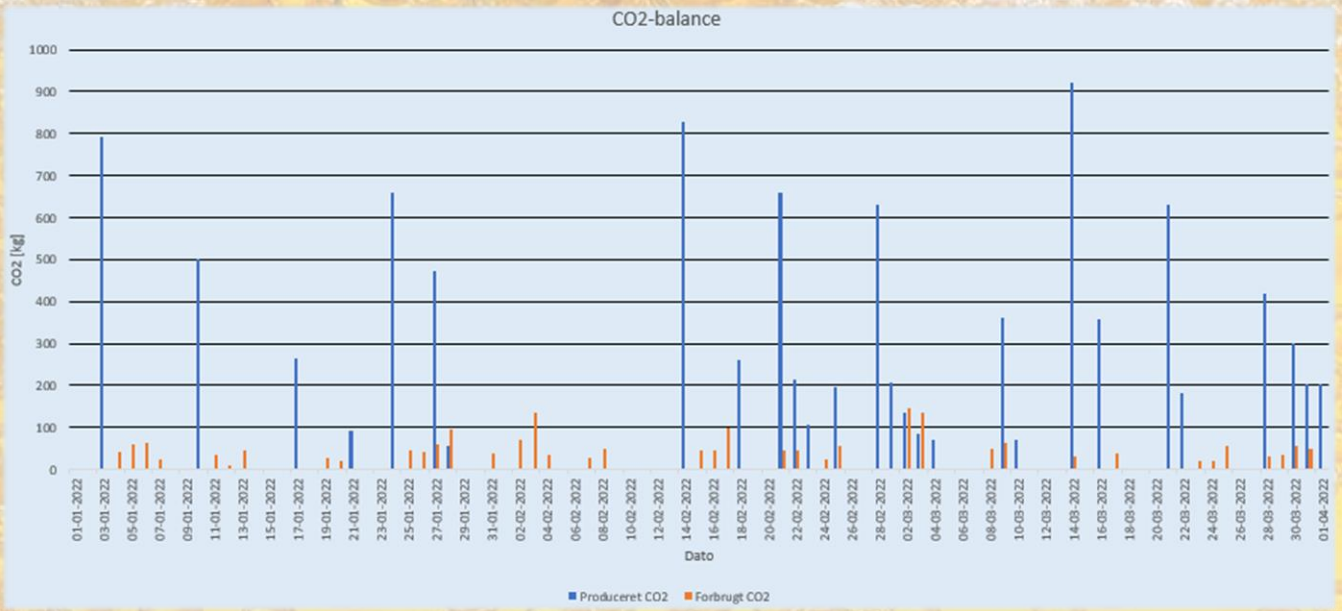


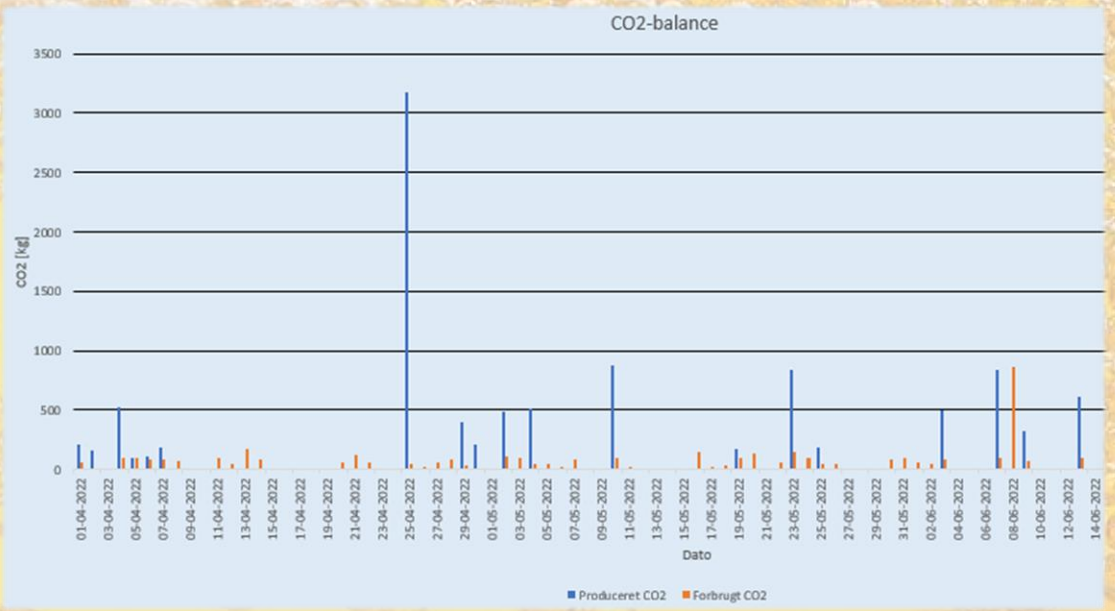
# $CO_2$-recovery plant
# 4. quarter of 2021



# $CO_2$-recovery plant
# 1. and 2. quarter of 2022

→ after several improvements



# Feasability of $CO_2$-recovery (state of the art 2024)

| PRODUCTION | Beer Hl/y | Alcohol % | CO2 production, kg | Recovery rate | CO2 Recovery Kg | | |
|---|---|---|---|---|---|---|---|
| From fermentation | 16.385 | 5,30 | 69.472 | 0,75 | 52.104 | 3,18 | kg/hl |
| Purge gas recovery | 16.385 | 2,00 | 3.277 | 0,65 | 2.130 | | |
| | | | | | 54.234 | | |

| COST | kg/year | price | cost EUR | | | |
|---|---|---|---|---|---|---|
| CO2 usage, bulk | 37.253 | 0,613 | 22.836 | | | |
| CO2 usage, cylinders | 720 | 3,662 | 2.637 | Cylinders | | |
| CO2 total | 37.973 | | 25.473 | | | |
| Rent of storage tank and vaporizer | | | 2.580 | | | |
| TOTAL ANNUAL COST OF CO2 | | | 28.053 | | | |
| Labour cost €/y | 1/4 hour/day | | 1.000 | | | |
| Maintenance €/y | | | 1.711 | 1.711 | 2,50% | |
| Electricity incl cooling | 16.270 | kW | 2.831 | 0,174 | €/kWh | |
| Water | | | 224 | 4,13 | €/m3 | |
| Variable Cost of recovered CO2 | 54.234 | | 5.766 | 0,11 | €/kg | |
| Created Value (measured by bulk gas) | | | 30.059 | | | |
| Savings | | | 22.286 | | | |

| Investment | 0 |
|---|---|
| 1 pc. 15 kg CO2 unit with foam trap | 68.450 |
| CO2-collection system | 10.700 |
| Piping to storage tank | 8.460 |
| Options (cladding, burette, O2-sensor, CO2-alarm) | 3.735 |
| Complete System | 91.345 |

| | |
|---|---|
| 5 ton storage tank with vaporizer, budget | 38.400 |
| Cylinder filling station | 12.000 |
| TANK + FILLER SOLUTION | 50.400 |
| Compleete System | 141.745 |

→ Break-even obtained after 4 years when selling surplus $CO_2$

→ Svaneke (2021): 160.000 EUR, break-even 4 ½ years

| FOR BULK USE ONLY, OWN tank | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 | 2032 | 2033 |
| Production Hl Beer | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 | 16.385,00 |
| CO2 Usage | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 | 37.973,00 |
| Recovery | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 | 54.234,35 |
| Created Value (measured by bulk gas) | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 |
| kg/h, 47 weeks/y | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 | 6,87 |
| No inflation | | | | | | | | | | | | |
| Cash Flow of operations | | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 |
| Working Capital | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Increase in working capital | | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Capital investment | | 141.745,00 | | | | | | | | | | |
| Sale of plant | | | | | | | | | | | | |
| Net cash flow | 0,00 | -111.685,61 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 | 30.059,39 |
| Accumulated Cash Flow | | -111.685,61 | -81.626,23 | -51.566,84 | -21.507,46 | 8.551,93 | 38.611,31 | 68.670,70 | 98.730,08 | 128.789,47 | 158.848,86 | 188.908,24 |
| Present Value 2023 at 5% | 0,00 | -106.367,25 | 27.264,75 | 25.966,43 | 24.729,93 | 23.552,32 | 22.430,78 | 21.362,64 | 20.345,38 | 19.376,55 | 18.453,86 | 17.575,10 |
| Cost of capital rate | 1,0500 | | | | | | | | | | | |
| Net Present Value (at 5%) | 114.690,47 | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| Saving as for demand | | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 |
| Net cash flow demand | | -119.924,89 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 | 21.820,11 |
| Accumulated Cash Flow demand | | -119.924,89 | -98.104,79 | -76.284,68 | -54.464,57 | -32.644,46 | -10.824,36 | 10.995,75 | 32.815,86 | 54.635,97 | 76.456,07 | 98.276,18 |
| Earnings (e.g. sale in cylinders or bulk) | | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 | 8.239,28 |

# Electric vans and company cars since 2022

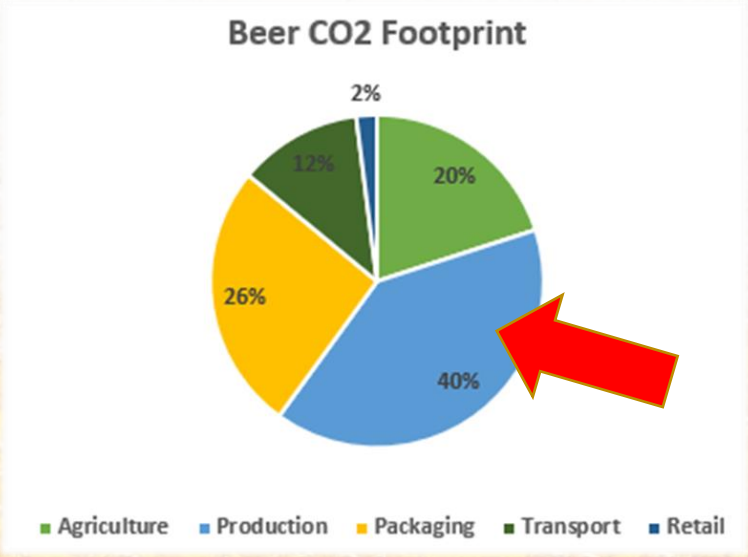

# Waste water turned into biogas since 2023

All waste water from beer production is turned into biogas (methane) at a local plant. From 2024 this gas will be used for steam production and heating, thus replacing imported Bio LPG


On-site waste water treatment using algae failed

# Verified $CO_2$-neutral by FORCE Certification

- As of **January 19th 2021**
- ONLY production and processing!
- NOT the brewery, NOT the products!
- Verification done according to international standards ISO 14064 part 3 and ISO 14065 and renewed on an annual base
- Scope 1 and 2 by ”Green House Gas Protocol Standards” was obtained in 2023 i.e. all direct (gas) and indirect $CO_2$-emissions (electricity) from the production site are $CO_2$-neutral and company cars are electrically powered → In other words: Things that we can control ourselves!
- **$CO_2$-recovery in fact makes production and processing $CO_2$-negative** → For each kilogram $CO_2$ produced by an industrial gas company there is 1 kg $CO_2$ emissions (production and transport), so by every kilogram $CO_2$ recovered a total of 2 kg $CO_2$ -emissions are reduced
- Scope 3: Life Cycle Assessment (LCA) is difficult to reach → Climate tool for Product Environmental Footprint (PEF) available as an online calculator supplied by “The Brewers of Europe”
- However: **If everyone reaches scope 2, then scope 3 for all will be the natural result!**




FORCE Certification

# Thank you for your attention!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