Alcohol Elimination Service (AES)

MAGFO

IBE Capstone

IBE

Integrated Business and Engineering
Honors Program

Alex

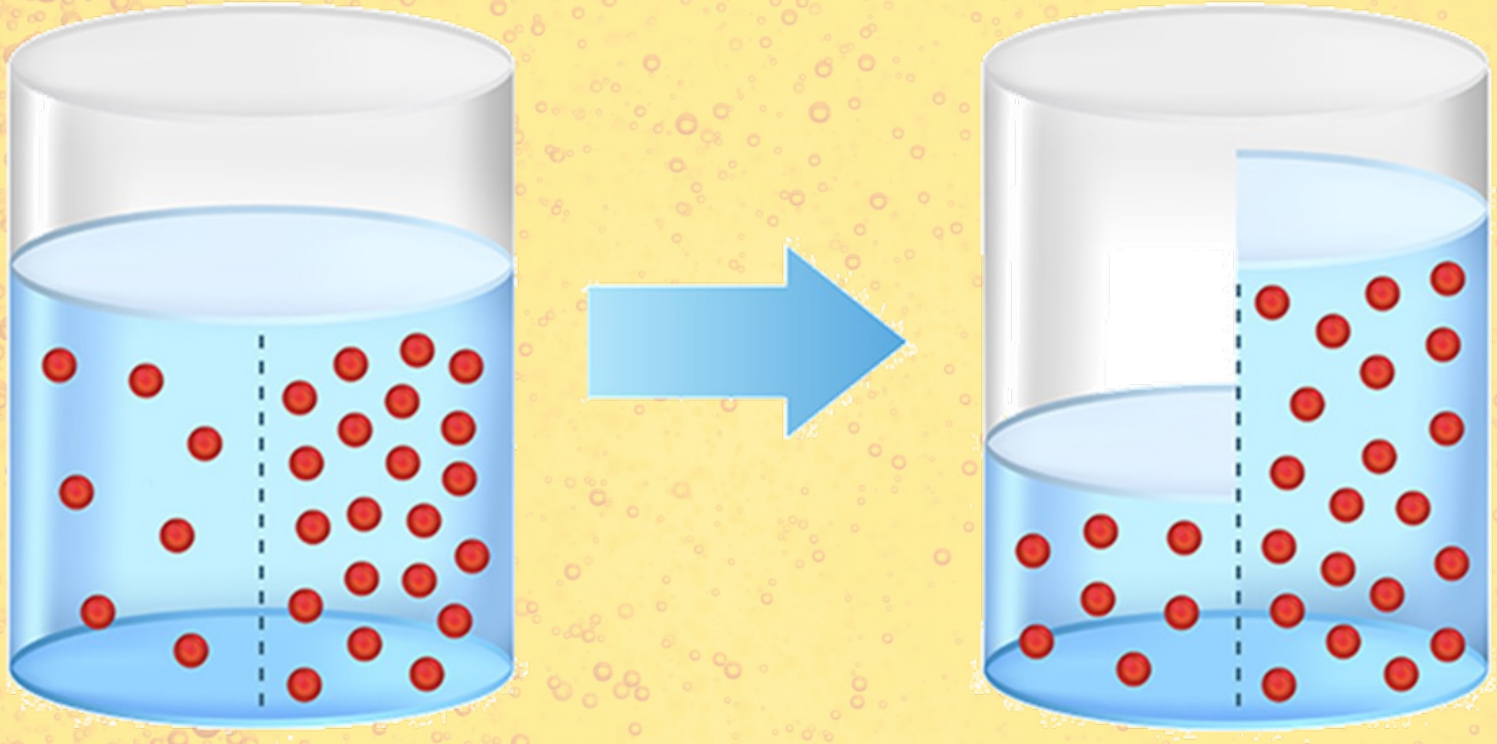
MAGFO

The Origins of MagFO

Robert Creighton – Project Sponsor

Alex

Osmosis



Alex

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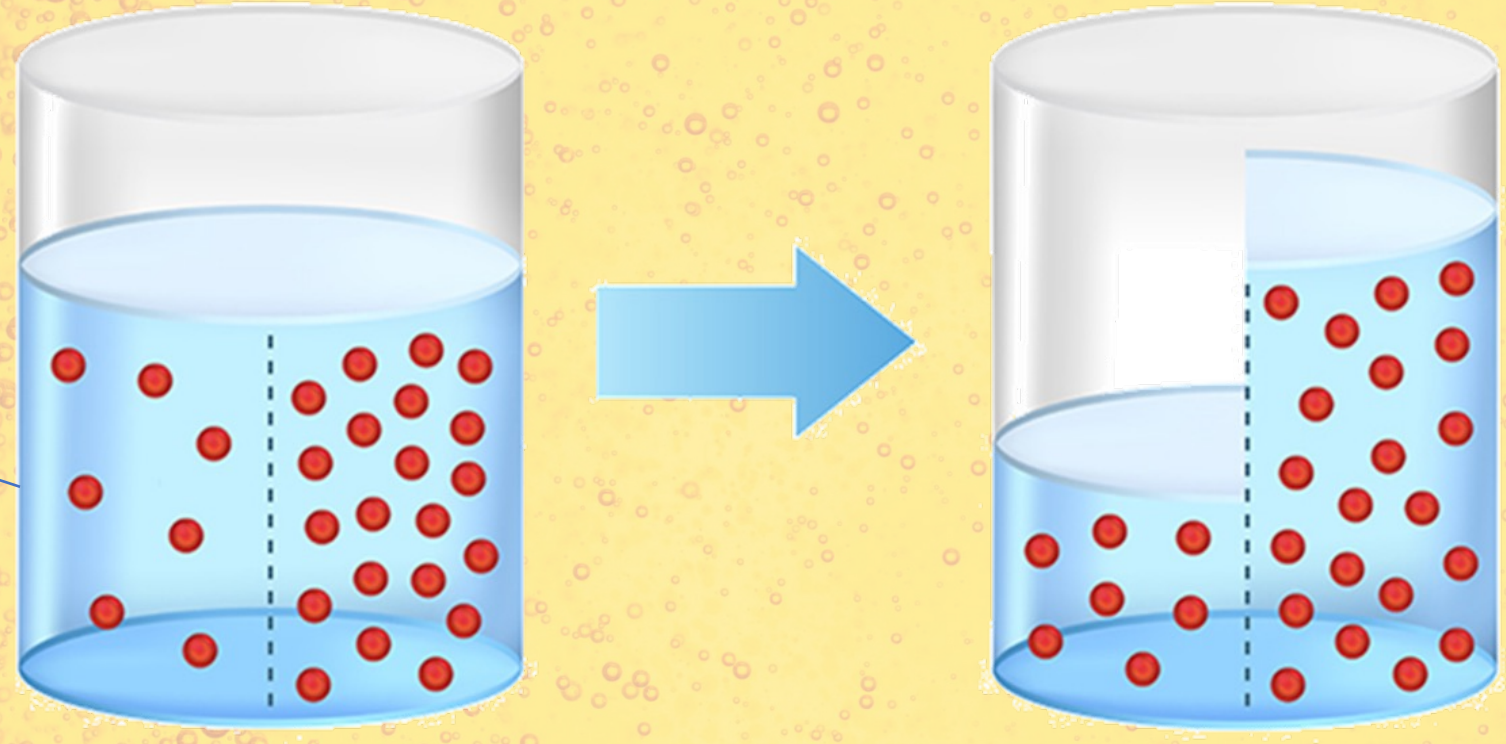
Osmosis



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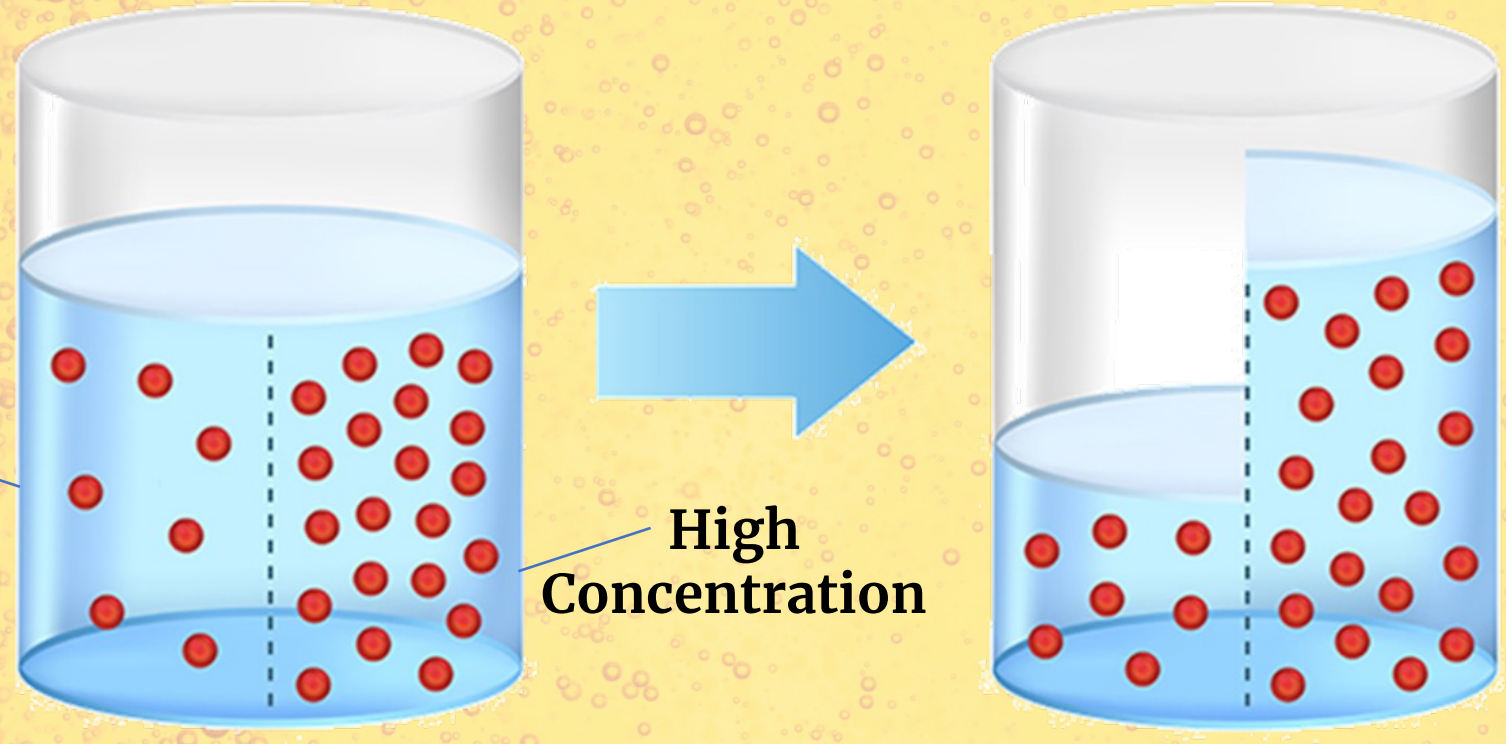
Osmosis



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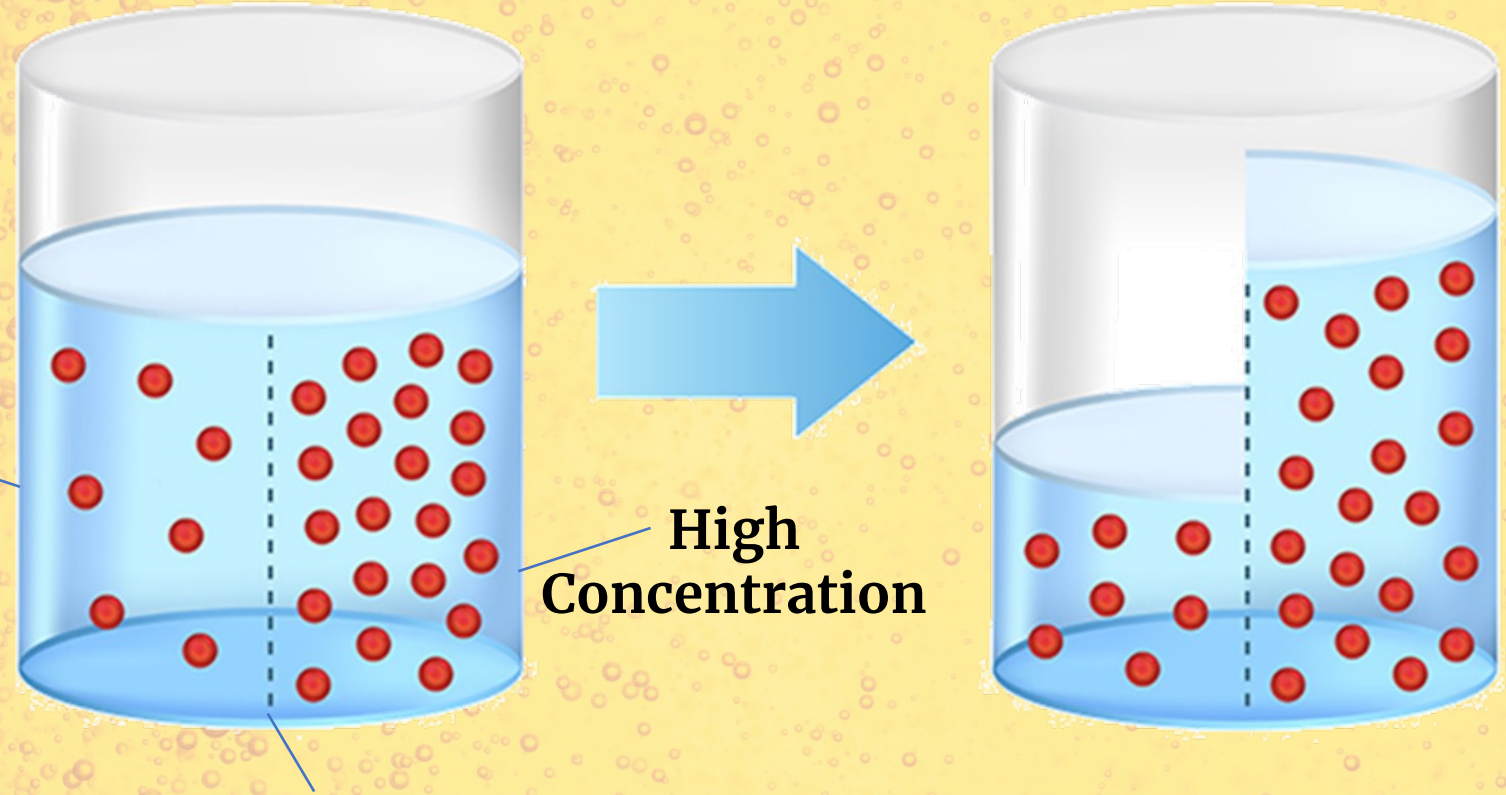
Osmosis



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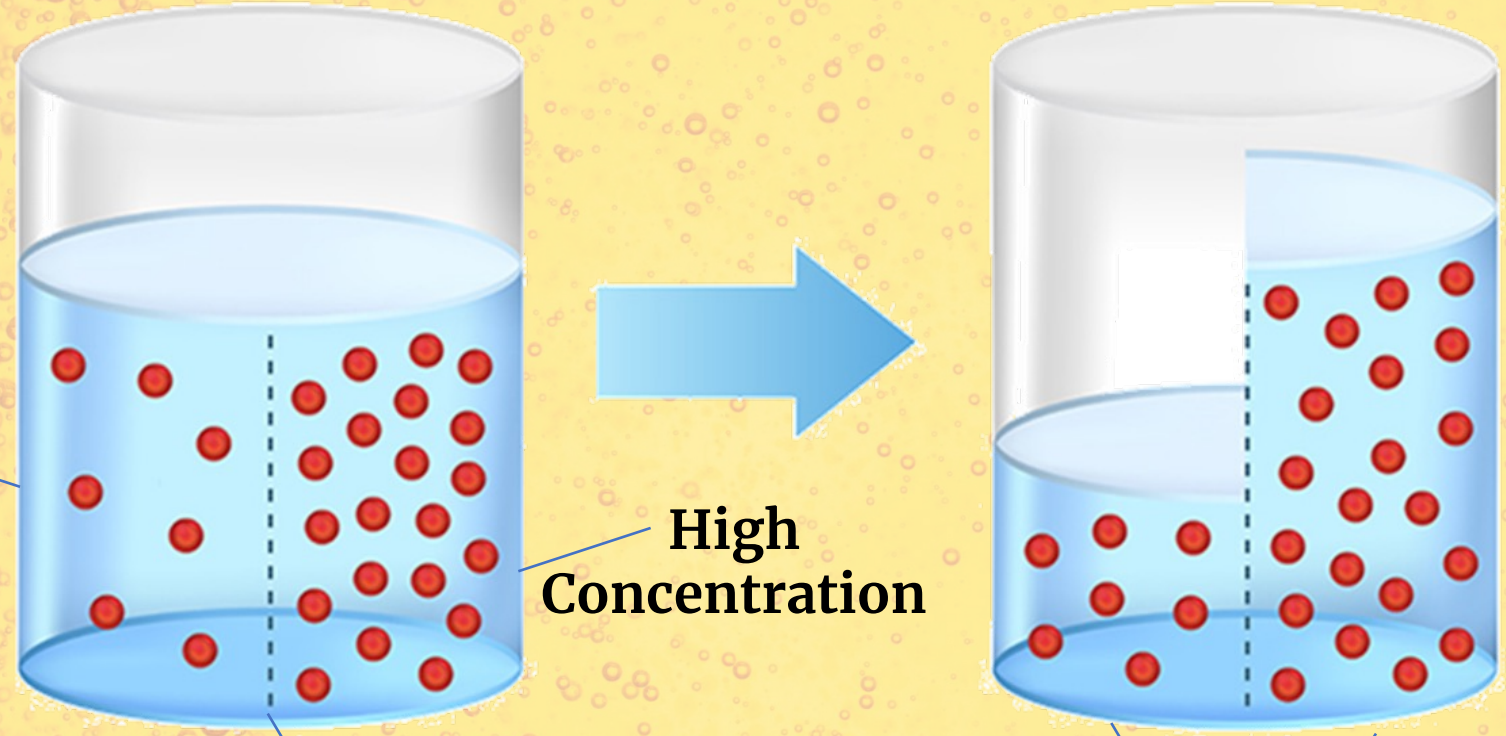
Osmosis



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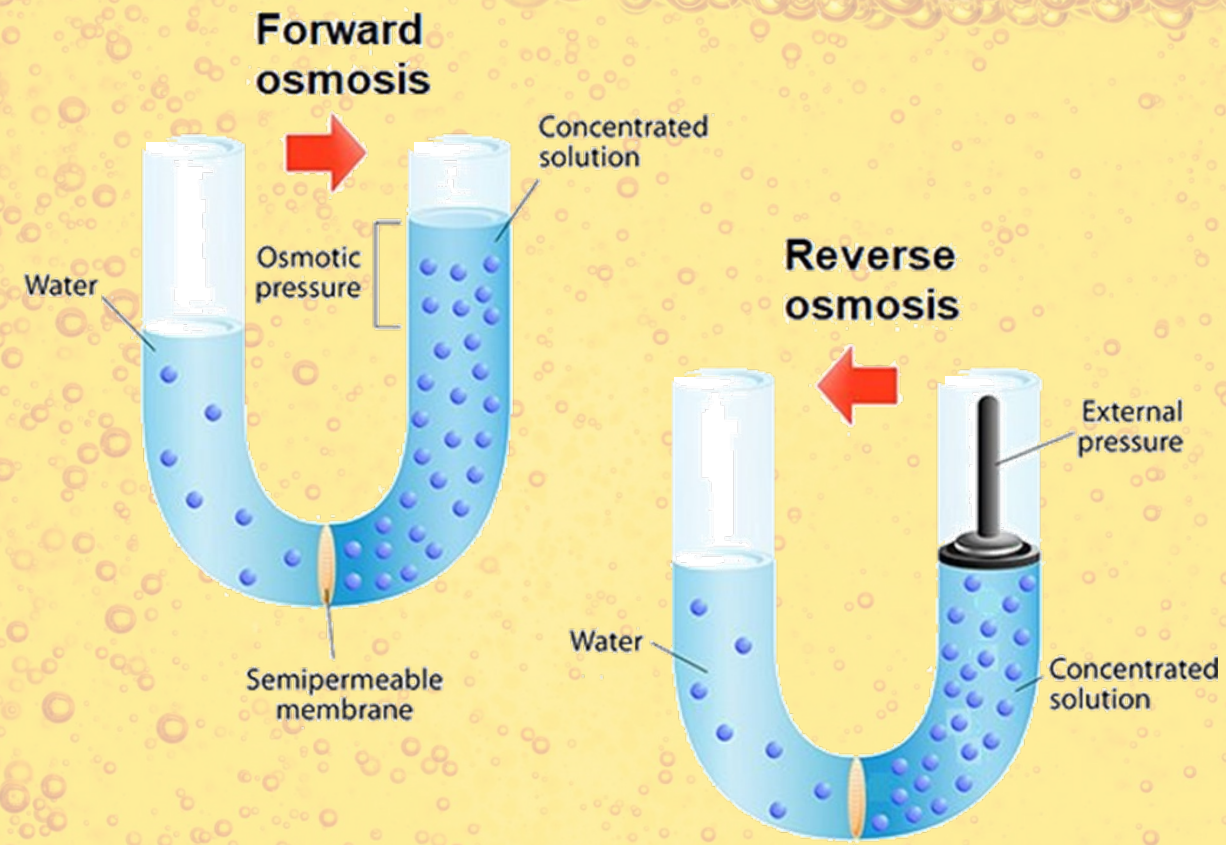
Forward/Reverse Osmosis



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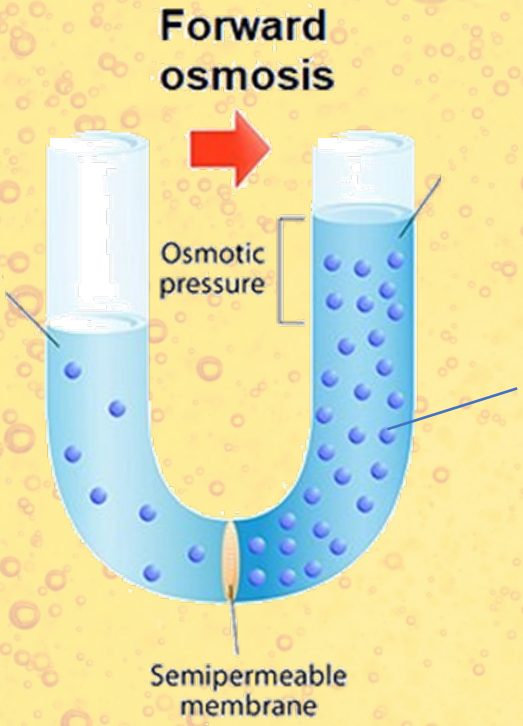

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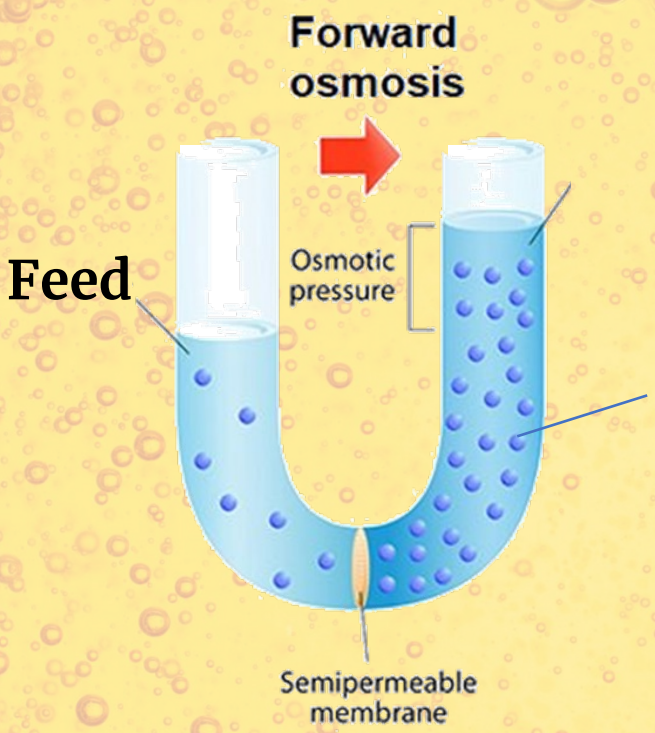

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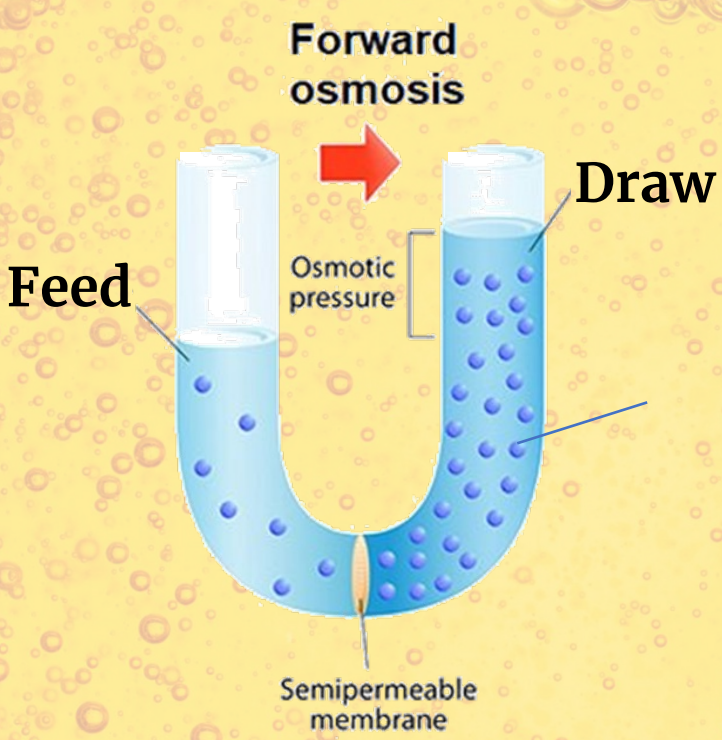
Forward/Reverse Osmosis



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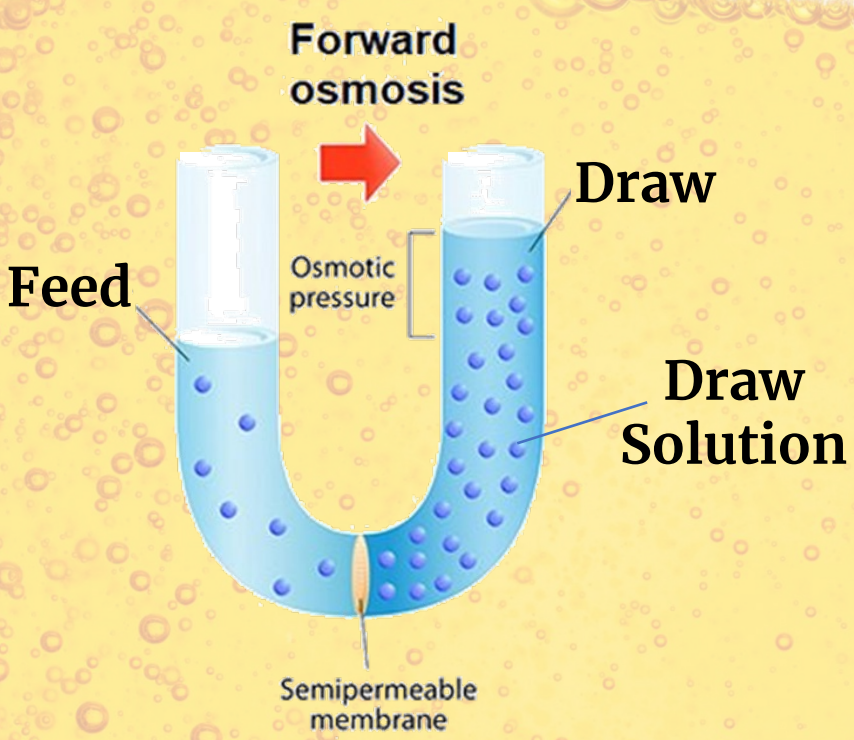

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Forward/Reverse Osmosis

Alex

Forward/Reverse Osmosis

Hydraulics

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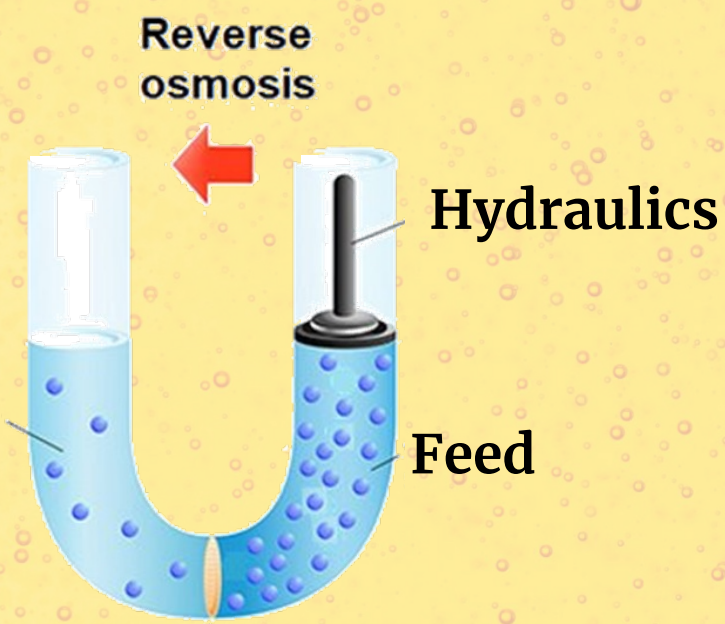
Forward/Reverse Osmosis



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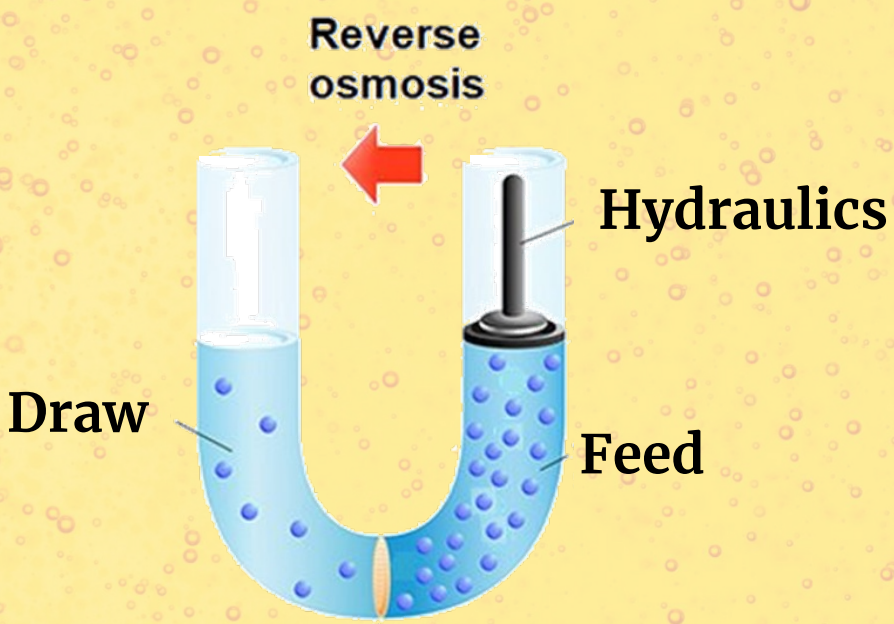

Alex

FO vs RO

FO

RO

Alex

FO vs RO

FO	**Requires draw solution**
RO	**Requires hydraulics**

Alex

FO vs RO

FO	Requires draw solution	Weak
RO	Requires hydraulics	Strong

Alex

FO vs RO

FO	Requires draw solution	Weak	Energy Efficient
RO	Requires hydraulics	Strong	Energy Intensive

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FO vs RO

FO	Requires draw solution	Weak	Energy Efficient	Longer membrane lifespan
RO	Requires hydraulics	Strong	Energy Intensive	Prone to membrane damage

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Terms

Osmotic Pressure

Alex

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Terms

Osmotic Pressure

Flux Rate

Alex

Terms

Flux Rate

Alex

Terms

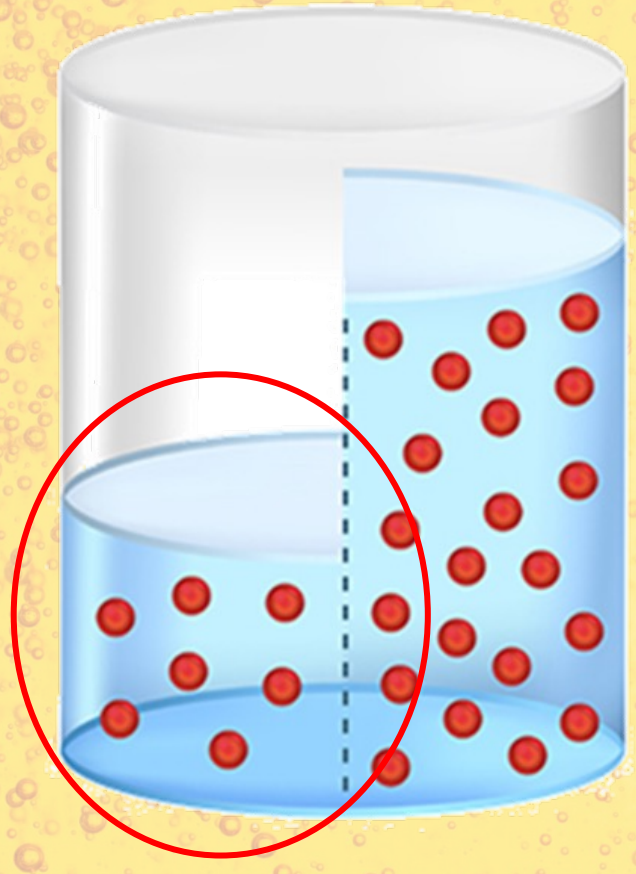
Osmotic Pressure

Flux Rate

Brine

Alex

Terms



Brine

Alex

Terms

Osmotic Pressure

Flux Rate

Brine

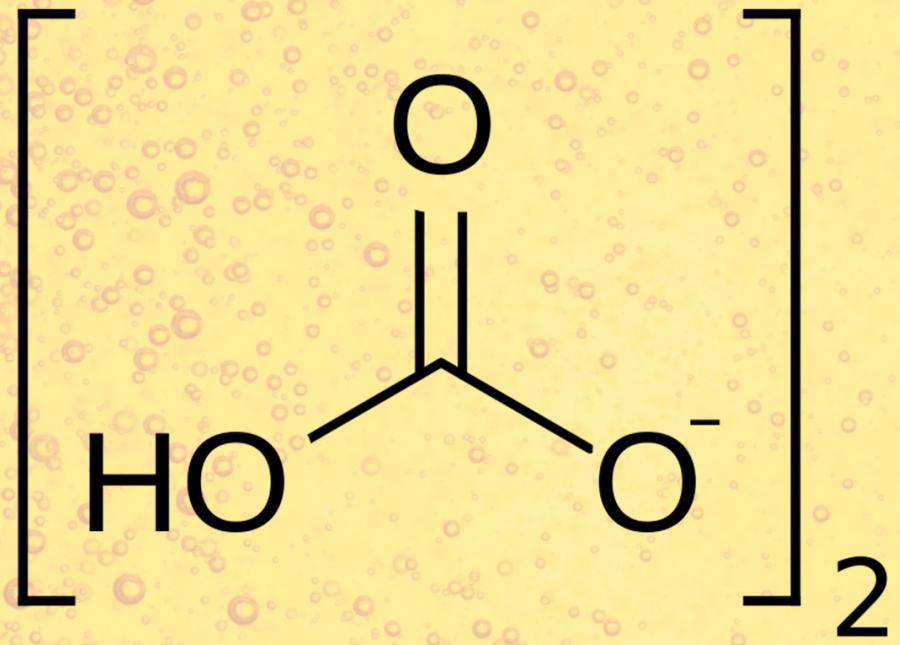
Alex

The Origins of MagFO

Robert Creighton – Project Sponsor

Alex

The Origins of MagFO



Mg^{2+}

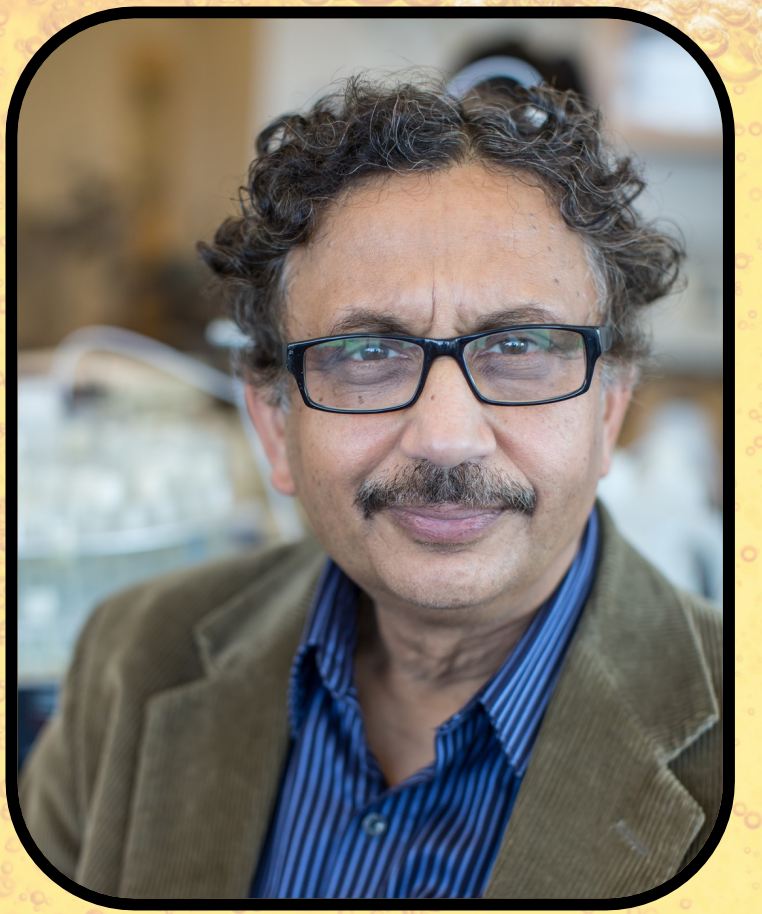
Alex

The Origins of MagFO

Professor Arup K. SenGupta
Lehigh University

Alex

The Origins of MagFO



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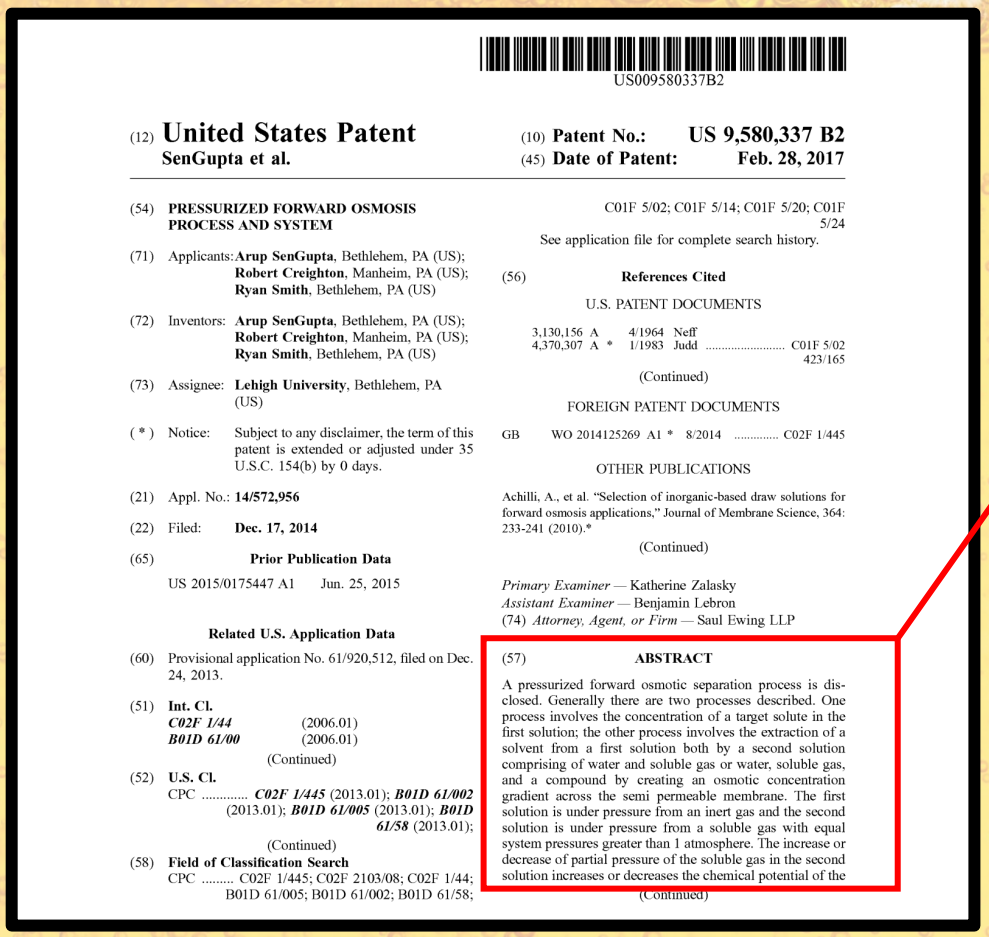

US009580337B2

(12) **United States Patent**
SenGupta et al.

(10) **Patent No.: US 9,580,337 B2**
(45) **Date of Patent: Feb. 28, 2017**

(54) **PRESSURIZED FORWARD OSMOSIS PROCESS AND SYSTEM**

(71) Applicants: **Arup SenGupta**, Bethlehem, PA (US); **Robert Creighton**, Manheim, PA (US); **Ryan Smith**, Bethlehem, PA (US)

(72) Inventors: **Arup SenGupta**, Bethlehem, PA (US); **Robert Creighton**, Manheim, PA (US); **Ryan Smith**, Bethlehem, PA (US)

(73) Assignee: **Lehigh University**, Bethlehem, PA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/572,956**

(22) Filed: **Dec. 17, 2014**

(65) **Prior Publication Data**

US 2015/0175447 A1 Jun. 25, 2015

Related U.S. Application Data

(60) Provisional application No. 61/920,512, filed on Dec. 24, 2013.

(51) **Int. Cl.**
C02F 1/44 (2006.01)
B01D 61/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***C02F 1/445*** (2013.01); ***B01D 61/002*** (2013.01); ***B01D 61/005*** (2013.01); ***B01D 61/58*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC C02F 1/445; C02F 2103/08; C02F 1/44; B01D 61/005; B01D 61/002; B01D 61/58; C01F 5/02; C01F 5/14; C01F 5/20; C01F 5/24
See application file for complete search history.

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(Continued)

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Achilli, A., et al. "Selection of inorganic-based draw solutions for forward osmosis applications," Journal of Membrane Science, 364: 233-241 (2010).*
(Continued)

Primary Examiner — Katherine Zalasky
Assistant Examiner — Benjamin Lebron
(74) *Attorney, Agent, or Firm* — Saul Ewing LLP

(57) **ABSTRACT**

A pressurized forward osmotic separation process is disclosed. Generally there are two processes described. One process involves the concentration of a target solute in the first solution; the other process involves the extraction of a solvent from a first solution both by a second solution comprising of water and soluble gas or water, soluble gas, and a compound by creating an osmotic concentration gradient across the semi permeable membrane. The first solution is under pressure from an inert gas and the second solution is under pressure from a soluble gas with equal system pressures greater than 1 atmosphere. The increase or decrease of partial pressure of the soluble gas in the second solution increases or decreases the chemical potential of the
(Continued)

(57) **ABSTRACT**

A pressurized forward osmotic separation process is disclosed. Generally there are two processes described. One process involves the concentration of a target solute in the first solution; the other process involves the extraction of a solvent from a first solution both by a second solution comprising of water and soluble gas or water, soluble gas, and a compound by creating an osmotic concentration gradient across the semi permeable membrane. The first solution is under pressure from an inert gas and the second solution is under pressure from a soluble gas with equal system pressures greater than 1 atmosphere. The increase or decrease of partial pressure of the soluble gas in the second solution increases or decreases the chemical potential of the

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Rick Smith
Director of Technology Transfer Office

Alex

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Robert Creighton – Project Sponsor

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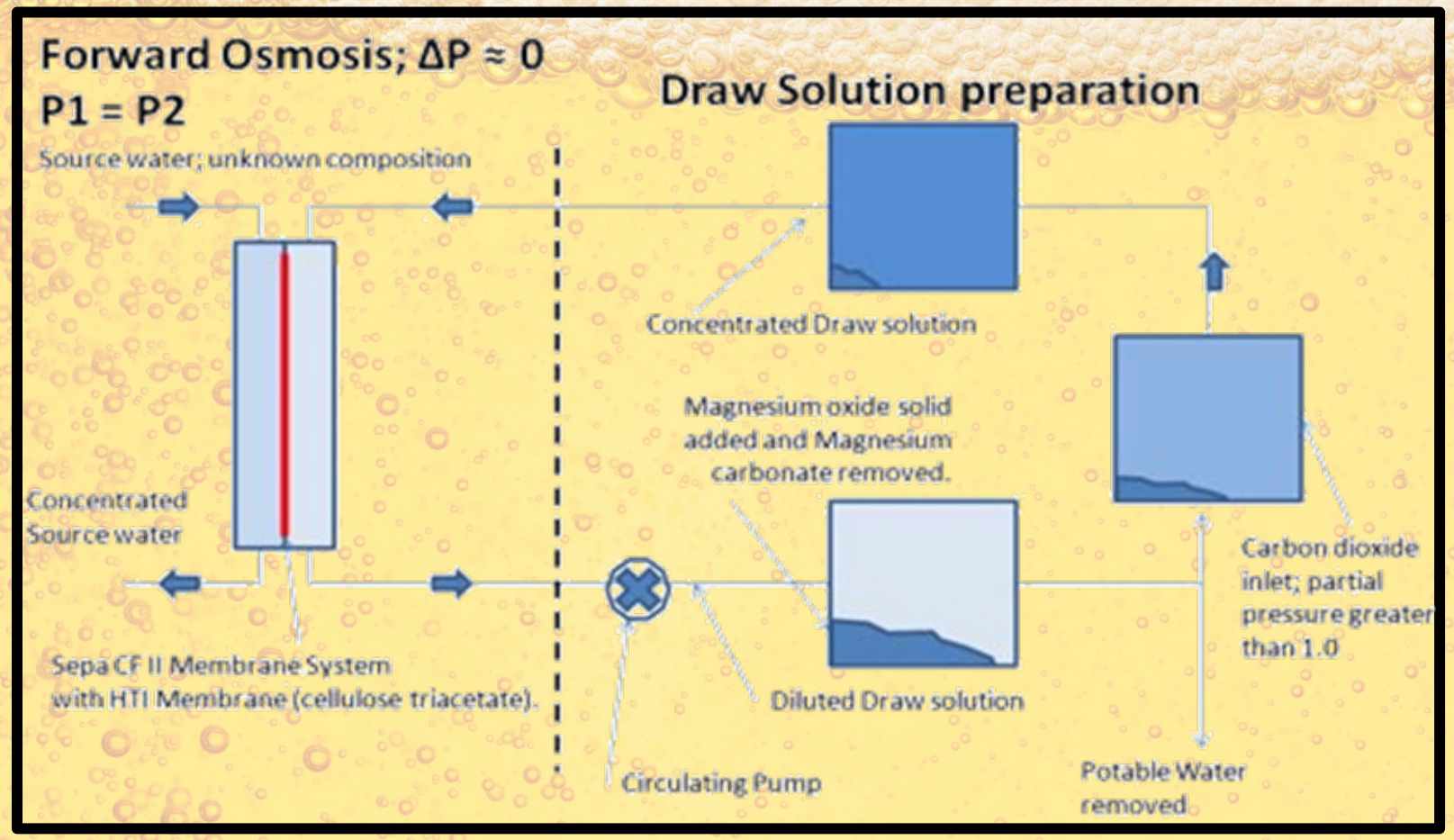
Forward Osmosis; ΔP ≈ 0
P1 = P2
Draw Solution preparation
Source water; unknown composition
Concentrated Draw solution
Magnesium oxide solid added and Magnesium carbonate removed.
Concentrated Source water
Carbon dioxide inlet; partial pressure greater than 1.0
Sepa CF II Membrane System with HTI Membrane (cellulose triacetate).
Diluted Draw solution
Circulating Pump
Potable Water removed

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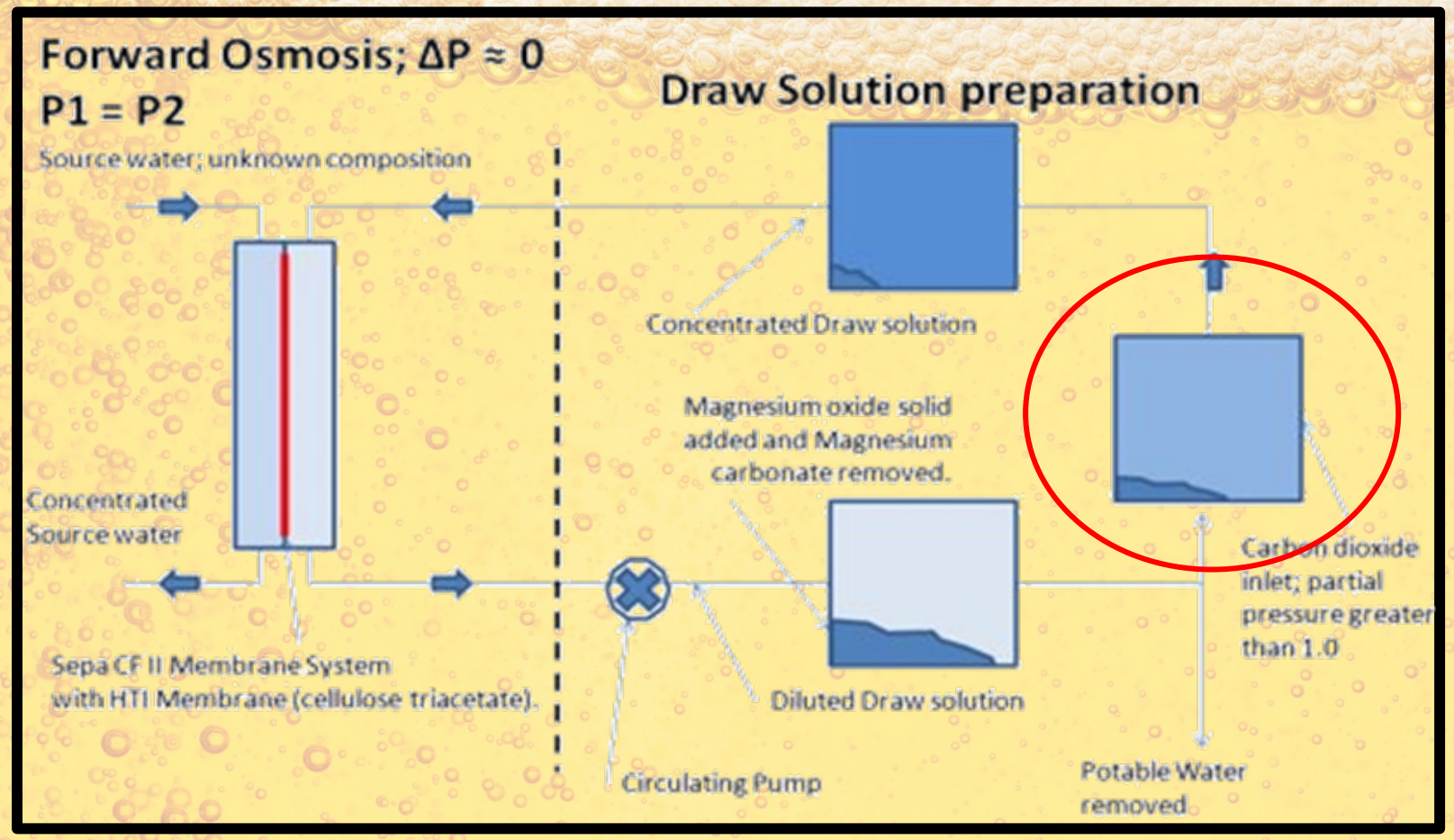

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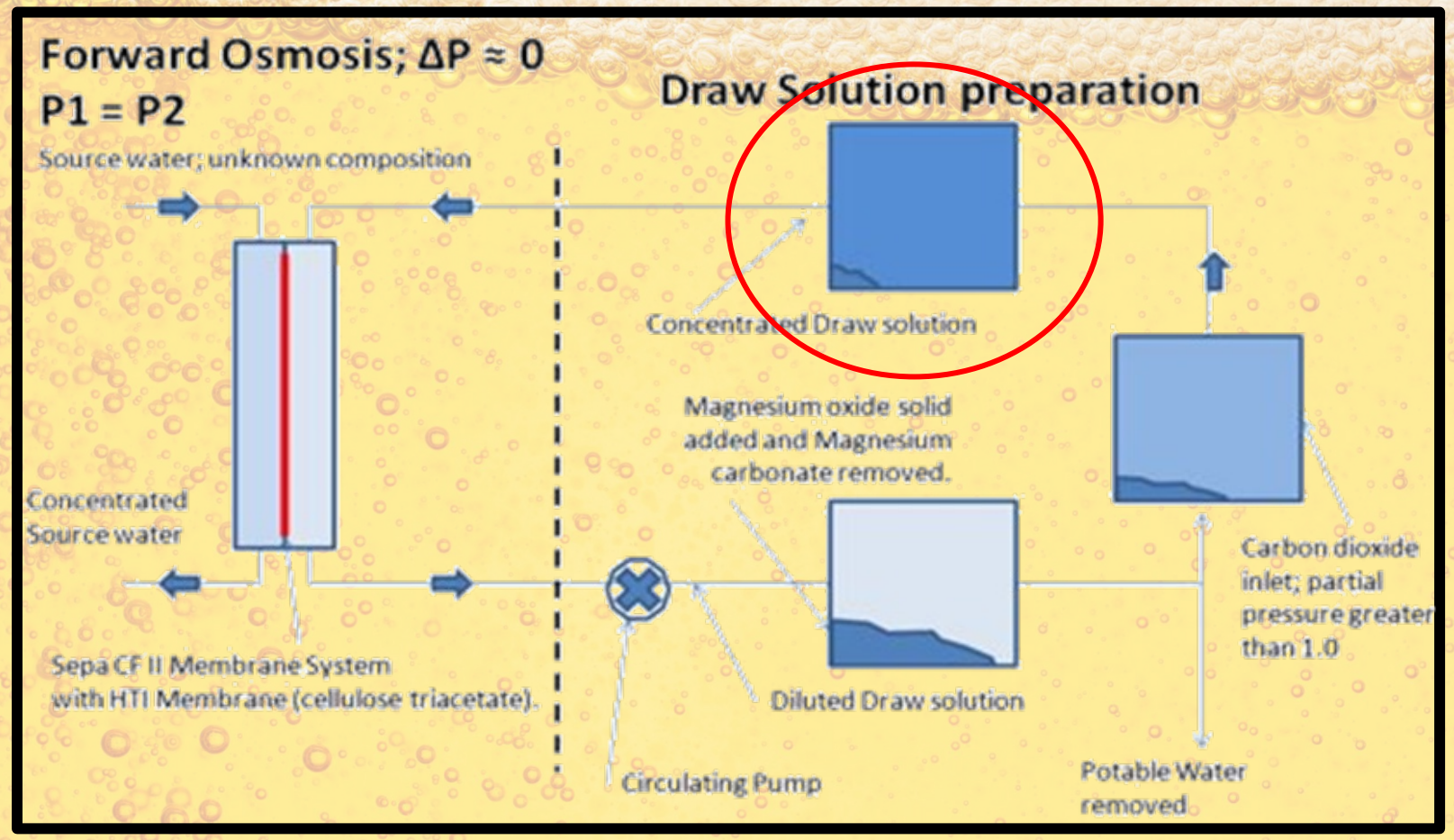
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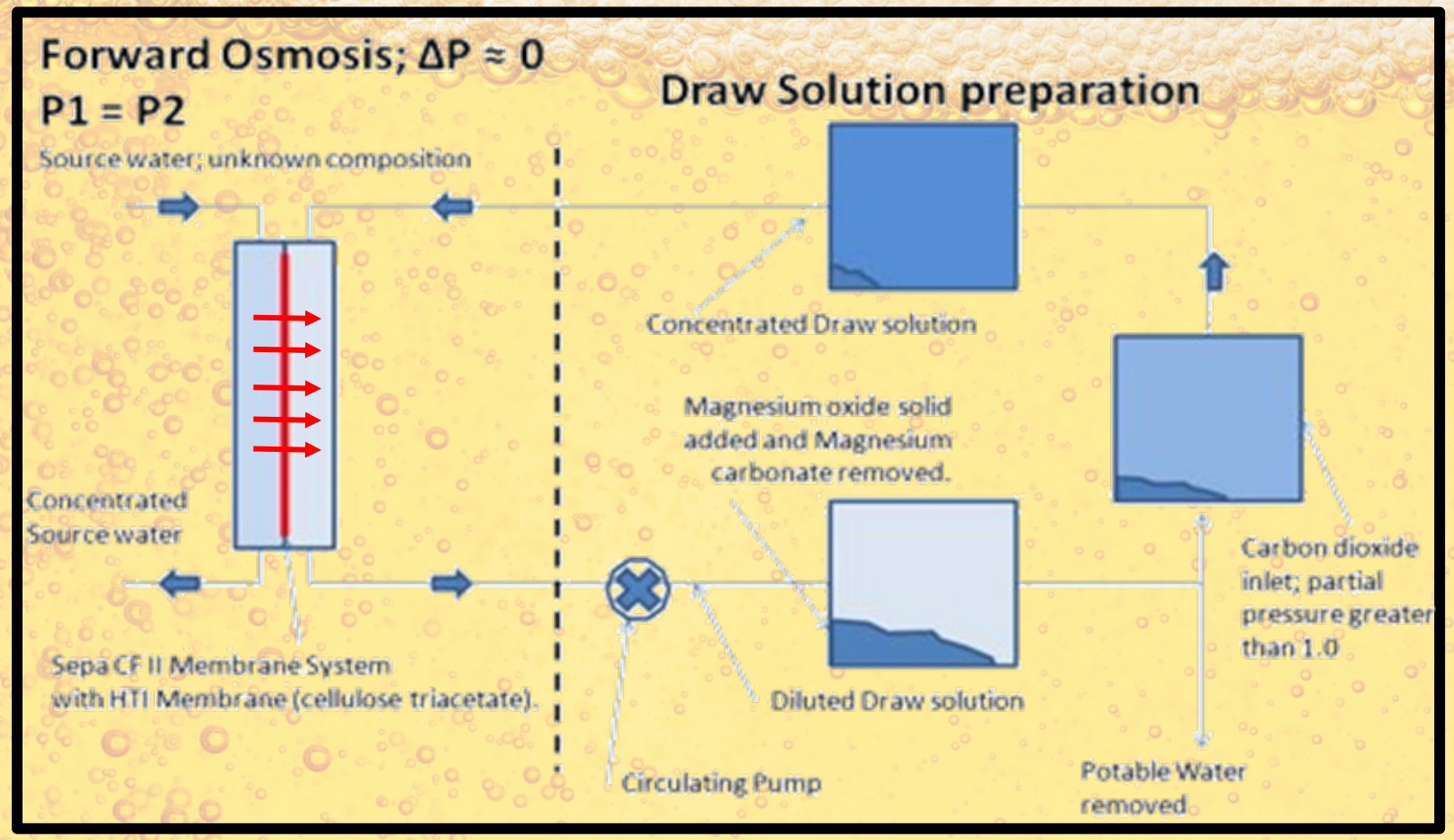
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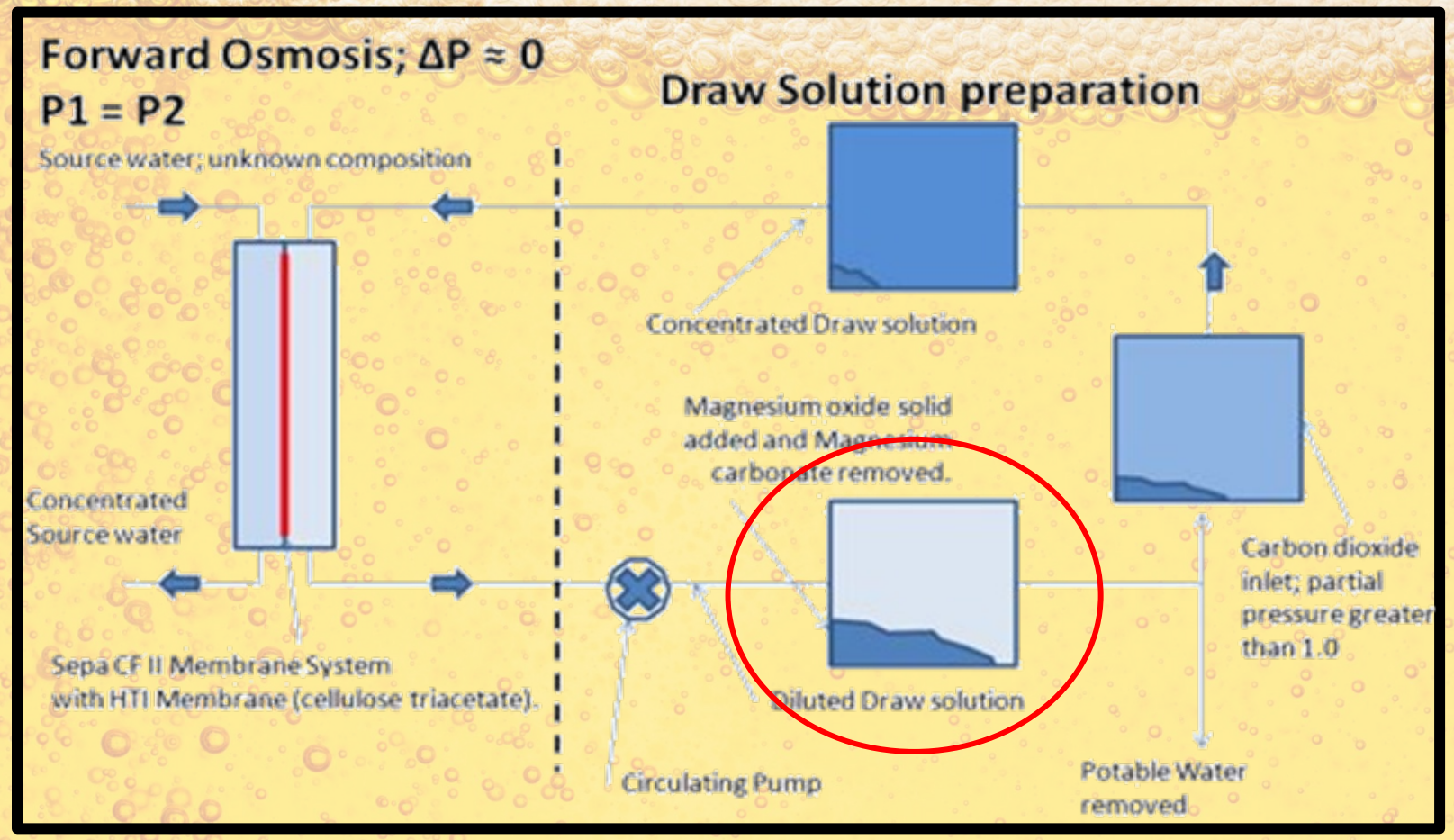
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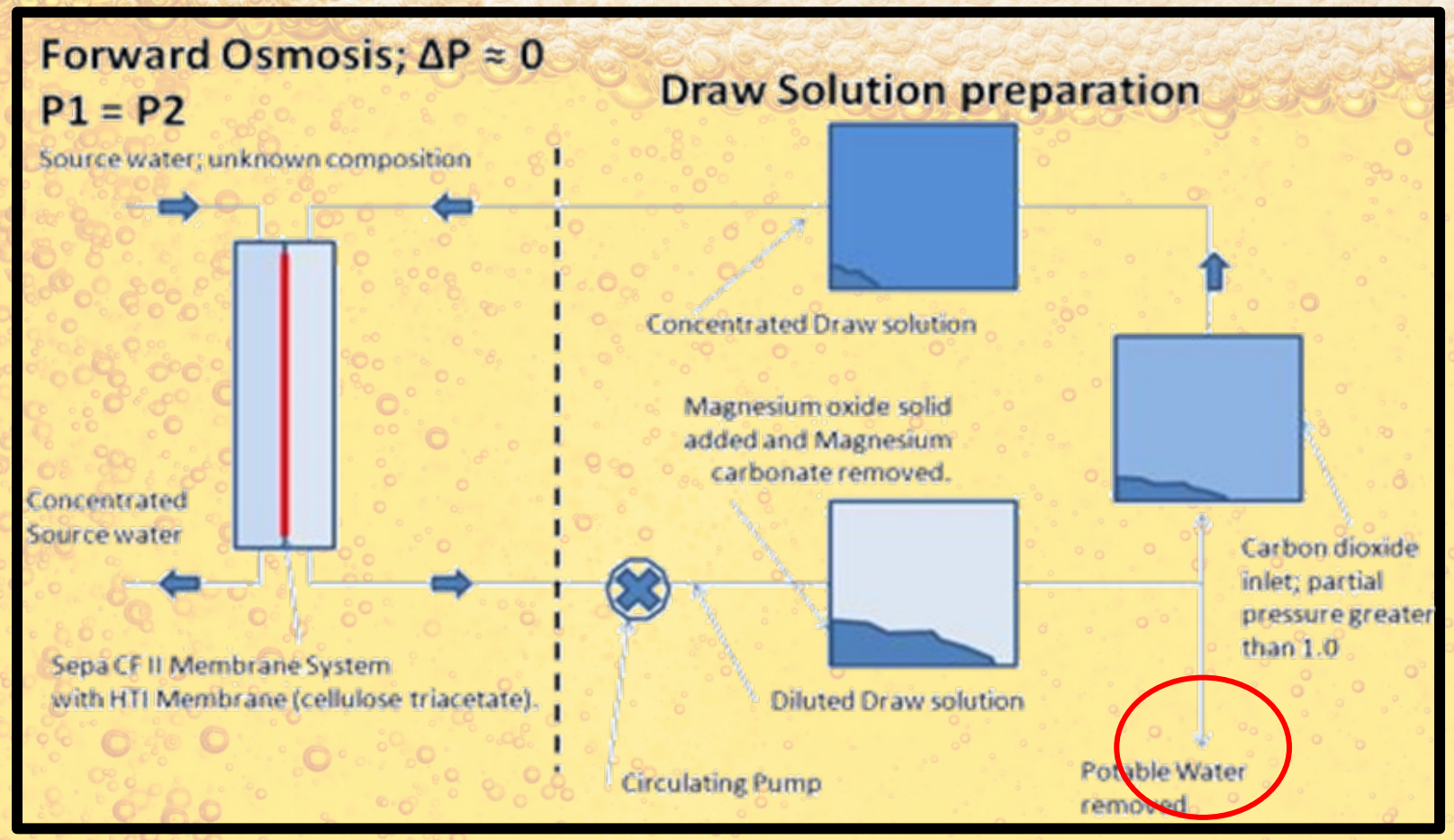
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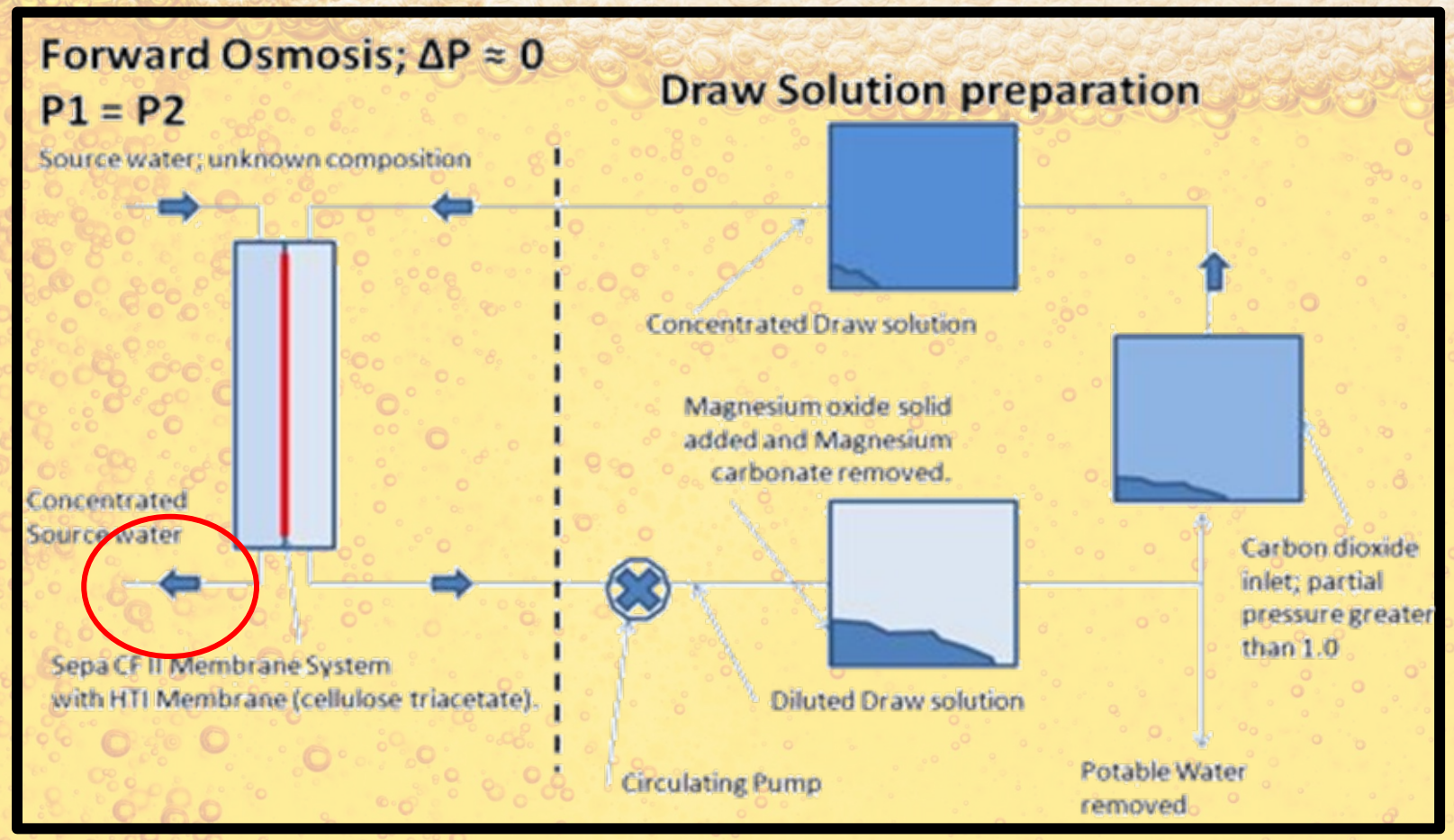

Alex

MAGFO

SWOT Analysis – MagFo

Strengths:

- Affordable

Alex

SWOT Analysis – MagFO

Strengths:	Weaknesses:
- Affordable	- Low Osmotic Pressure - Low Flux Rate

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SWOT Analysis – MagFO

Strengths: - Affordable	**Weaknesses:** - Low Osmotic Pressure - Low Flux Rate
Opportunities: - Broader Market Penetration with Lower Operating Costs - Carbon Capture	

Alex

SWOT Analysis – MagFO

Strengths:	Weaknesses:
- Affordable	- Low Osmotic Pressure - Low Flux Rate
Opportunities:	**Threats:**
- Broader Market Penetration with Lower Operating Costs - Carbon Capture	- Recent CO_2 Shortages - Speed and Strength

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Membrane Technology

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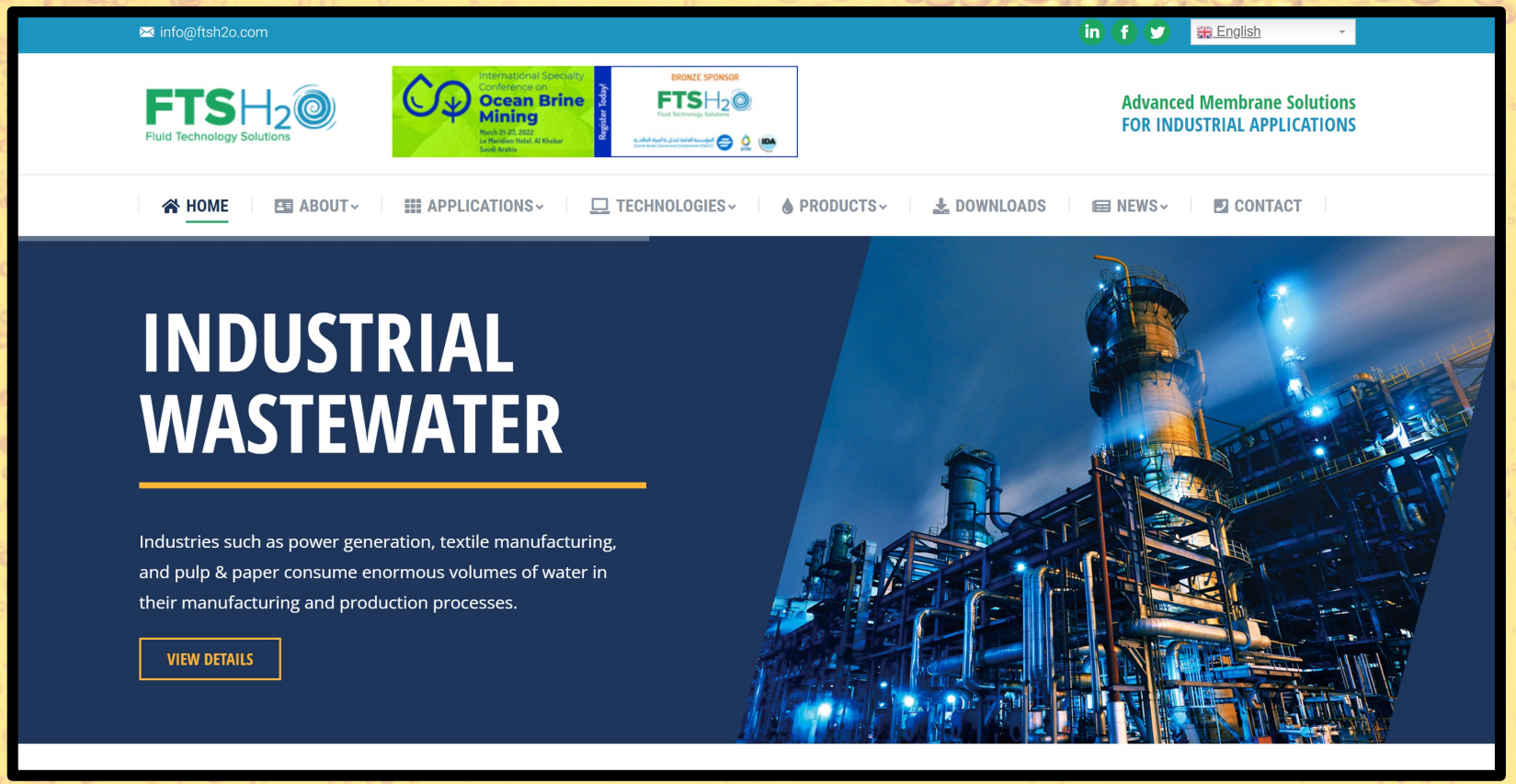
Membrane Technology



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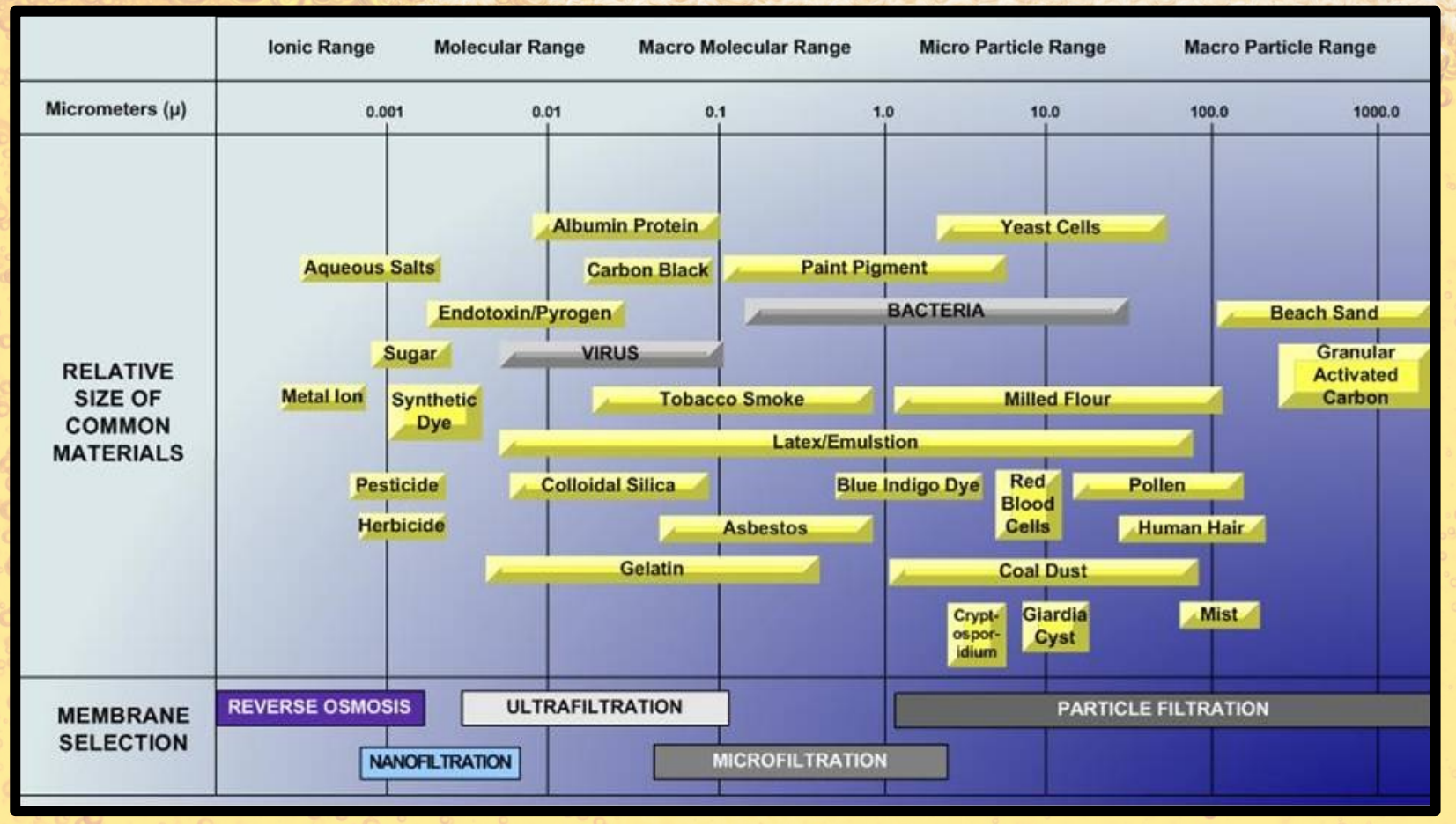
Membrane Technology



Alex

Industry: Wastewater

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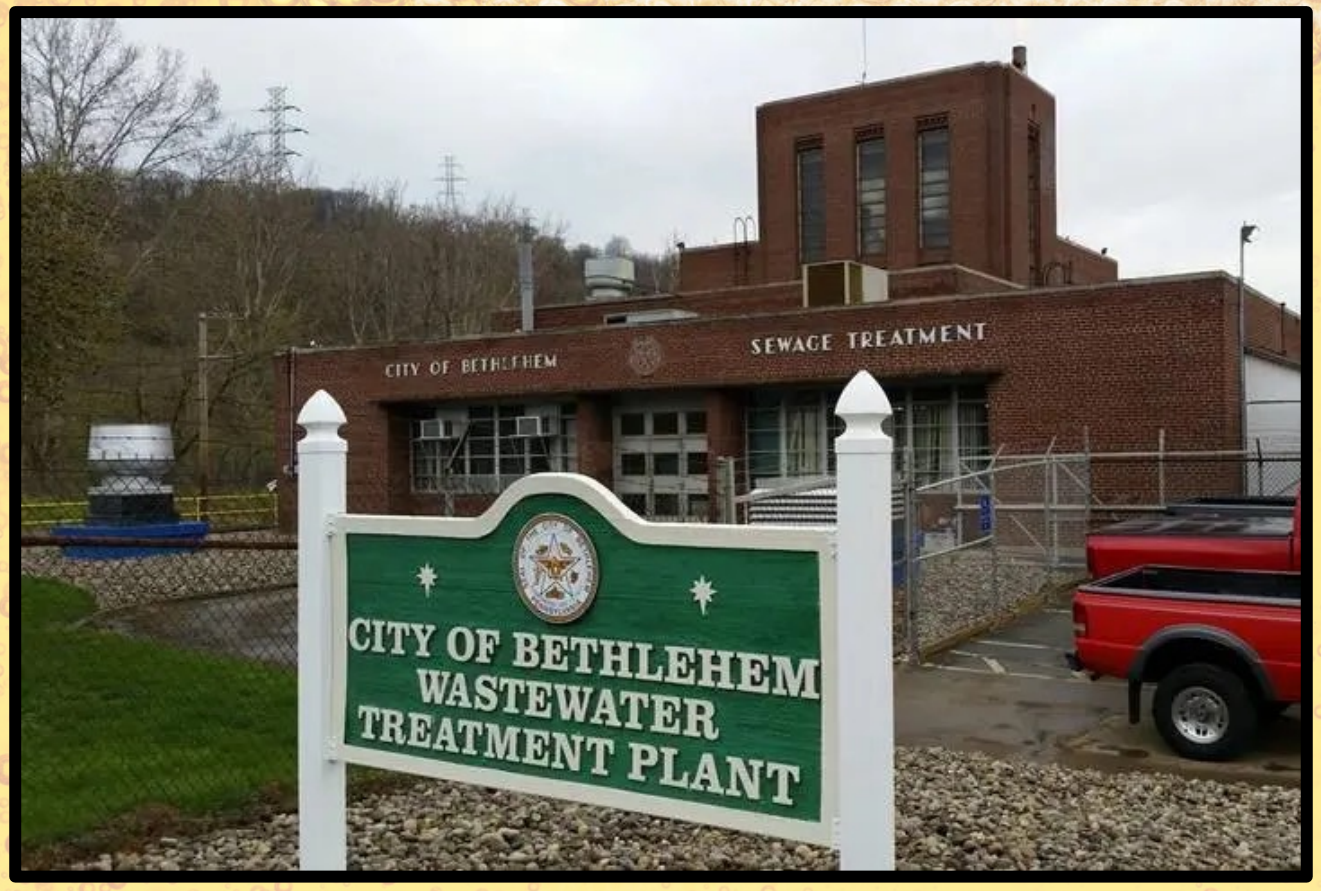
Industry: Wastewater



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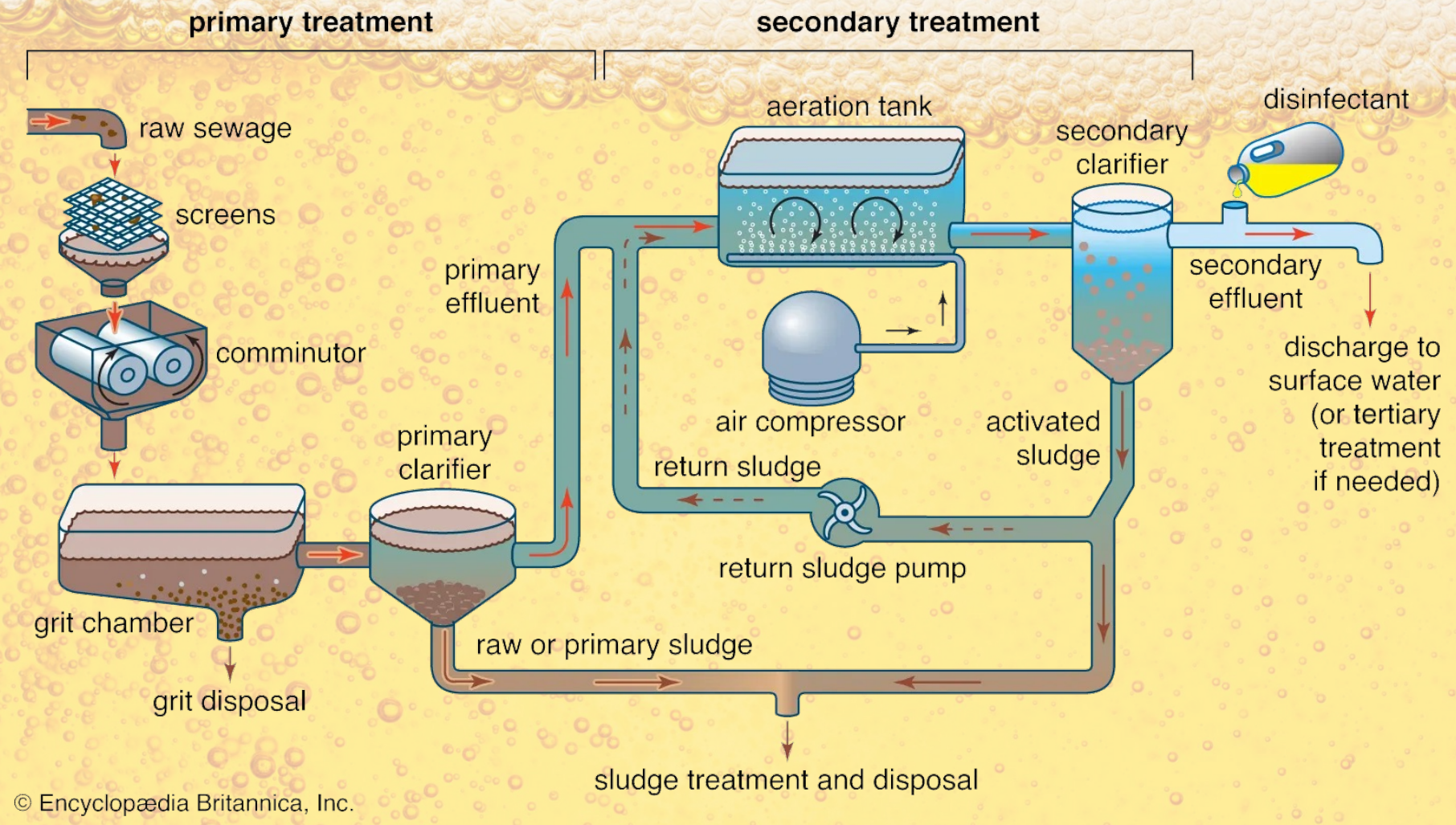

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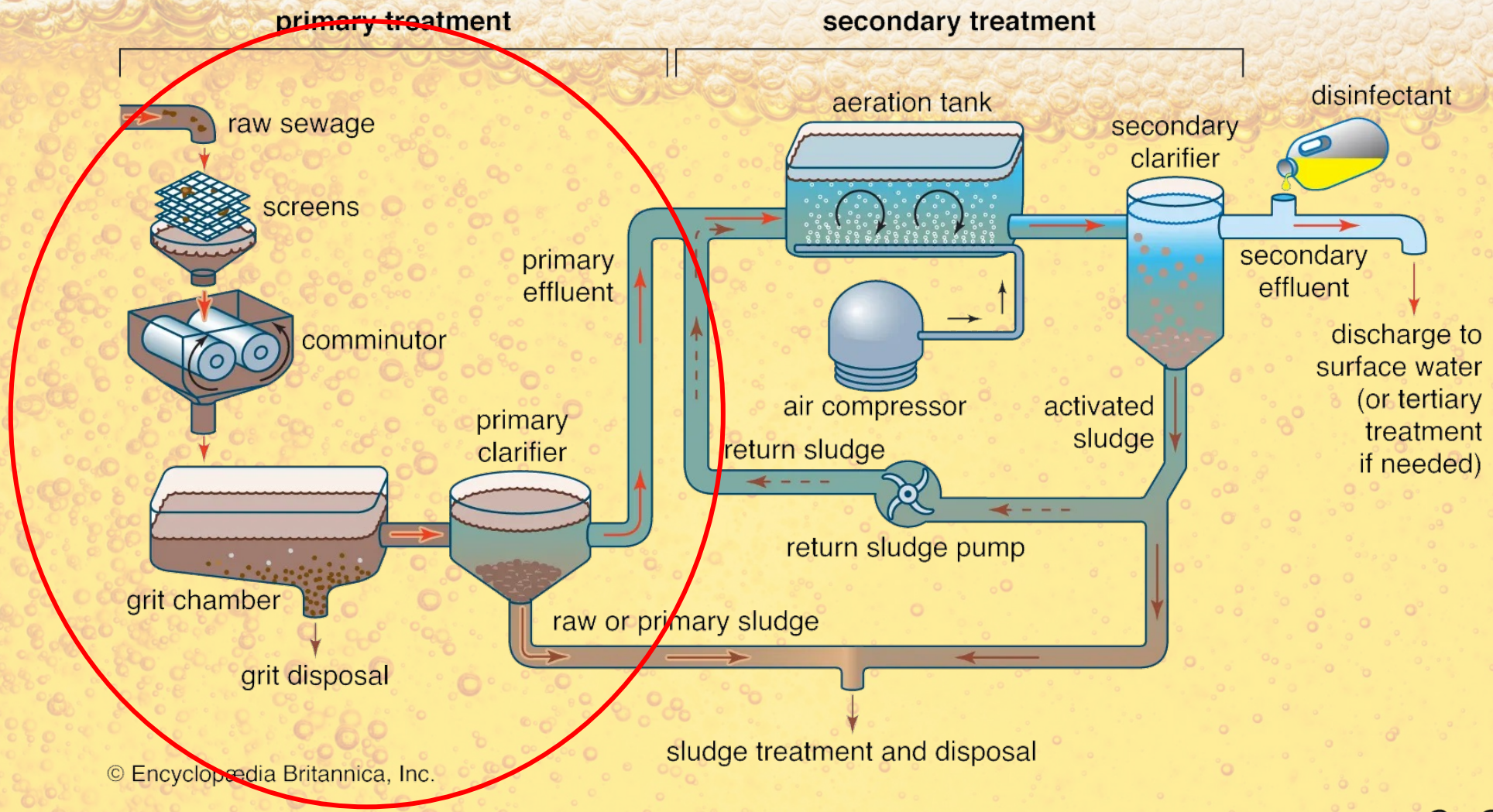

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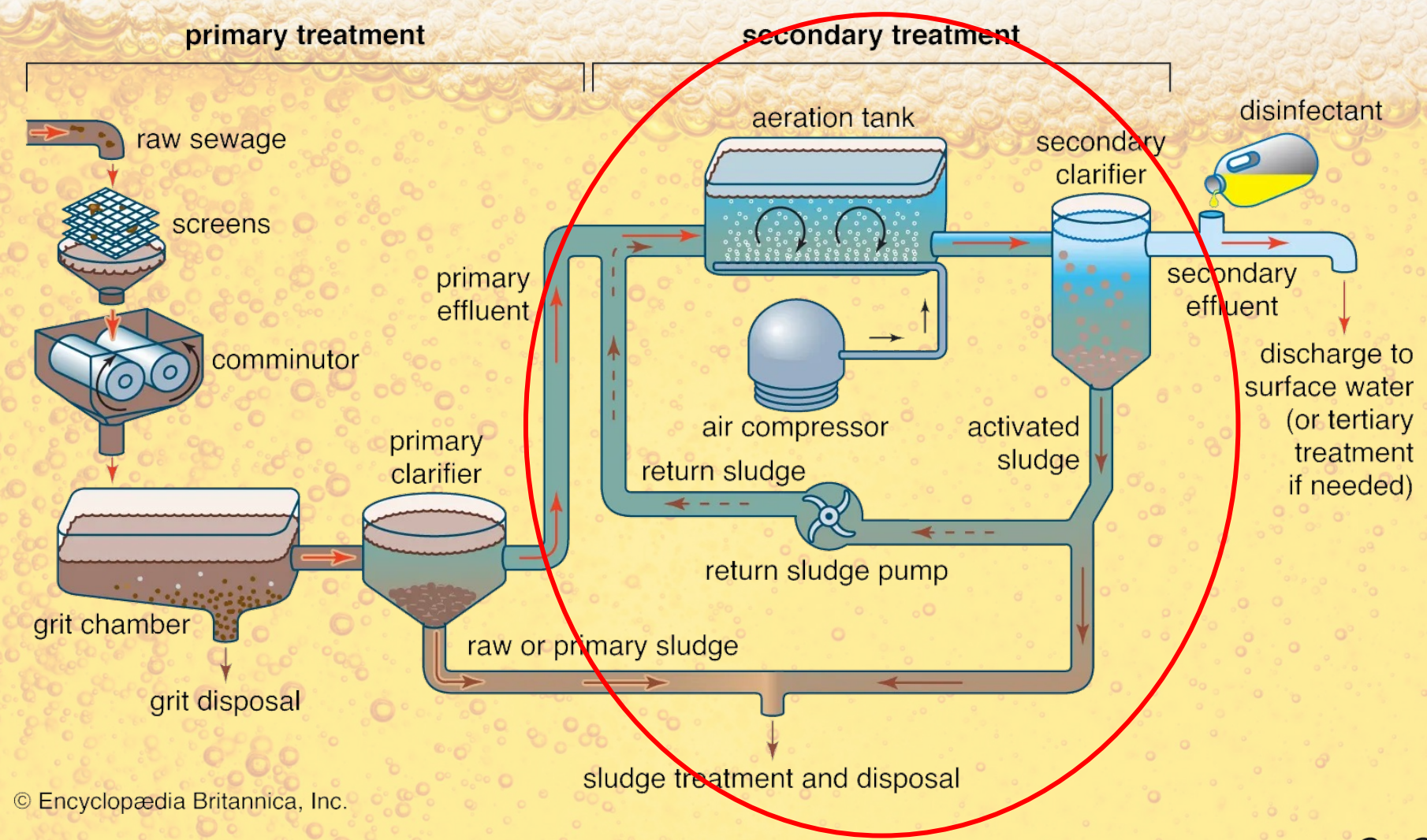

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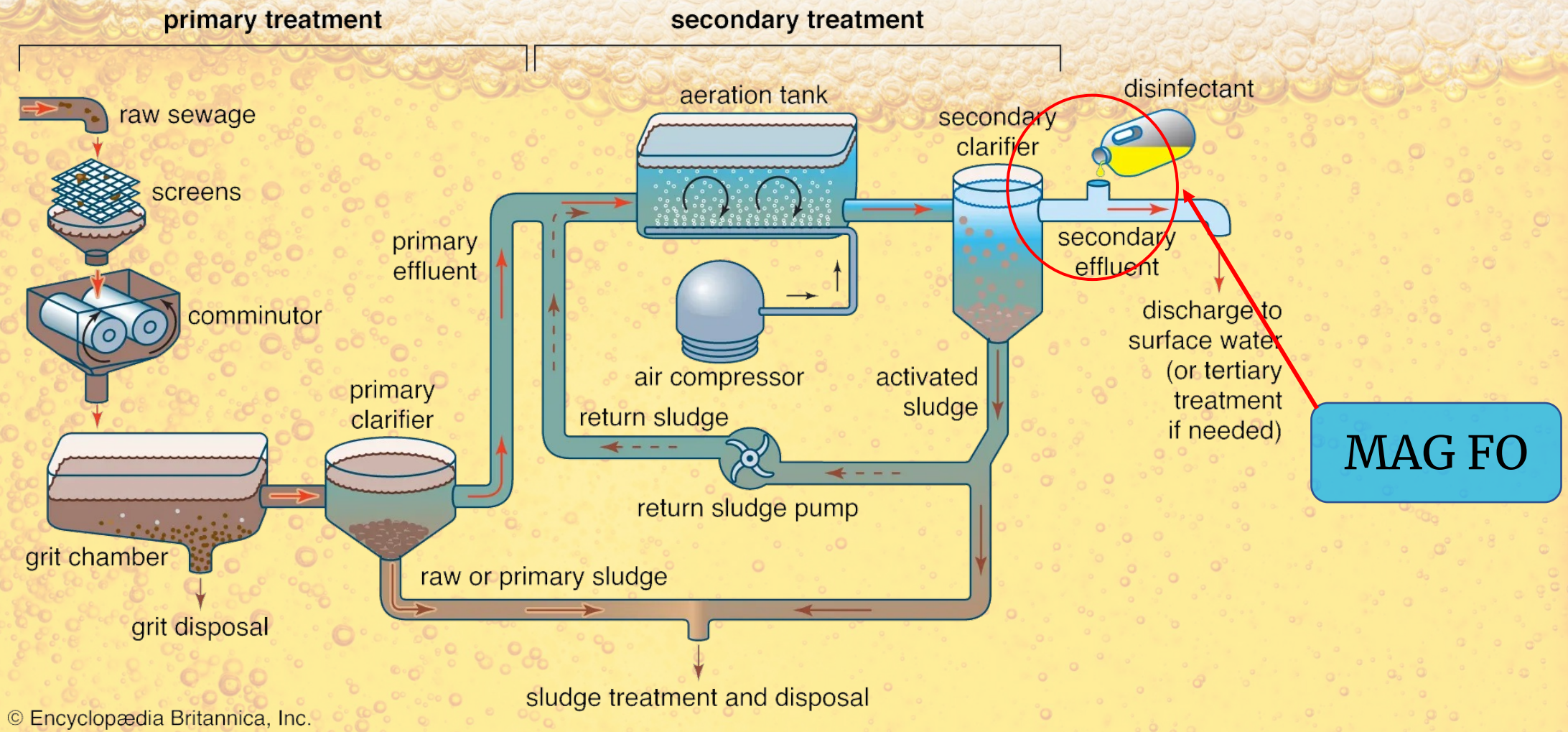
Industry: Wastewater



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Industry: Wastewater

Alex

Industry: Wastewater

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Industry: Wastewater

City Approvals

Alex

Industry: Wastewater

City Approvals

Flux Rate

Alex

MAGFO

Industry: Wastewater

Flux Rate

Alex

Industry: Wastewater

City Approvals

Flux Rate

Brine

Alex

Industry: Wastewater

Brine

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Industry: Wastewater

City Approvals

Flux Rate

Brine

Alex

Industry: Landfills

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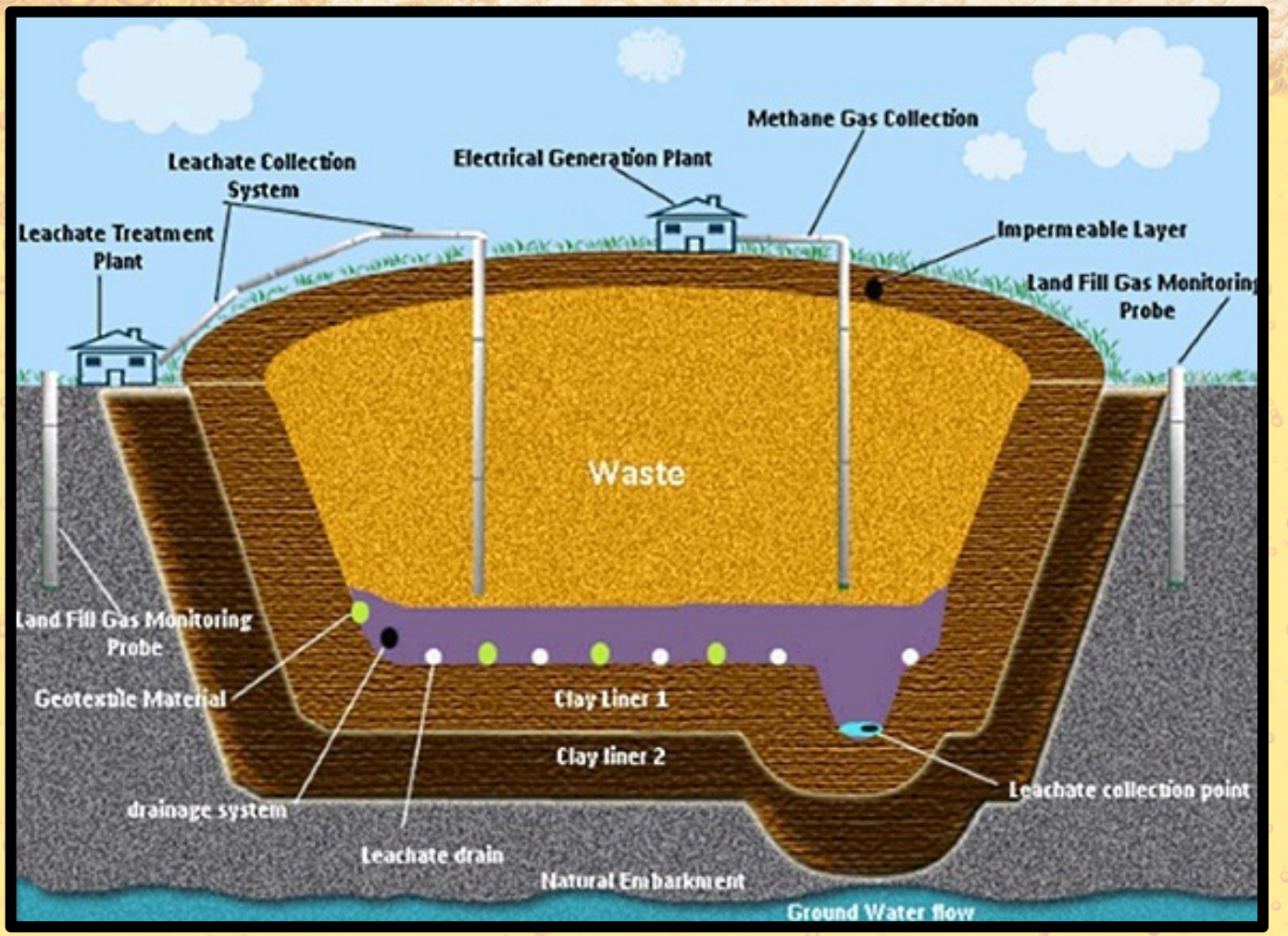
Industry: Landfills



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Industry: Landfills

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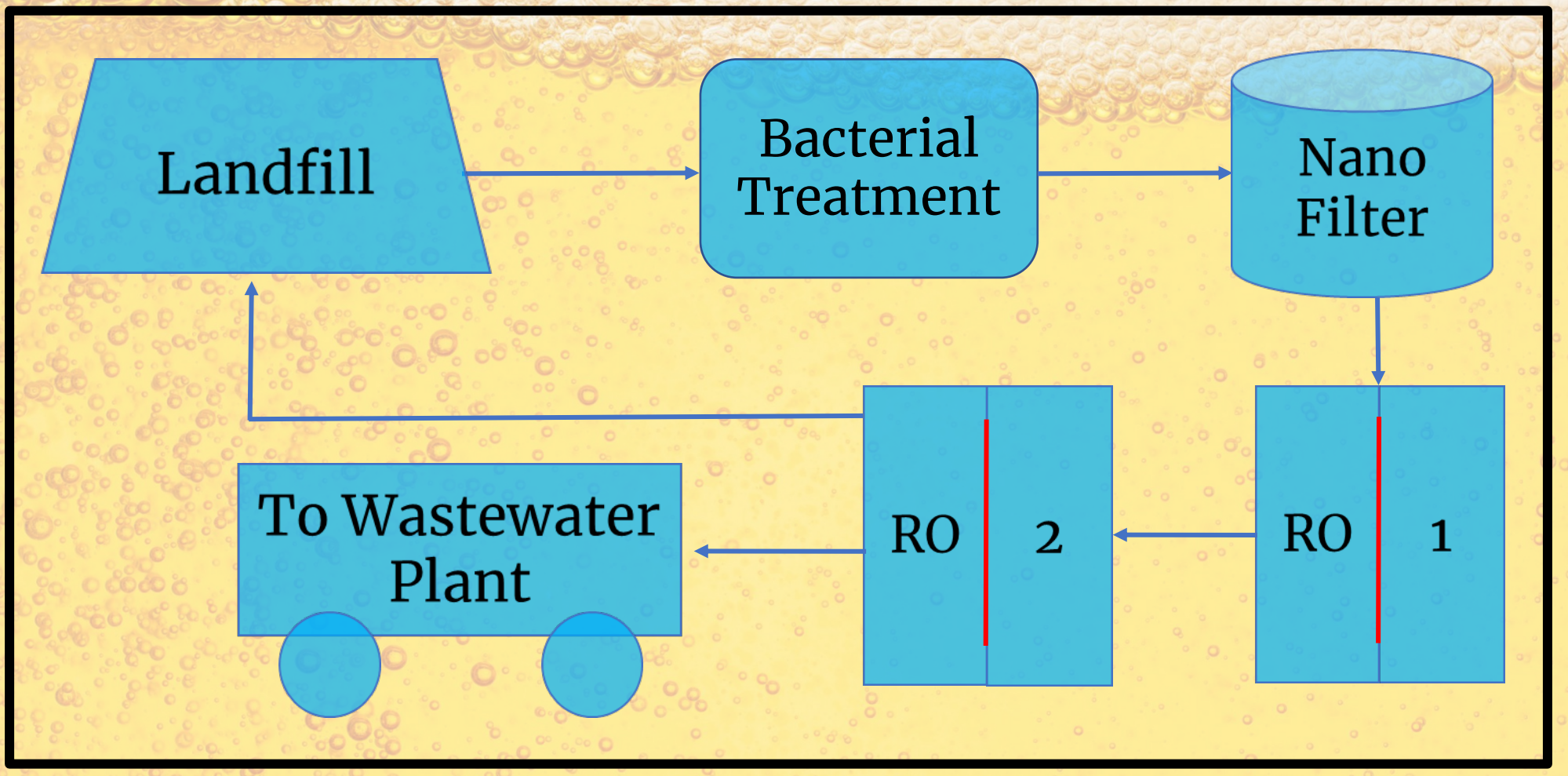
Industry: Landfills



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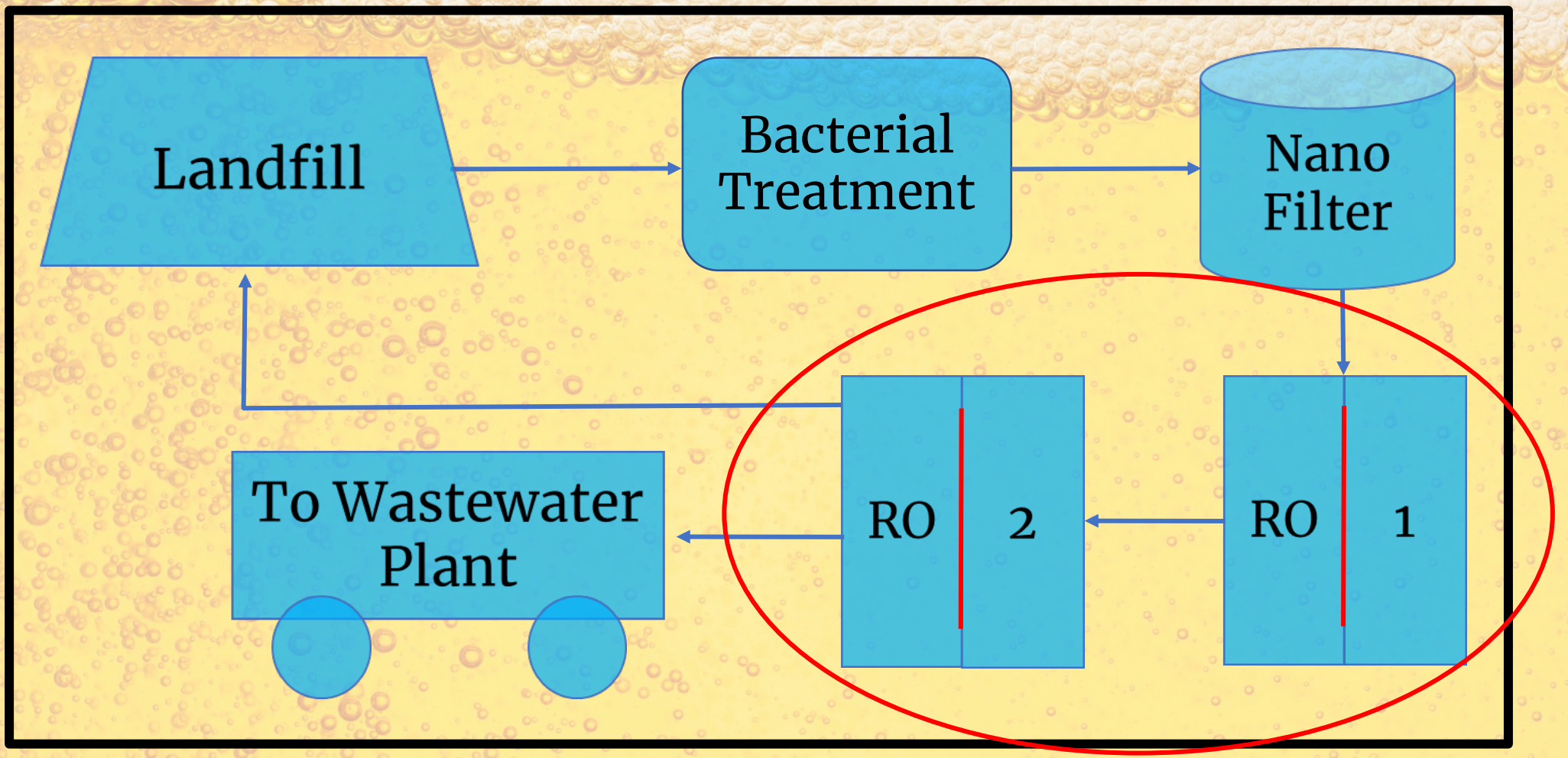

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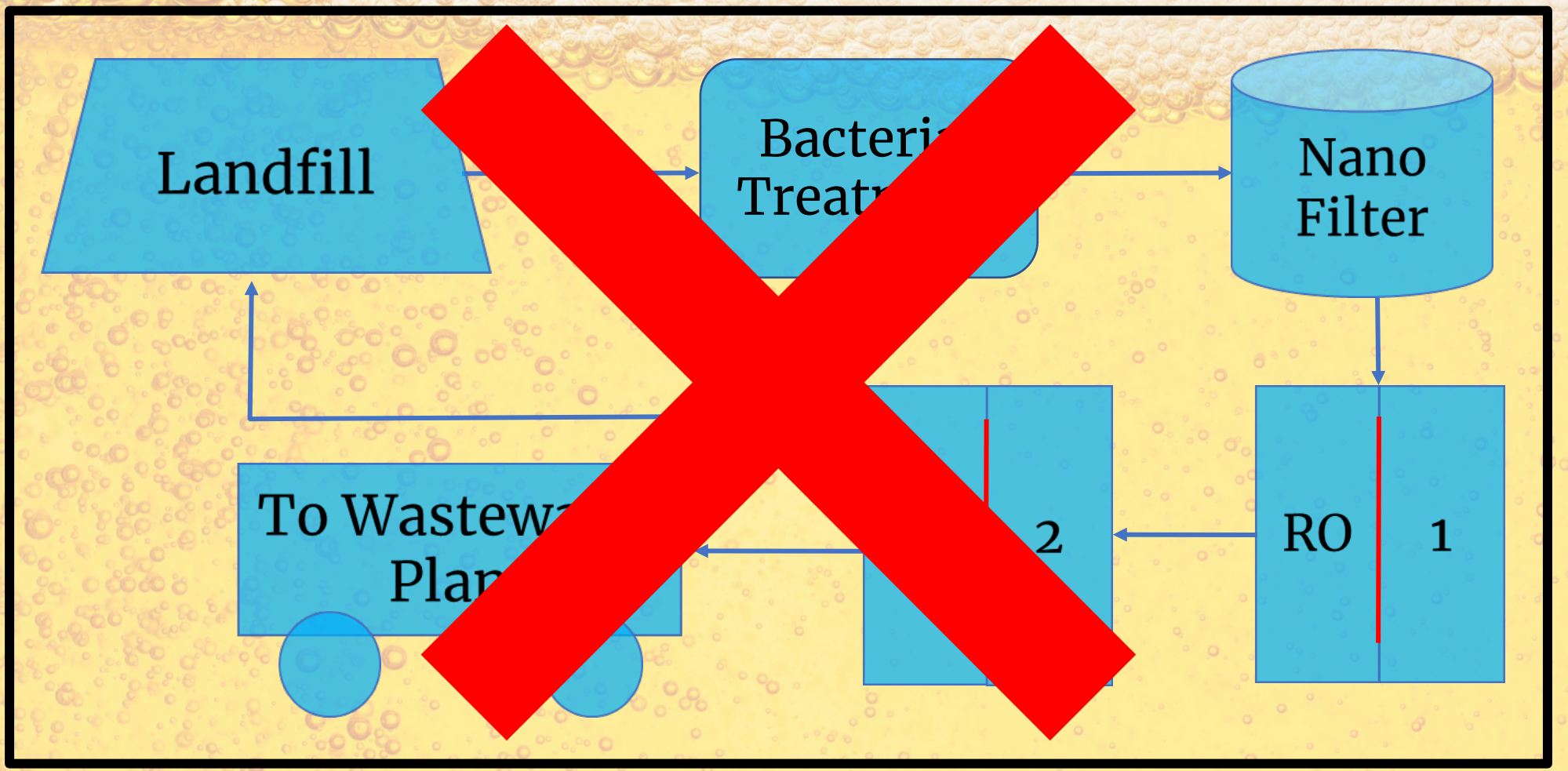

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Industry: Hemodialysis

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Industry: Hemodialysis

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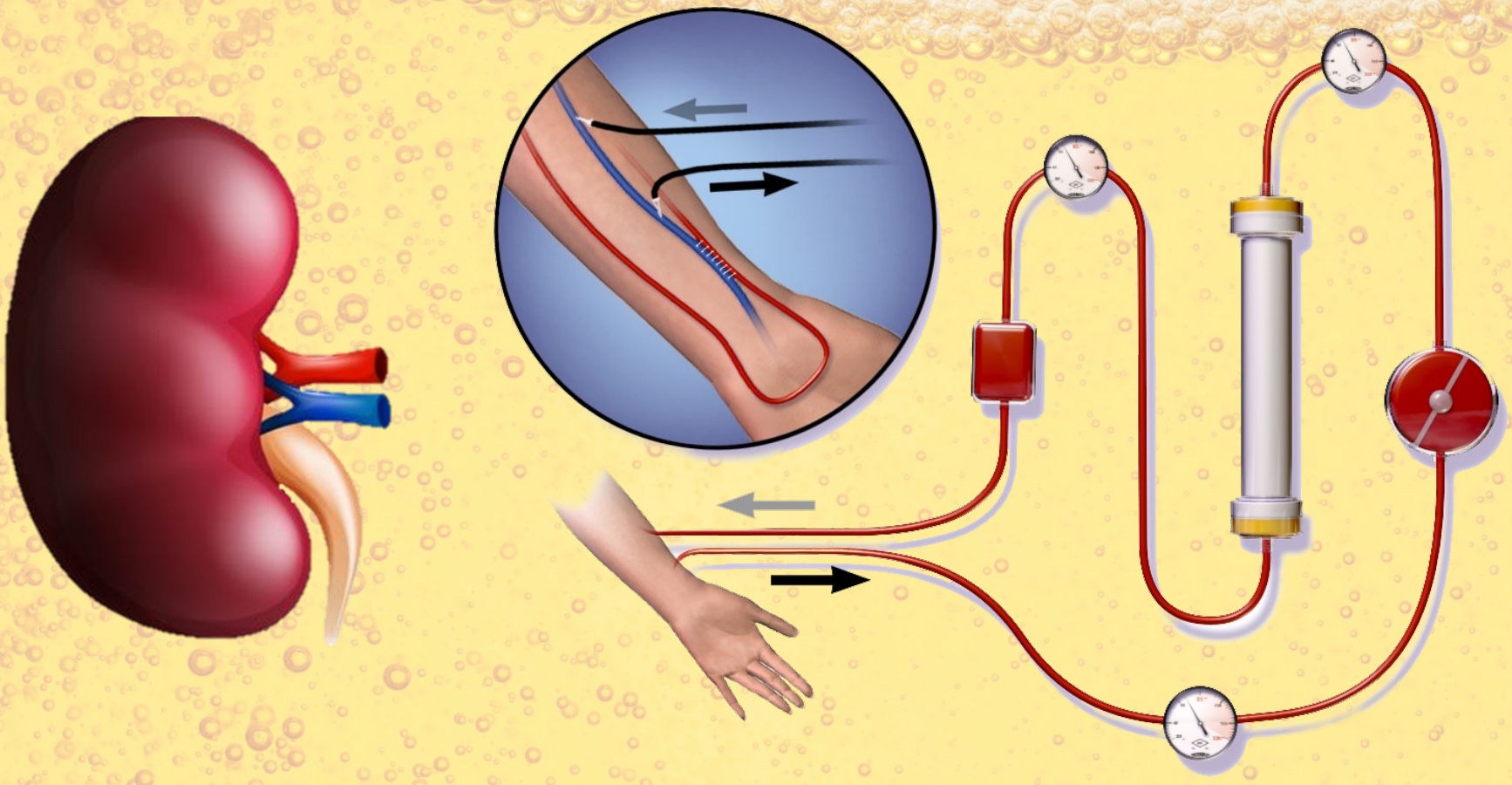
Industry: Hemodialysis



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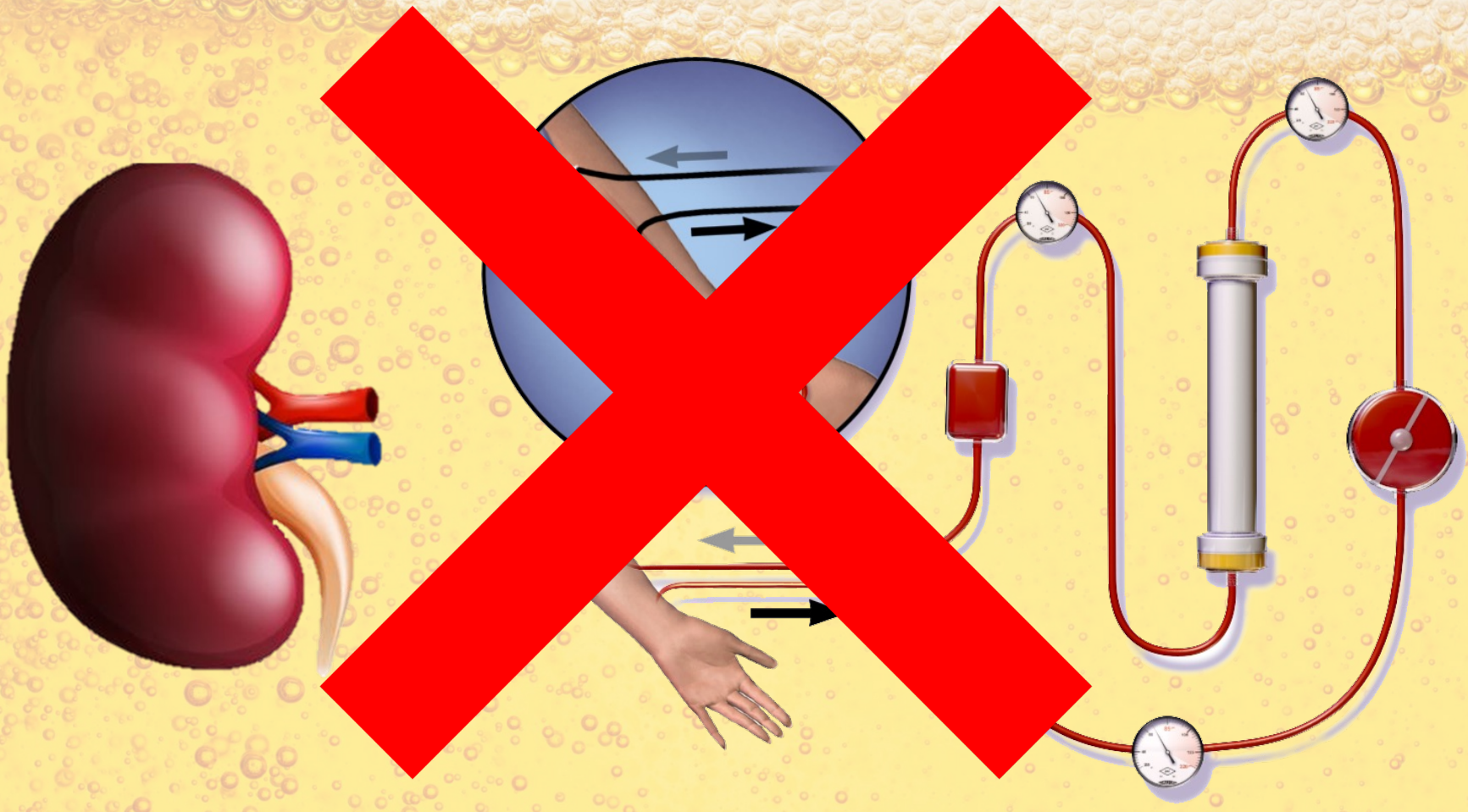
Industry: Hemodialysis



Alex

Industry: Hemodialysis

Flux Rate

Alex

Industry: Hemodialysis

Flux Rate

Draw Solution Contamination

Alex

Introduction & Market Research
Alex Romanowski

Industry Research
Jack Lee

Market Opportunity
Ethan Hughes

Customer Needs
Austin McCullough

The AES Product
Grace Ingabire Kuzwa

Business Model
Janik Wing

Marketing
Marina Mendez

Financials & Next Steps
Anna Harvey

MAGFO

Overview of Beer Industry Research

Jack

MAGFO

Early Research

Alternative uses for FO – Beer Concentration

Jack

Early Research

Jack

MAGFO

Early Research

Jack

NIH National Library of Medicine

MAGFO

Early Research

Jack

Early Research

Jack

Early Research

Jack

MAGFO

Early Research

Beer Concentration

- Used for transportation
- Cuts packaging and shipping costs
- Reduces environmental impact

Jack

MAGFO

Early Research

Jack

Early Research

Alternative uses for FO – **Beer Dealcoholization**

Jack

Field Visits

Jack

MAGFO

Field Visits

Jack

Field Visits

Jack

MAGFO

Field Visits

Jack

MAGFO

Field Visits

Jack

Field Visits

Jack

Field Visits

Non-alcoholic ‘Good for You’ section at Shangy’s Beer Distributor

Jack

MAGFO

Personal Interviews

Raphael Broh
Director of Brewing
Technologies at SBT

SUSTAINABLE BEVERAGE TECHNOLOGIES

Jack

MAGFO

Personal Interviews

Ed Yashinsky
Manager of Operations for
Tröegs

Jack

Personal Interviews

Dante Fierro
Owner of Super Beverage Warehouse Beer Distributor

Jack

Personal Interviews

Matt Cole
Owner / Brewmaster at
Fat Head's Brewery

Jack

Non-Alcoholic Beer

Jack

MAGFO

NA Beer Drinkers

Jack

MAGFO

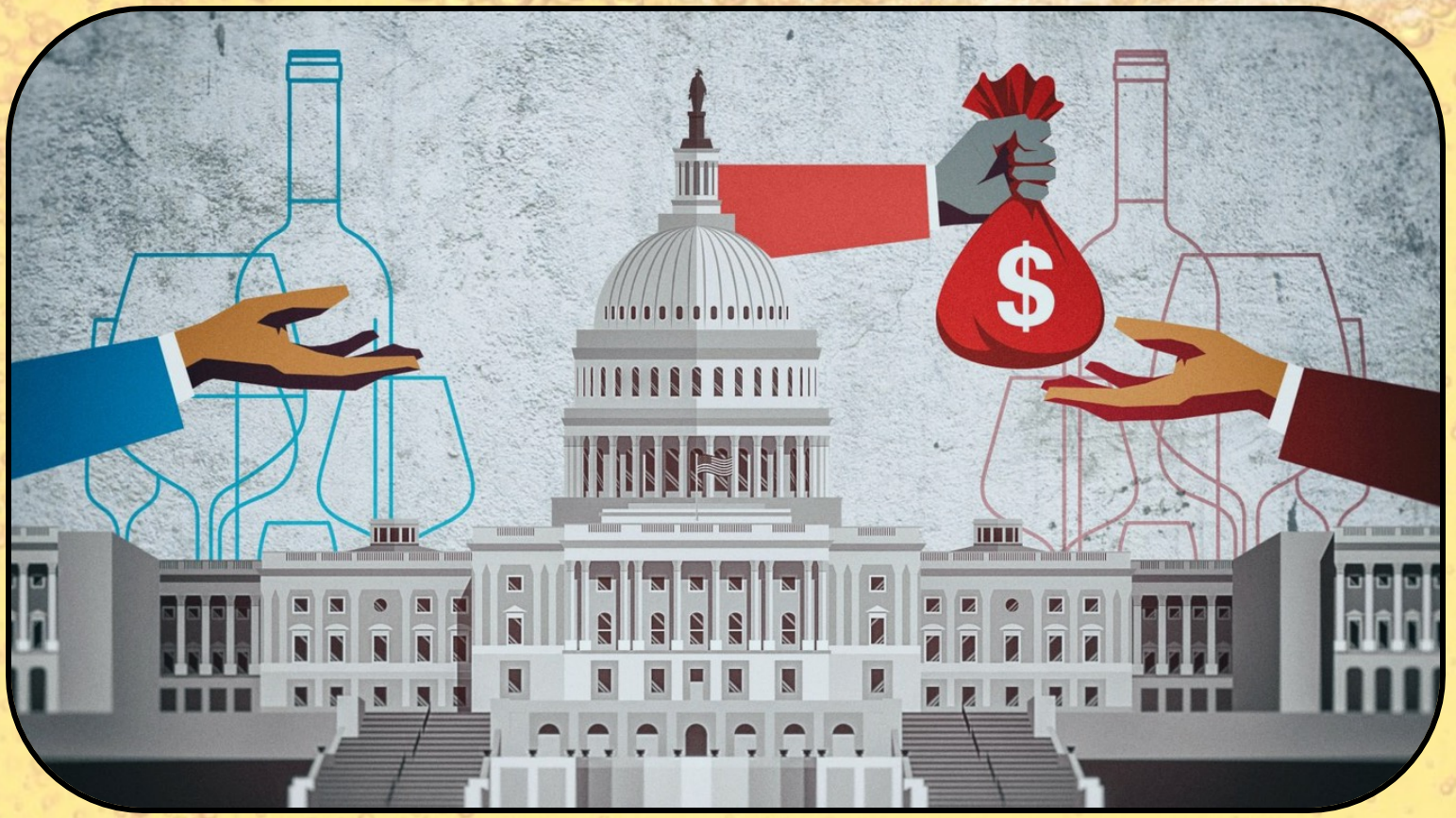
NA Beer Drinkers

Jack

NA Beer Drinkers

Jack

NA Beer Drinkers



Jack

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NA Beer Drinkers

Why drink NA beer?

- Cutting down on drinking
- Religion
- Health-oriented individuals
- No alcohol tax

Jack

Beer Market - Valuation

Jack

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Beer Market - Valuation

Jack

NA Beer Market - Valuation

Forbes 2021 valuation:

Jack

NA Beer Market - Valuation

Forbes 2021 valuation:

$16.65 billion

Jack

NA Beer Market - Projection

Forbes 2025 projection:

Jack

NA Beer Market - Projection

Forbes 2025 projection:

$23.27 billion

Jack

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Why We Chose Beer

Jack

Why We Chose Beer

CO_2 leaking through membrane

Jack

Why We Chose Beer

CO_2 leaking through membrane

Legitimate, tested application of FO tech

Jack

Why We Chose Beer

- CO_2 leaking through membrane
- Legitimate, tested application of FO tech
- Booming target market in NA beer

Jack

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Why We Chose Beer

- CO_2 leaking through membrane
- Legitimate, tested application of FO tech
- Booming target market in NA beer
- Attractive service model to brewers

Jack

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Introduction & Market Research
Alex Romanowski

Industry Research
Jack Lee

Market Opportunity
Ethan Hughes

Customer Needs
Austin McCullough

The AES Product
Grace Kuzwa

Business Model
Janik Wing

Marketing
Marina Mendez

Financials & Next Steps
Anna Harvey

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Market Opportunity

Ethan

Beer Market

Six distinct craft beer industry market segments

1. Microbreweries
2. Brewpubs
3. Taproom breweries
4. **Regional breweries**
5. Contract brewing companies
6. Alternating proprietors

Ethan

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Beer Market

1. Microbrewery

Bonn Place Brewing Company

Ethan

Beer Market

2. Brewpubs

Fegley's Bethlehem Brew Works

Ethan

Beer Market

3. Taproom Breweries

Lost Tavern Brewery

Ethan

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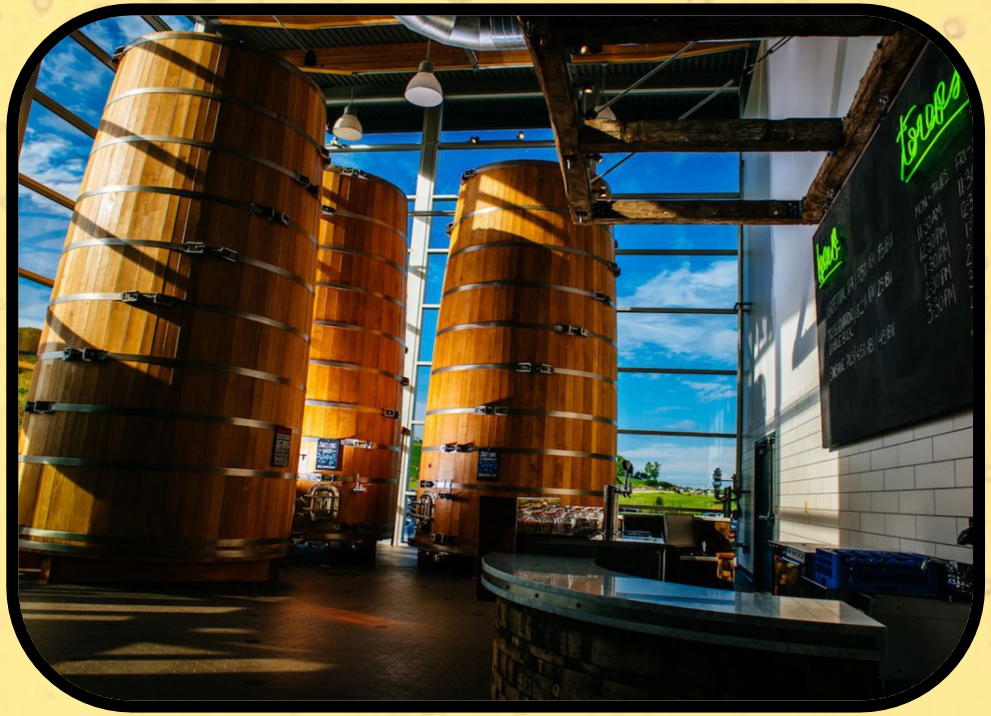
Beer Market

4. Regional Breweries

Tröegs Independent Brewing

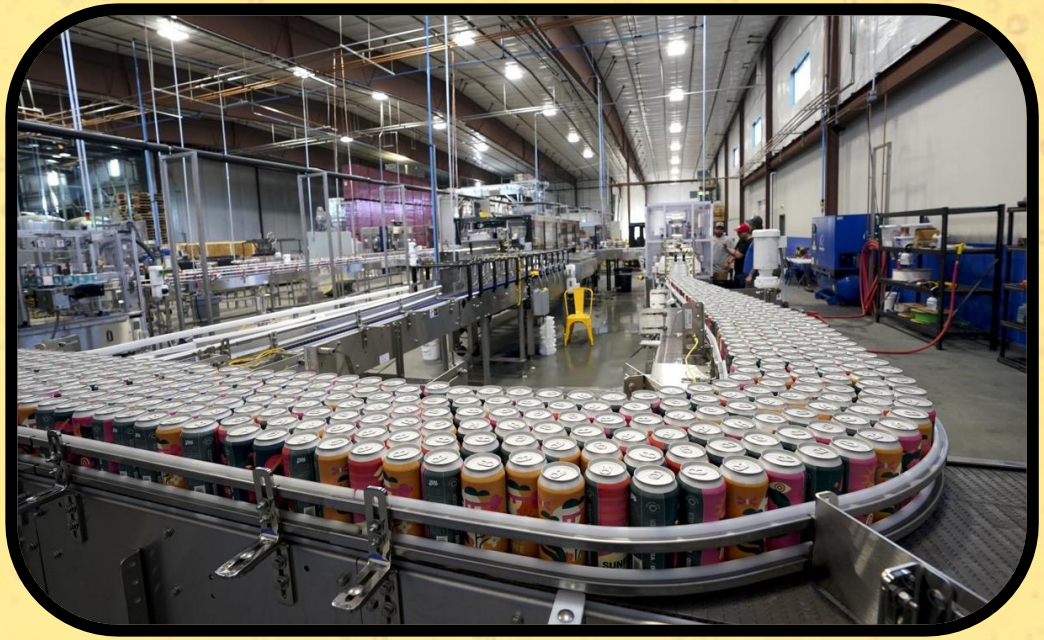


Ethan

Beer Market

5. Contract Brewing Companies

Octopi Brewing



Ethan

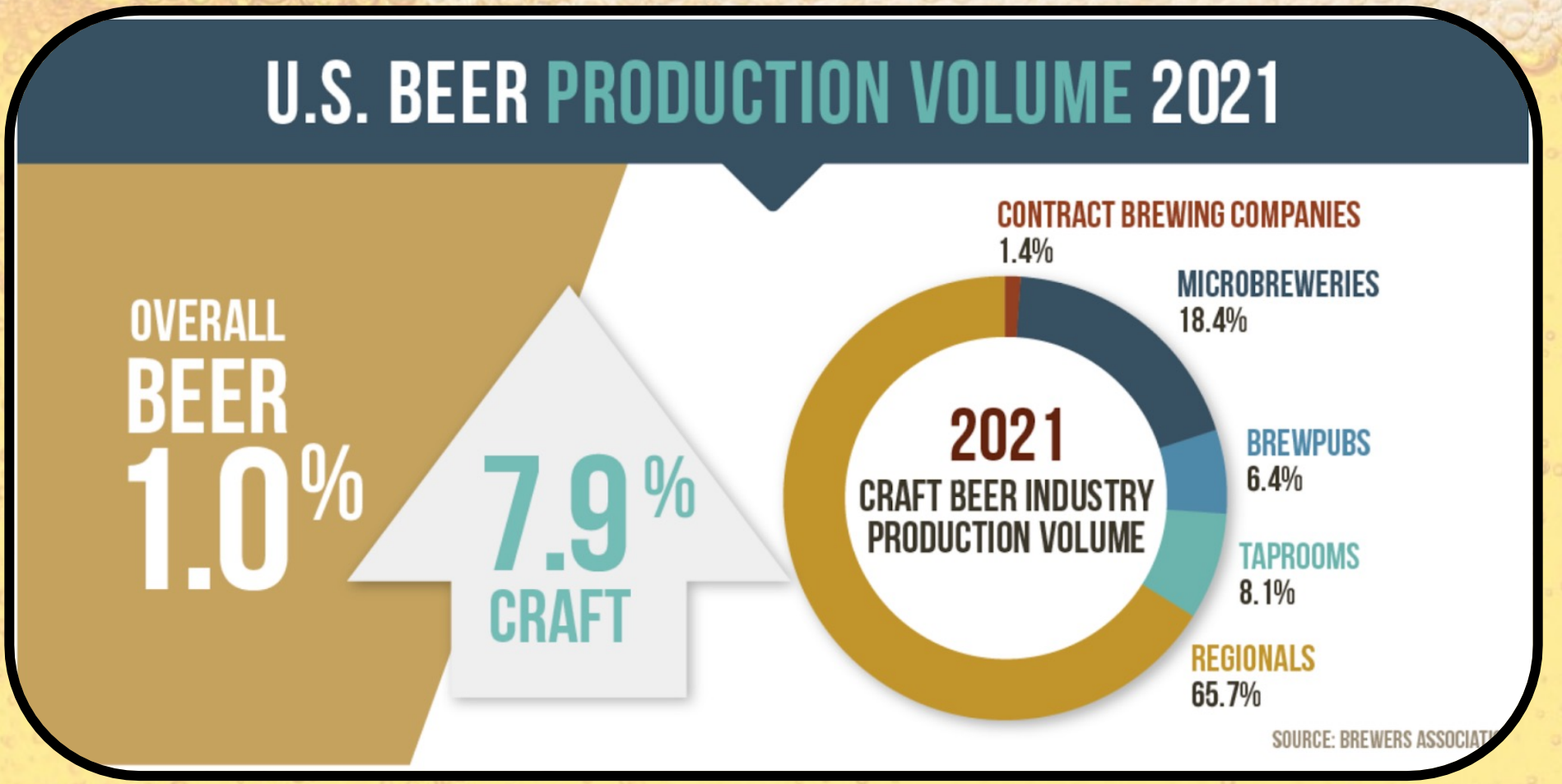
Beer Market

6. Alternating Proprietors

Funk Brewing

Ethan

Regional Breweries



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Regional Breweries

Brewers Association:

Regional Brewery is defined as a brewery with an annual beer production of between 15,000 and 6,000,000 barrels

Ethan

Regional Breweries

There are 6 Regional Breweries in Pennsylvania

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Regional Breweries

There are **246** Regional Breweries

across the country

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Target Customers

Large domestic brewers

Miller Lite

Coors

Mid-size regional b...s

TRÖEGS INDEPENDENT BREWING

YARDS BREWING COMPANY

Microbreweries

SEVEN SIRENS BREWING COMPANY

FUNK BREWING

bonn place brewing company

Ethan

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Target Customers

Large domestic brewers

Mid-size regional breweries

Microbreweries

Ethan

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Target Customers

Large domestic brewers

Able to produce Non-Alchoholic beer themselves

Mid-size regional breweries

Microbreweries

Ethan

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Target Customers

Large domestic brewers

Able to produce Non-Alchoholic beer themselves

Mid-size regional breweries

Microbreweries

Don’t have the production capabilities or customer base needed to introduce NA

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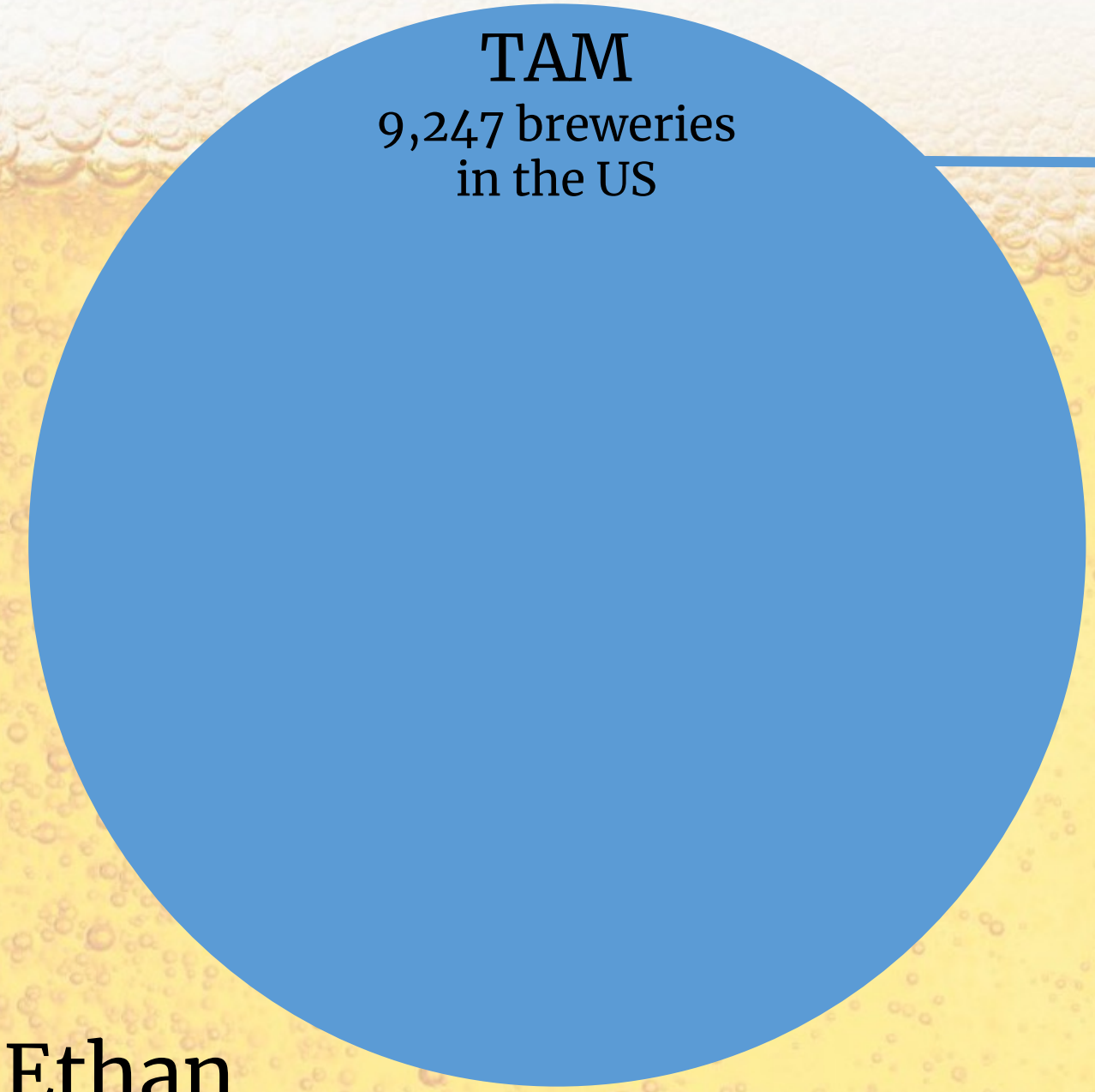

Total Addressable Market
All US breweries that don't currently offer NA beer

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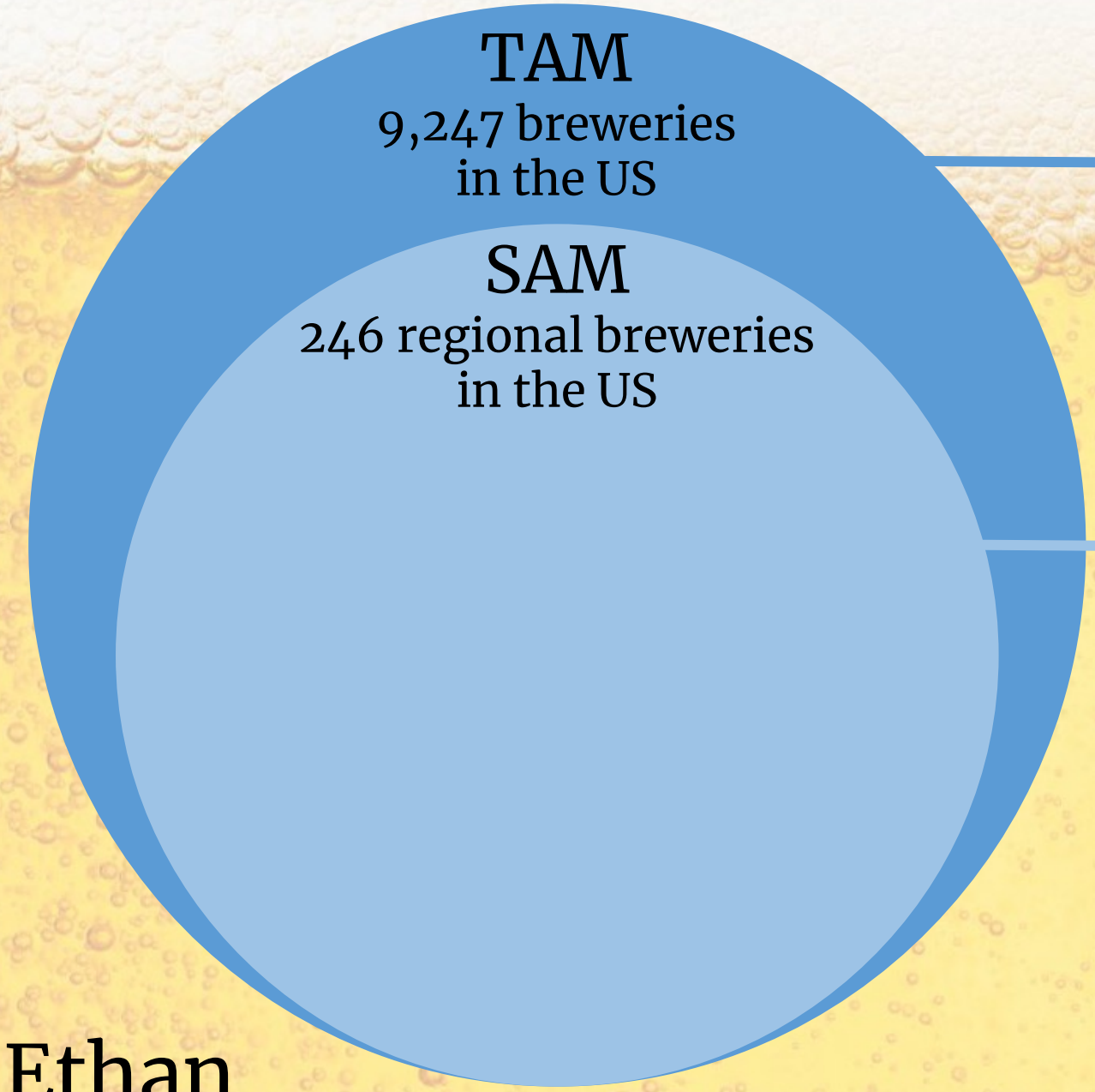

Total Addressable Market
All US breweries that don't currently offer NA beer

Serviceable Available Market
All U.S. breweries making a minimum of 15,000 barrels of beer annually

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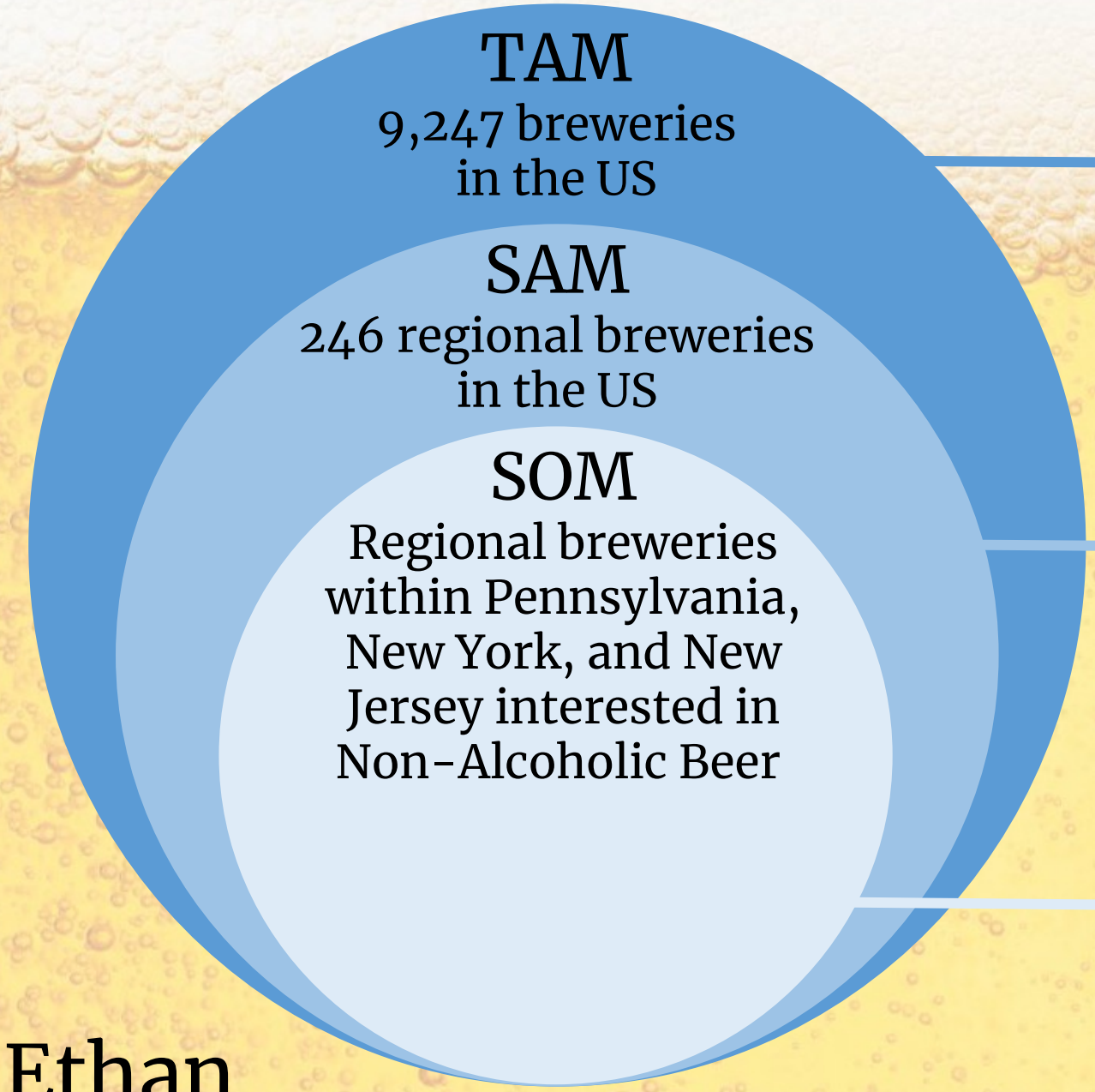

Total Addressable Market
All US breweries that don't currently offer NA beer

Serviceable Available Market
All U.S. breweries making a minimum of 5,000 barrels of beer annually

Serviceable Obtainable Market
Local mid-size regional breweries that are looking to expand into NA beer

Ethan

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Tröegs

Ben Bailey
Quality Assurance Manager
and Brewmaster for Tröegs

Ethan

Current NA Brewing Processes

Biological Processes

Physical Processes

Ethan

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Biological Processes

Ethan

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Biological Processes

Marcus Gichiengo
Project Engineer – The Boston Brewing Company

THE BOSTON BEER COMPANY INC.

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Biological Processes

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Adjusted Mashing Process

- Utilizes Standard Fermenting Equipment
- Often requires specialized malt and wheat strains
- Minimal production of aroma compounds

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Arrested Fermentation

- Utilizes Standard Fermenting Equipment
- Fermentation is halted before ethanol production
- Requires the use of specialized yeast strains
- Partially produces flavor and aroma compounds

Ethan

Cold Contact Fermentation

- Utilizes Standard Fermenting Equipment
- Increased aroma compound production
- Reduced aldehyde production
- 0.0% Beer is possible
- Requires longer fermentation time at very low temperatures

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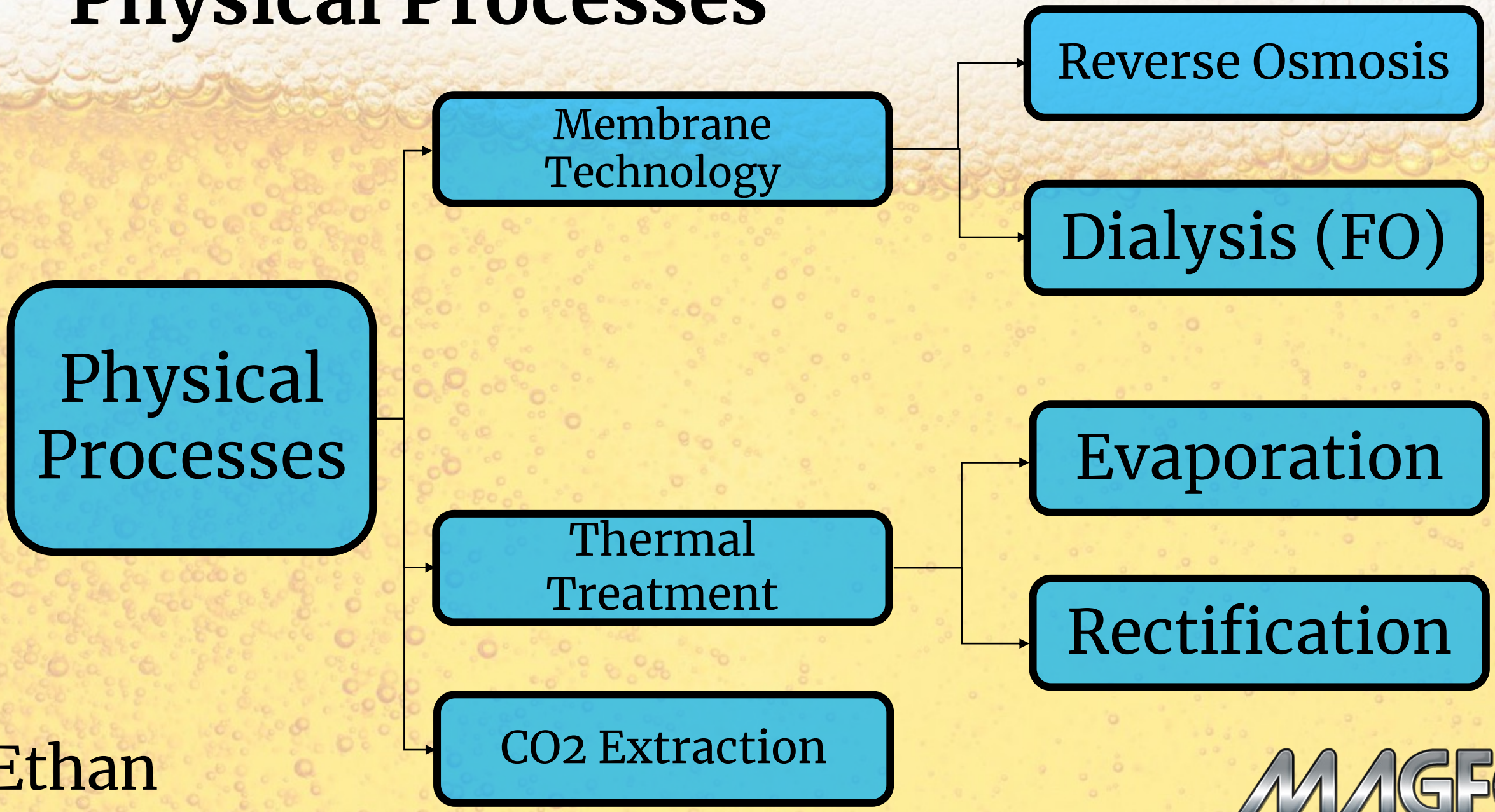
Current NA Brewing Processes

Biological Processes

Physical Processes

Ethan

Physical Processes



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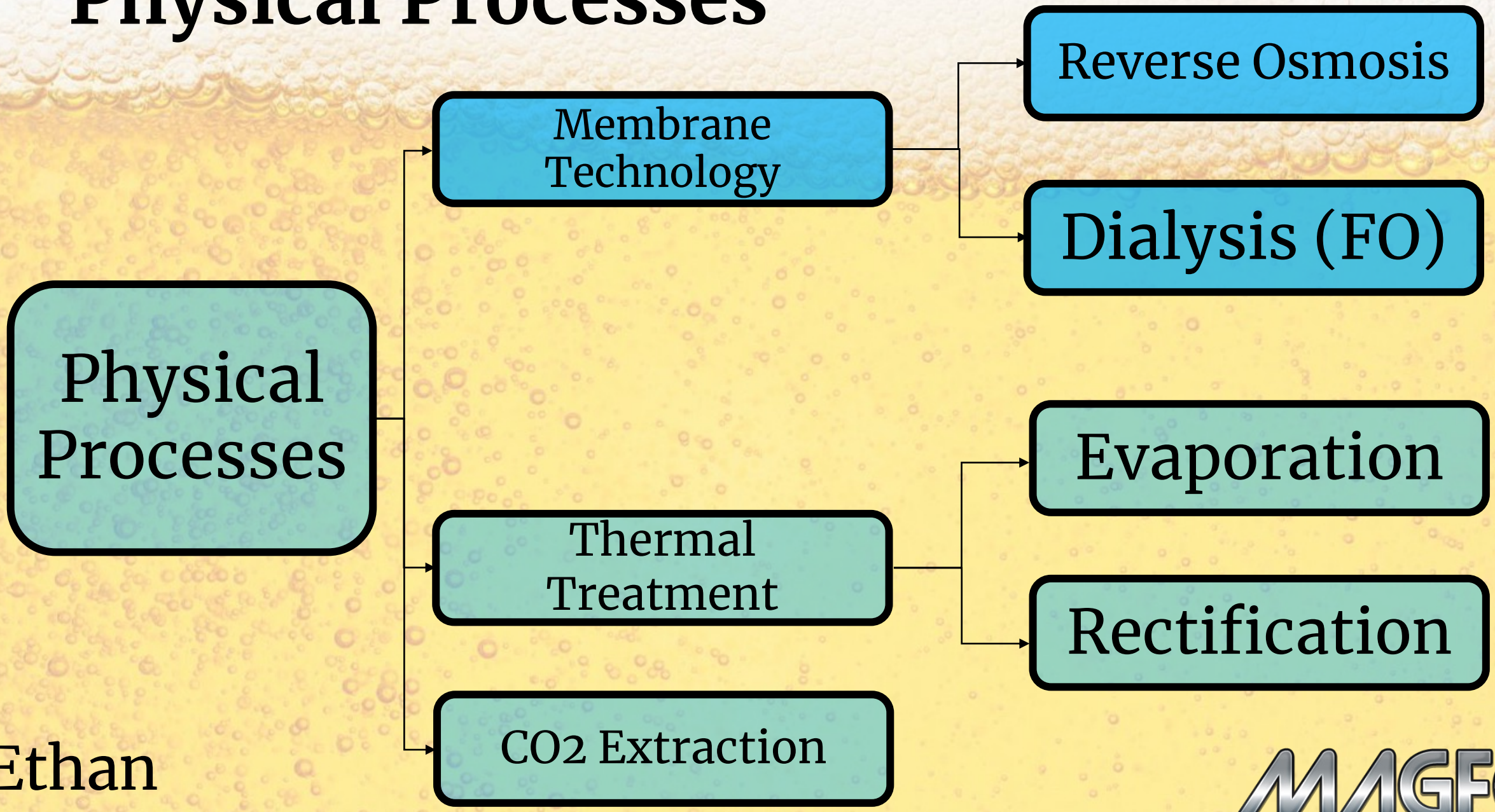
Physical Processes



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Reverse Osmosis

- Requires specialized de-alcoholization skid
- Moderate loss of volatile compounds
- Must operate under high pressure
- High overall energy cost
- Large footprint

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Dialysis (Forward Osmosis)

- Under-utilized due to complex systems
- Better preservation of volatile compounds
- Low pressure process reduces CO_2 consumption
- Lower overall energy cost

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MBAA Conference

Ethan

MBAA Conference

Urs Wellhoener
Technical Director of Brewing Innovation at Samuel Adams

SAMUEL ADAMS®

Ethan

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Optimal Non-Alchoholic Beer Creation

Initial Fermentation using Biological Processes

Ethan

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Optimal Non-Alchoholic Beer Creation

Initial Fermentation using Biological Processes → Target 1-2% ABV

Ethan

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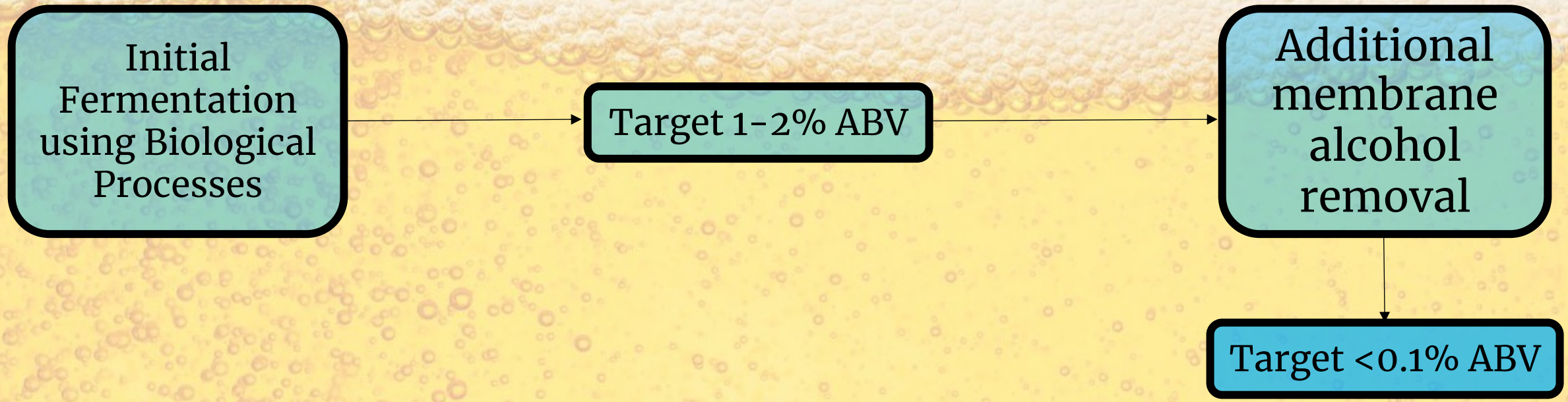
Optimal Non-Alchoholic Beer Creation

Ethan

Optimal Non-Alchoholic Beer Creation



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Optimal Non-Alchoholic Beer Creation

Ethan

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Optimal Non-Alchoholic Beer Creation

Ethan

Optimal Non-Alchoholic Beer Creation

Initial Fermentation using Biological Processes

Target 1-2% ABV

Additional membrane alcohol removal

Target <0.1% ABV

Re-introduce "Mother Beer"

Target <0.5% ABV

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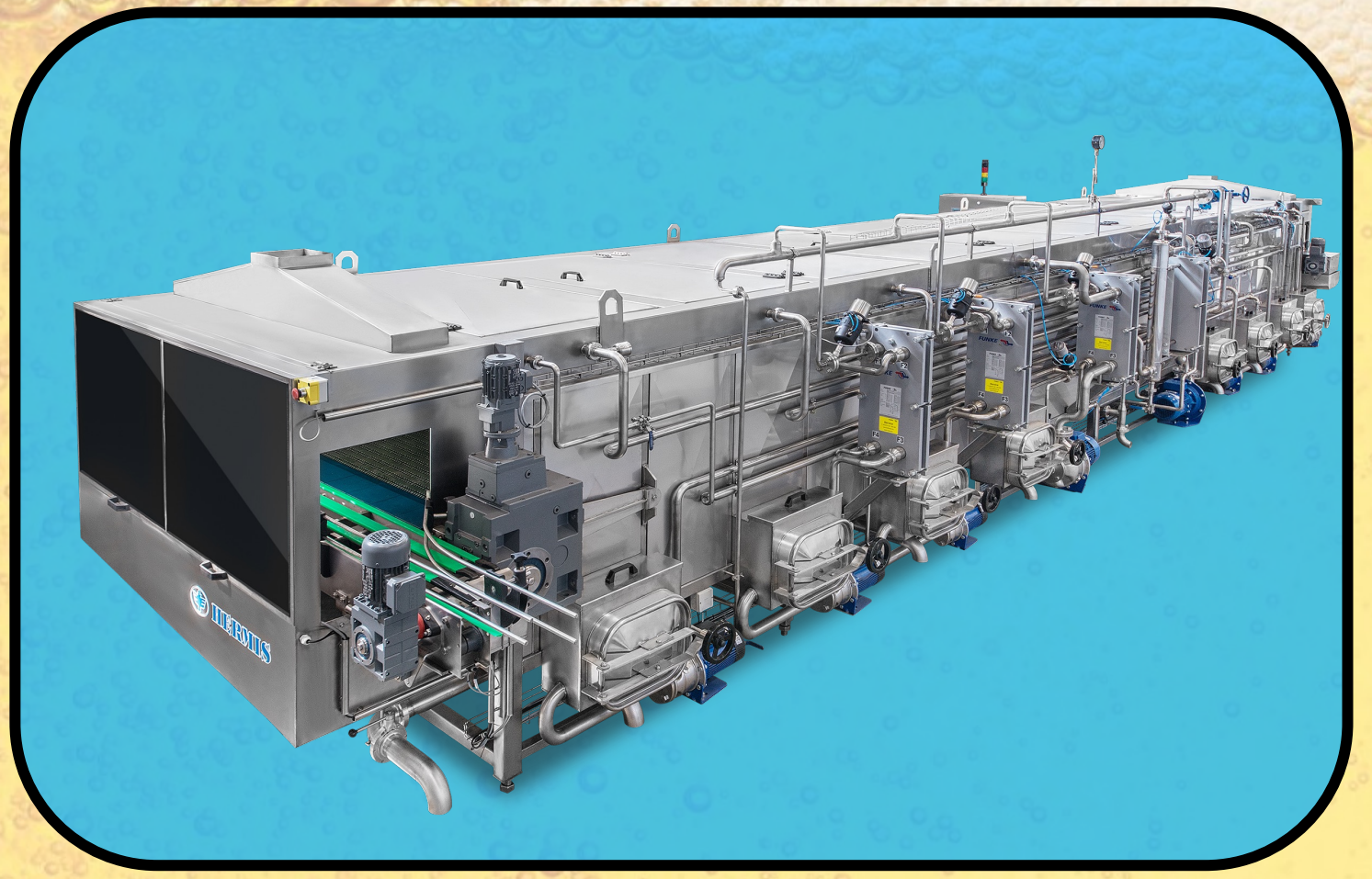
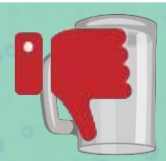
Pasteurization



- Flash pasteurization
- Tunnel pasteurizers
- Contract pasteurization firms

Ethan

	Aroma and Flavor Retention	Capital Costs	Energy Costs	Production Interference	<0.1% Beer Achievable
Adjusted Mashing Process					
Arrested Fermentation					
Cold Contact Fermentation					
Reverse Osmosis					
Forward Osmosis					
Combined Processes					

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Anna Harvey

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Customer Needs

Austin

Customer Needs

1. Taste & Aroma Retention

Austin

Customer Needs

1. Taste & Aroma Retention
2. Cost Effective

Austin

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Customer Needs

1. Taste & Aroma Retention
2. Cost Effective
3. Space Saving

Austin

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Customer Needs

1. Taste & Aroma Retention
2. Cost Effective
3. Space Saving
4. Flexible

Austin

MAGFO

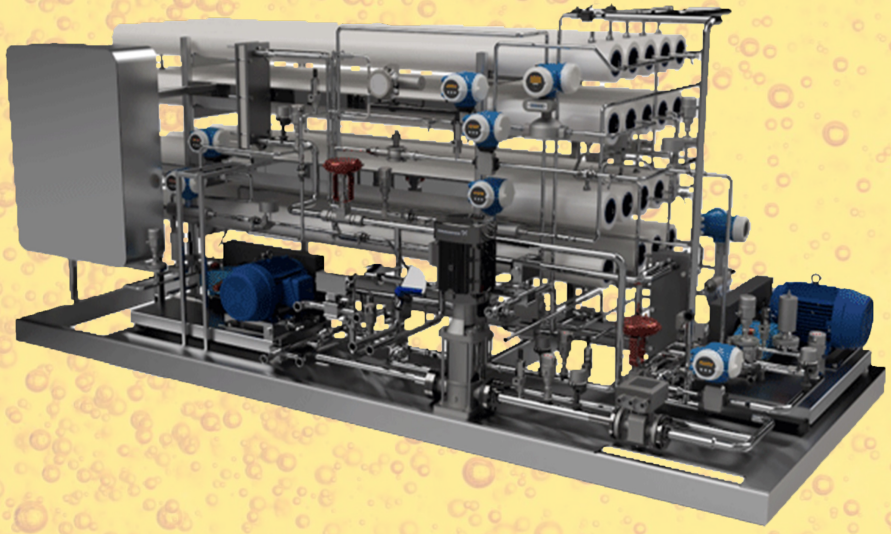
Customer Needs

1. Taste & Aroma Retention
2. Cost Effective
3. Space Saving
4. Flexible
5. Hands-off

Austin

Current Options

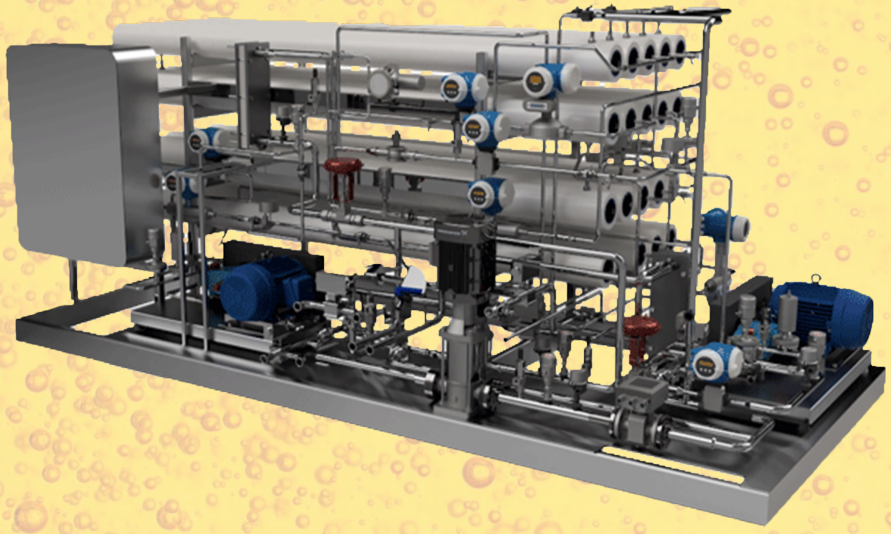
Revos (Alfa-Laval)



Austin

Current Options

Revos (Alfa-Laval)

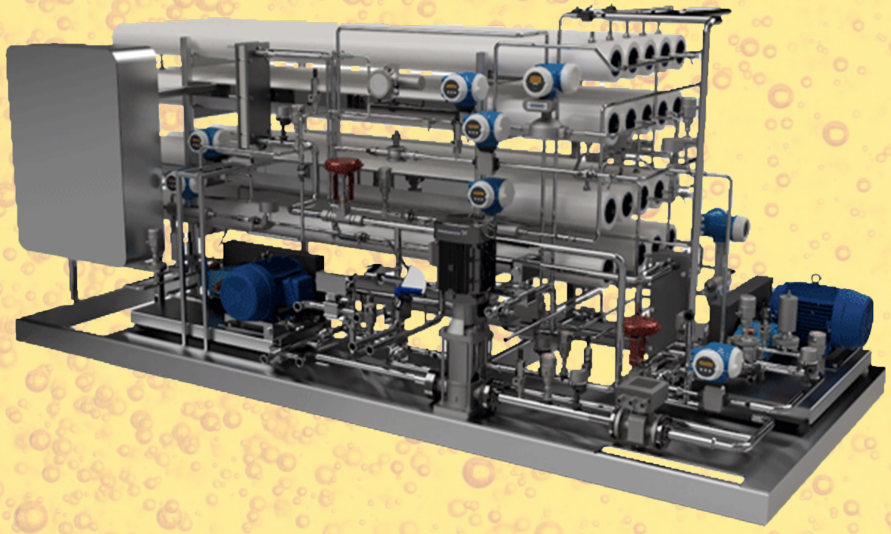


Reverse Osmosis

Austin

Current Options

Revos (Alfa-Laval)



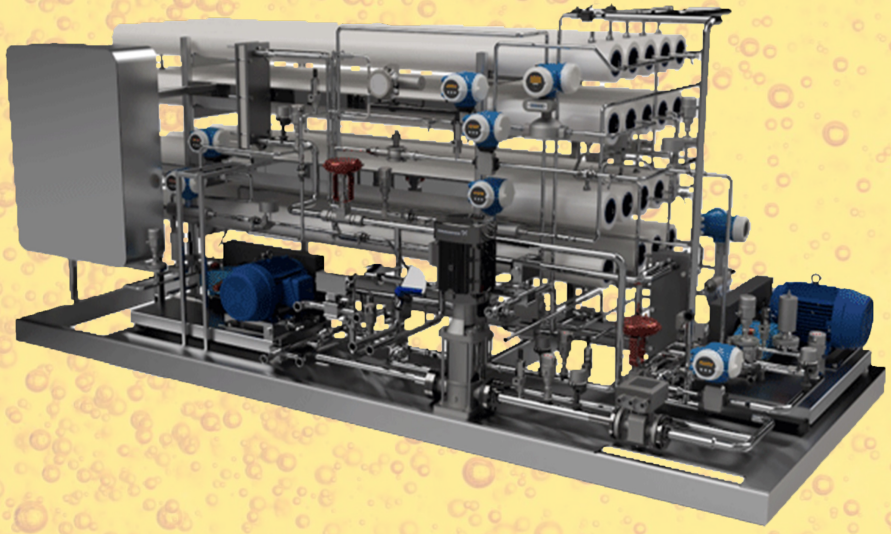
Reverse Osmosis

Adjustable Filtration

Austin

Current Options

Revos (Alfa-Laval)



Reverse Osmosis

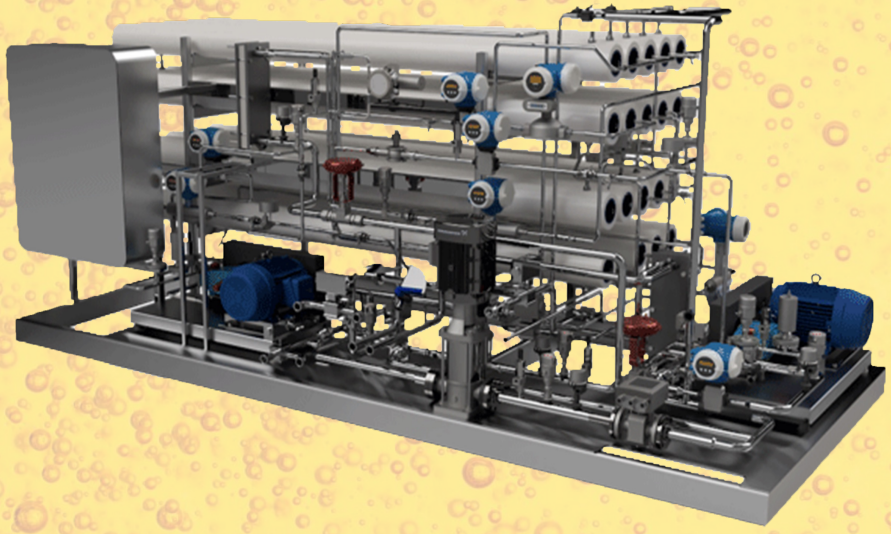
Adjustable Filtration

6' x 18'

Austin

Current Options

Revos (Alfa-Laval)

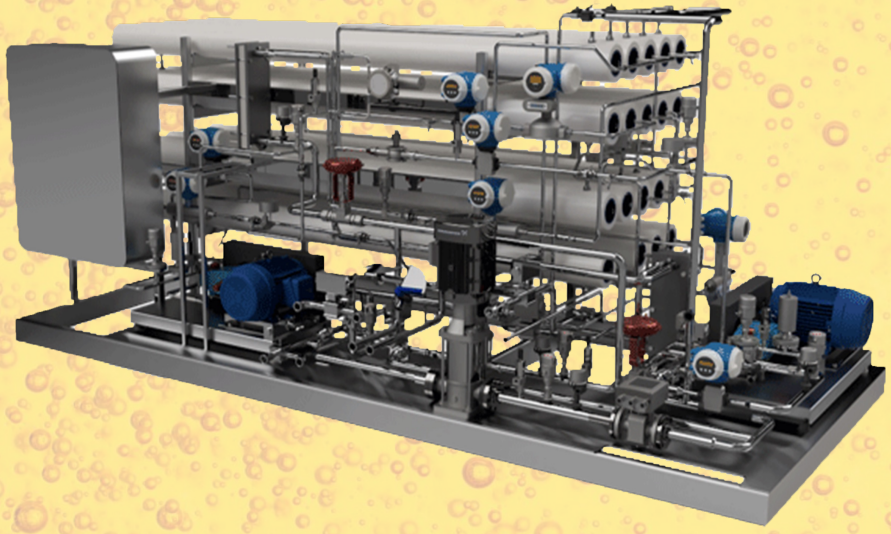


- Reverse Osmosis
- Adjustable Filtration
- 6' x 18'
- ~ $300k

Austin

Current Options

Revos (Alfa-Laval)

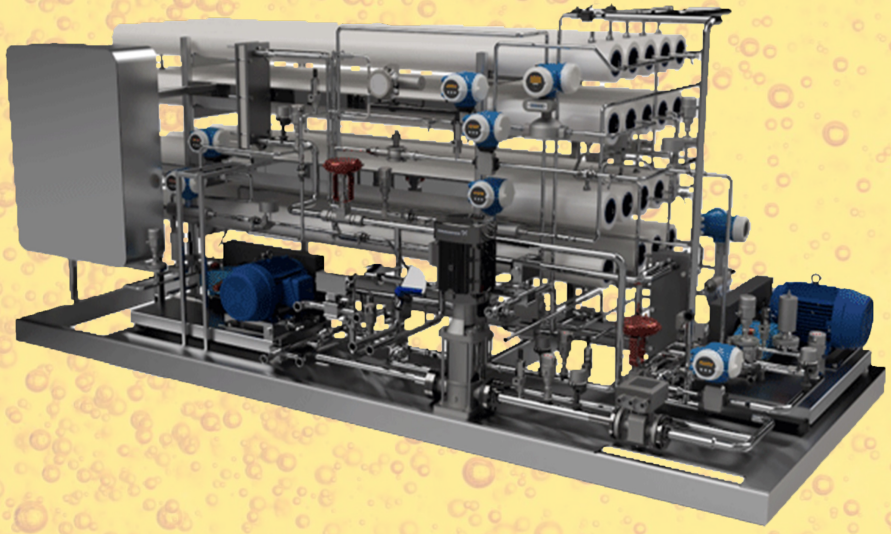


Taste & Aroma Retention	
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Revos (Alfa-Laval)

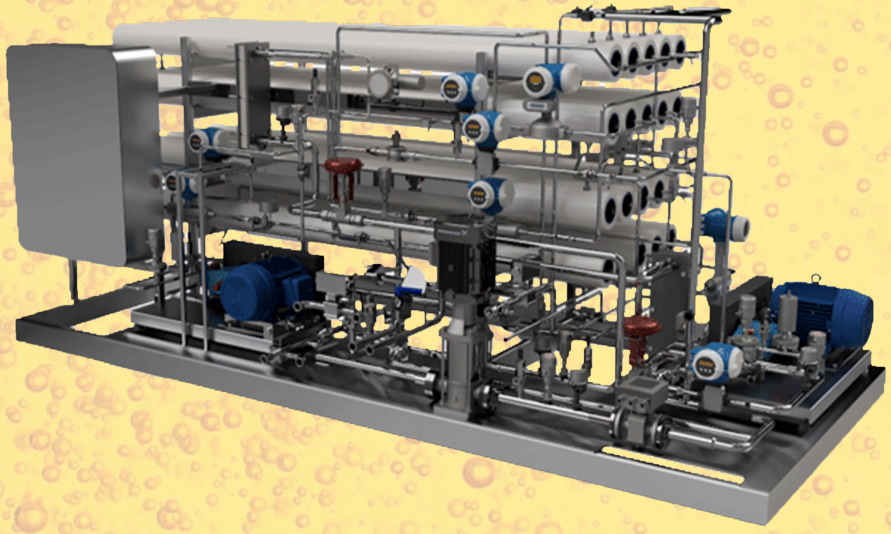


Taste & Aroma Retention	✕
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Revos (Alfa-Laval)

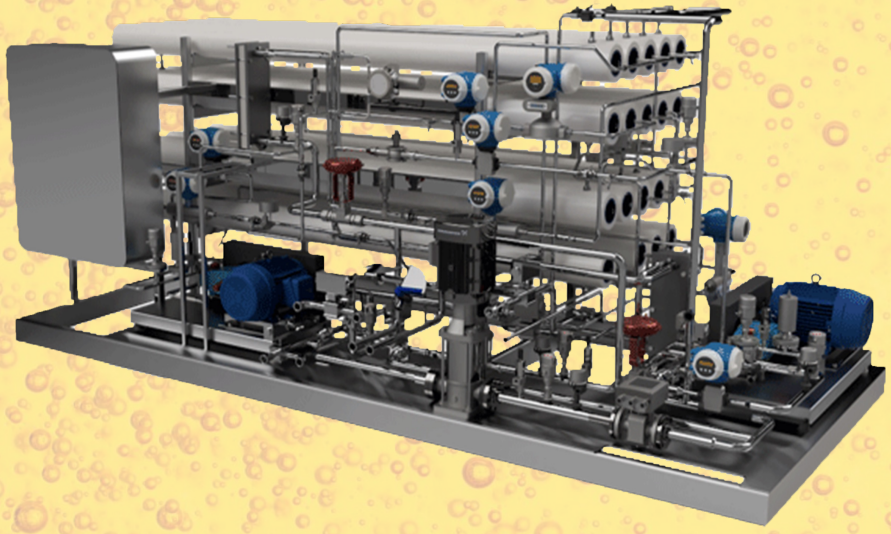


Taste & Aroma Retention	✕
Cost Effective	✕
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Revos (Alfa-Laval)

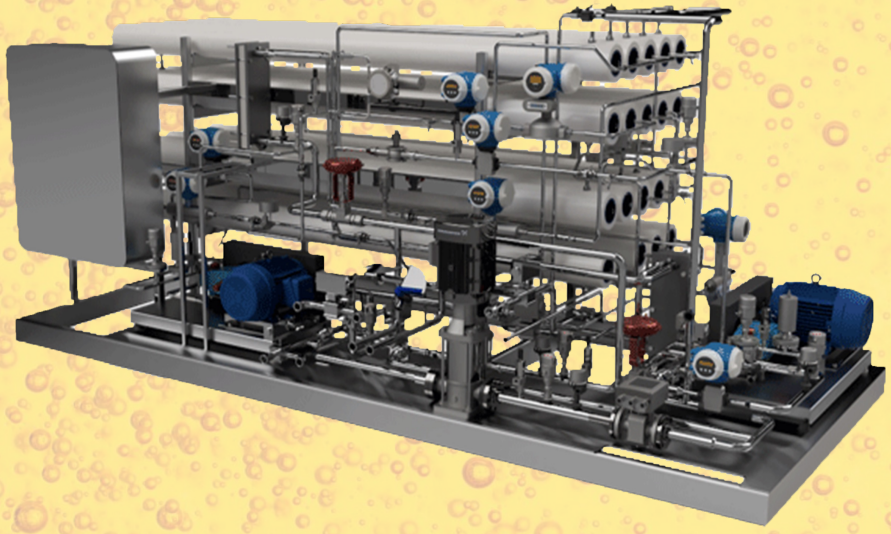


Taste & Aroma Retention	✕
Cost Effective	✕
Space Saving	✕
Flexible	
Hands-off	

Austin

Current Options

Revos (Alfa-Laval)

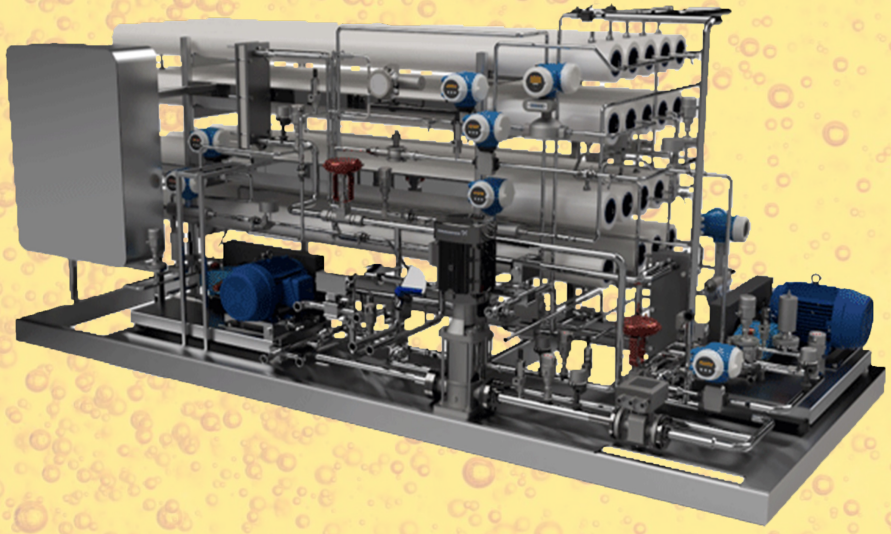


Taste & Aroma Retention	✗
Cost Effective	✗
Space Saving	✗
Flexible	
Hands-off	

Austin

Current Options

Revos (Alfa-Laval)



Taste & Aroma Retention	✗
Cost Effective	✗
Space Saving	✗
Flexible	
Hands-off	✗

Austin

Current Options

Alchemator
(ProBrew)

Austin

Current Options

Alchemator
(ProBrew)

Reverse Osmosis

Austin

Current Options

Alchemator
(ProBrew)

Reverse Osmosis

Full Concentration

Austin

Current Options

Alchemator
(ProBrew)

- Reverse Osmosis
- Full Concentration
- Scalable

Austin

Current Options

Alchemator
(ProBrew)

- Reverse Osmosis
- Full Concentration
- Scalable
- 3' x 5'

Austin

Current Options

Alchemator
(ProBrew)

- Reverse Osmosis
- Full Concentration
- Scalable
- 3' x 5'
- ~ $80k

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	✕
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	✕
Cost Effective	✕
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	✗
Cost Effective	✗
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	✗
Cost Effective	✗
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

Alchemator
(ProBrew)

Taste & Aroma Retention	✗
Cost Effective	✗
Space Saving	
Flexible	
Hands-off	✗

Austin

Current Options

BrewVo (SBT)

Austin

Current Options

BrewVo (SBT)

Reverse Osmosis

Austin

Current Options

BrewVo (SBT)

Reverse Osmosis

Full Concentration

Austin

Current Options

BrewVo (SBT)

Reverse Osmosis

Full Concentration

Scalable

Austin

Current Options

BrewVo (SBT)

- Reverse Osmosis
- Full Concentration
- Scalable
- 15' x 27'

Austin

Current Options

BrewVo (SBT)

- Reverse Osmosis
- Full Concentration
- Scalable
- 15' x 27'
- ~ $640k

Austin

Current Options

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

BREWVO

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

MAGFO

Current Options

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	✗
Space Saving	
Flexible	
Hands-off	

Austin

Current Options

BREWVO

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	✕
Space Saving	
Flexible	
Hands-off	

Austin

MAGFO

Current Options

BREWVO

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	✕
Space Saving	
Flexible	
Hands-off	

Austin

MAGFO

Current Options

BrewVo (SBT)

Taste & Aroma Retention	
Cost Effective	✕
Space Saving	
Flexible	
Hands-off	

Austin

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Anna Harvey

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The Product

Alcohol Elimination Service (AES)

Grace

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The Product Main Components

FO Membrane

- FTS H2O Membrane

Grace

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The Product Main Components

FO Membrane

- FTS H2O Membrane

Draw Solution

- CO_2 Pressurized $Mg(OH)_2$ solution

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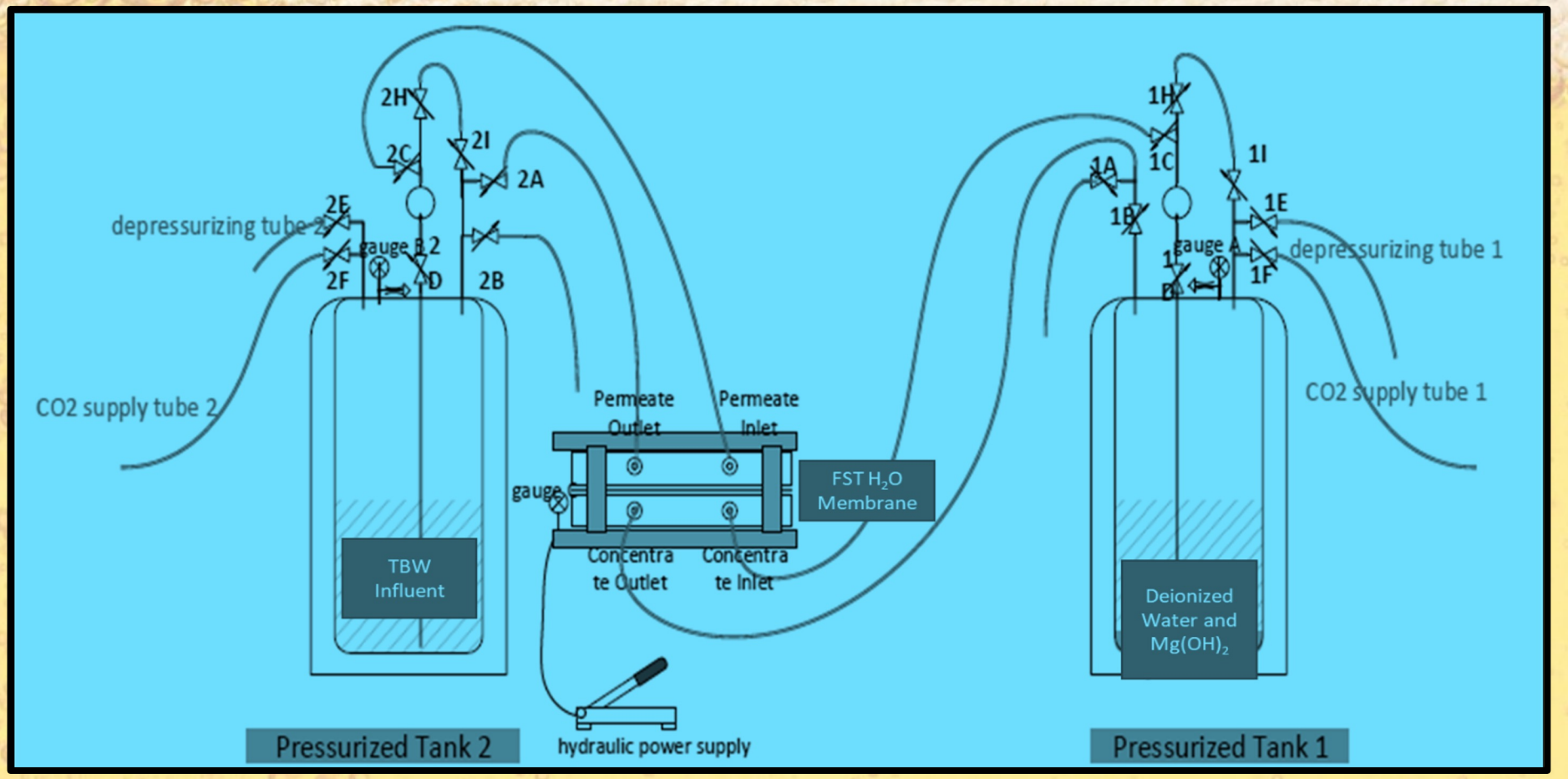
The Product Concept Schematics



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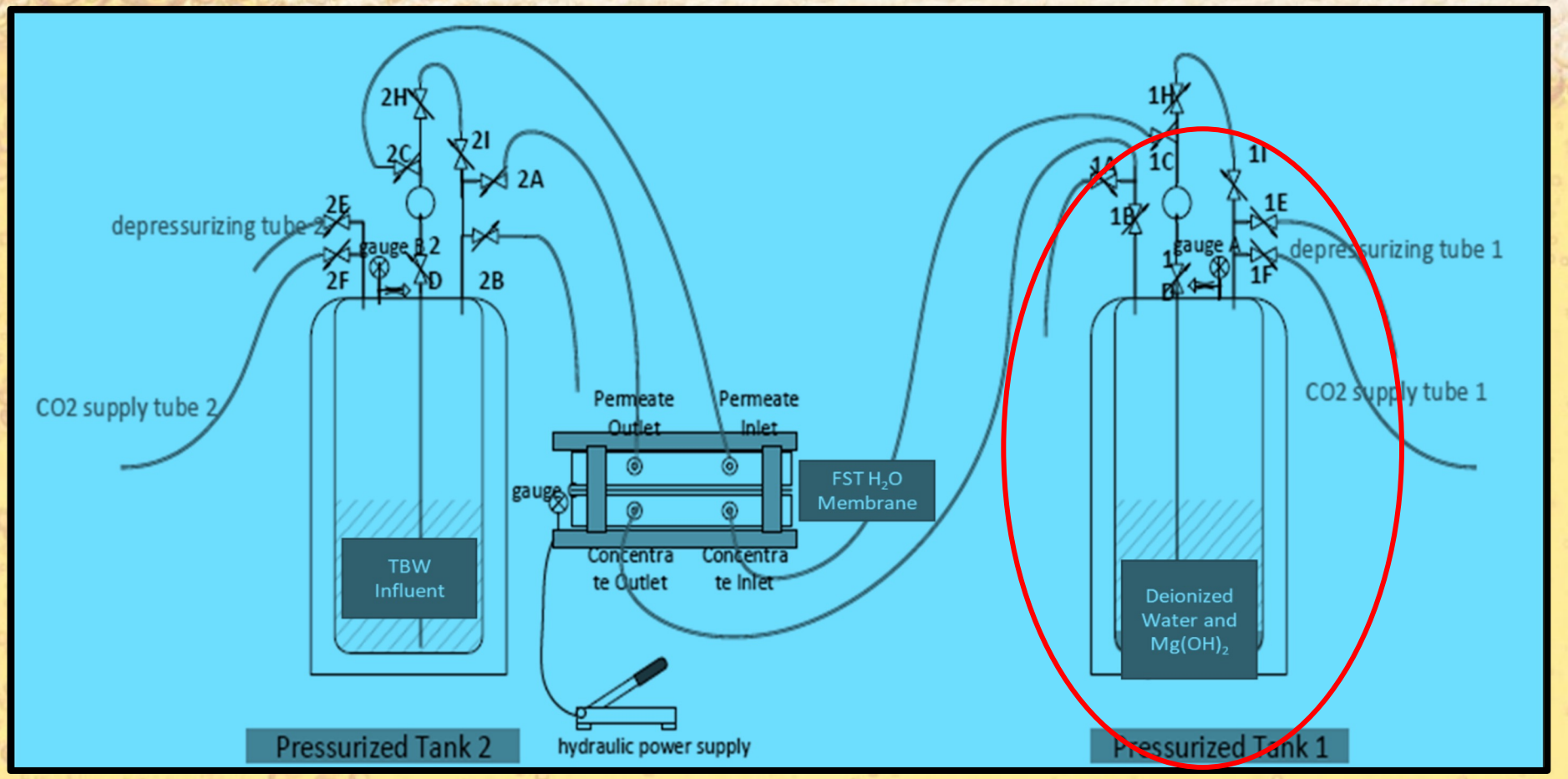
The Product Concept Schematics



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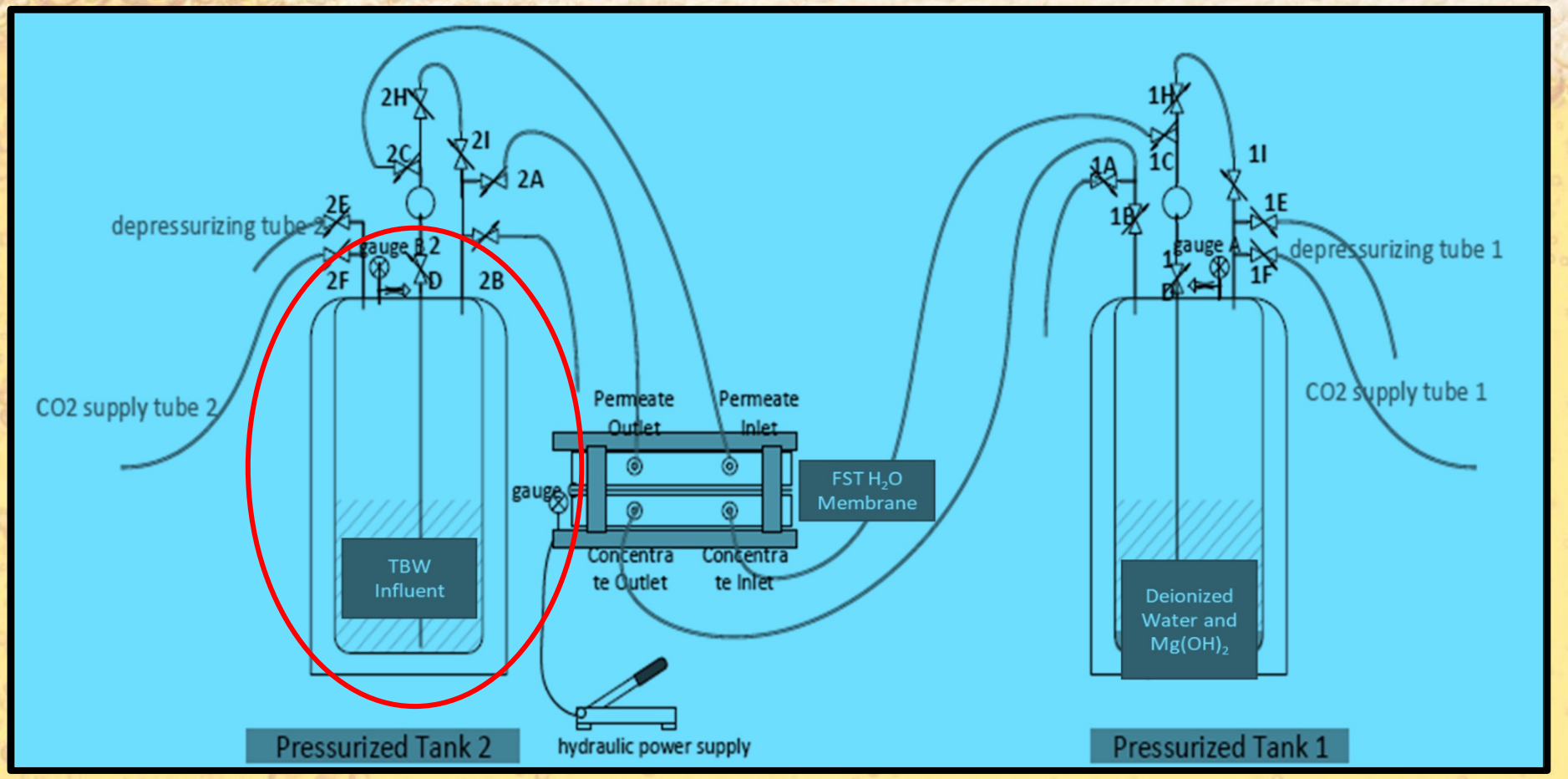
The Product Concept Schematics



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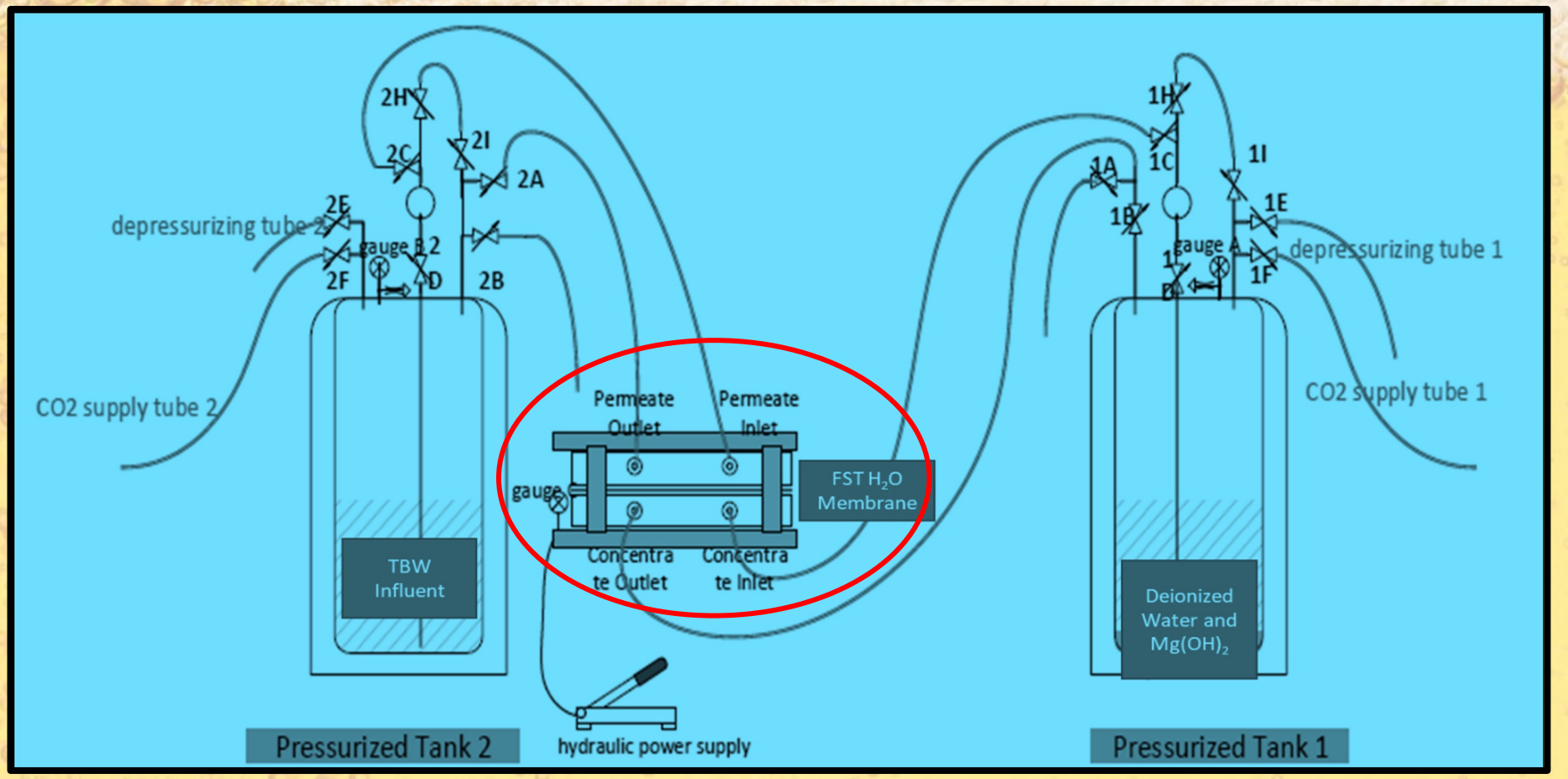
The Product Concept Schematics



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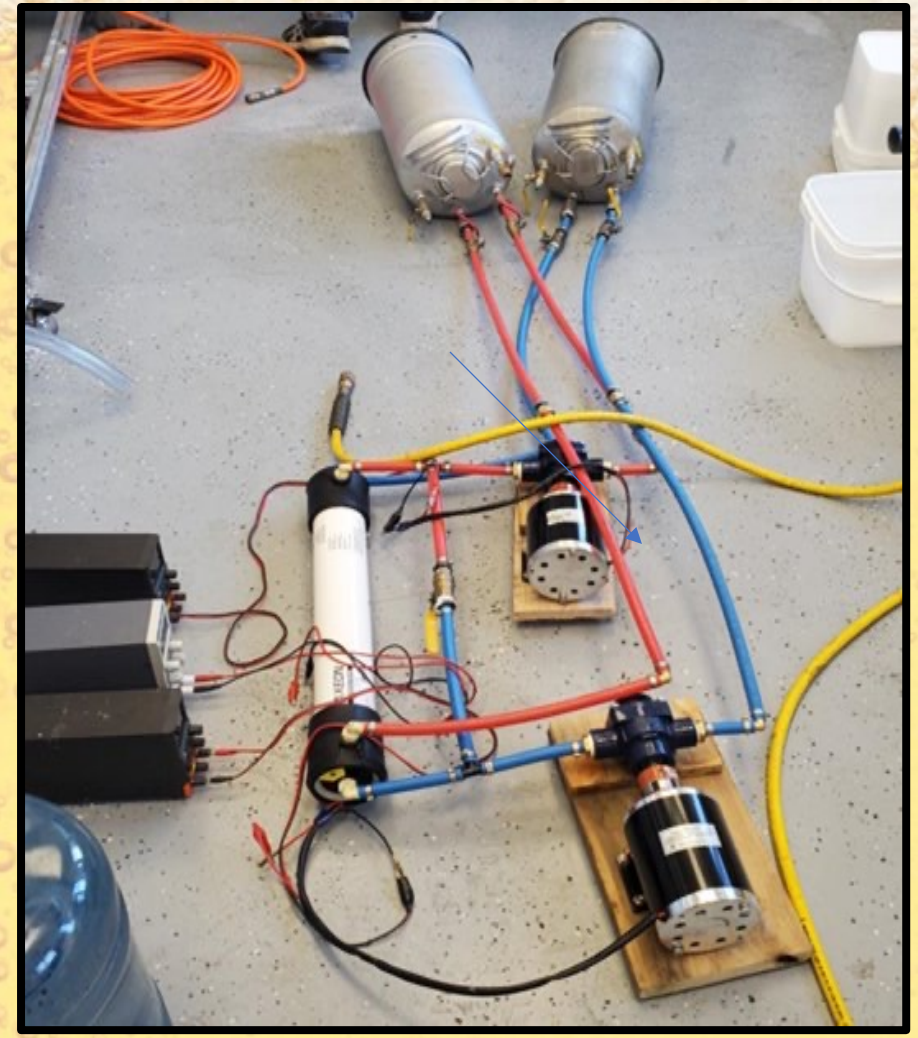
The Product Experimental Setup



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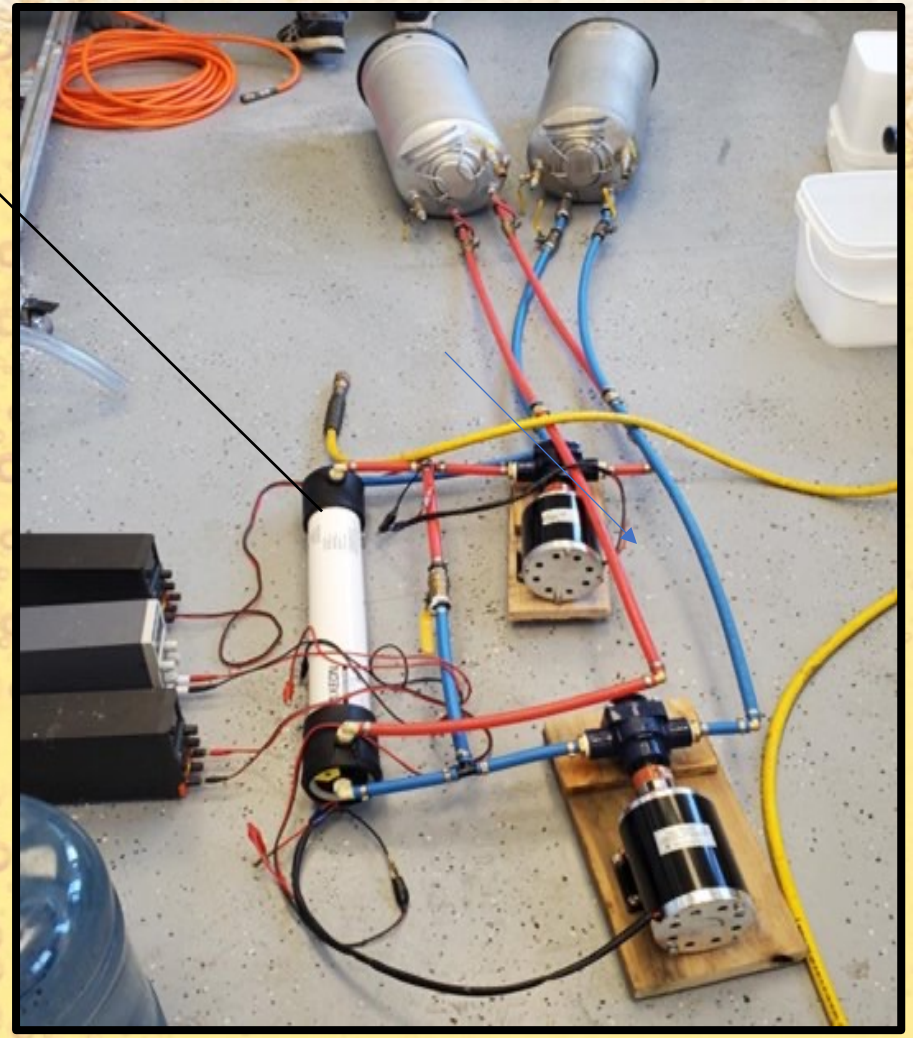
The Product Experimental Setup

Membrane Housing



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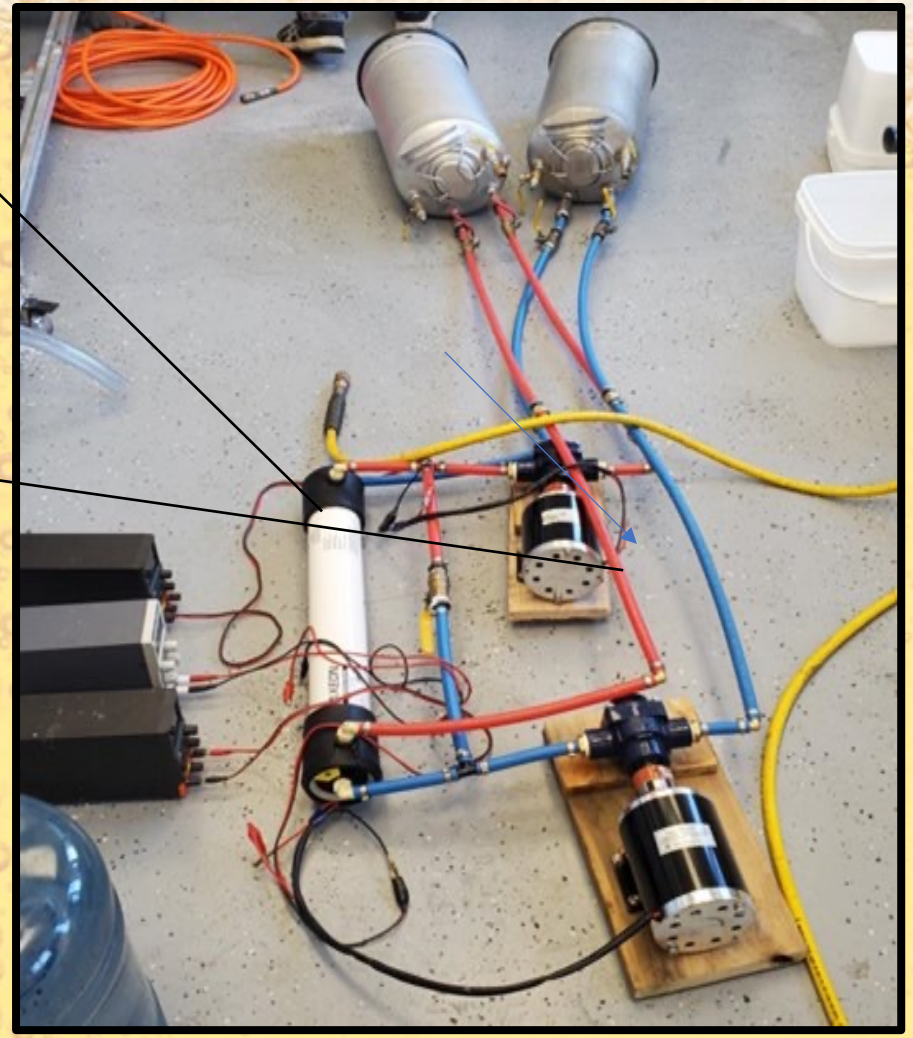
The Product Experimental Setup

Membrane Housing

Tubing



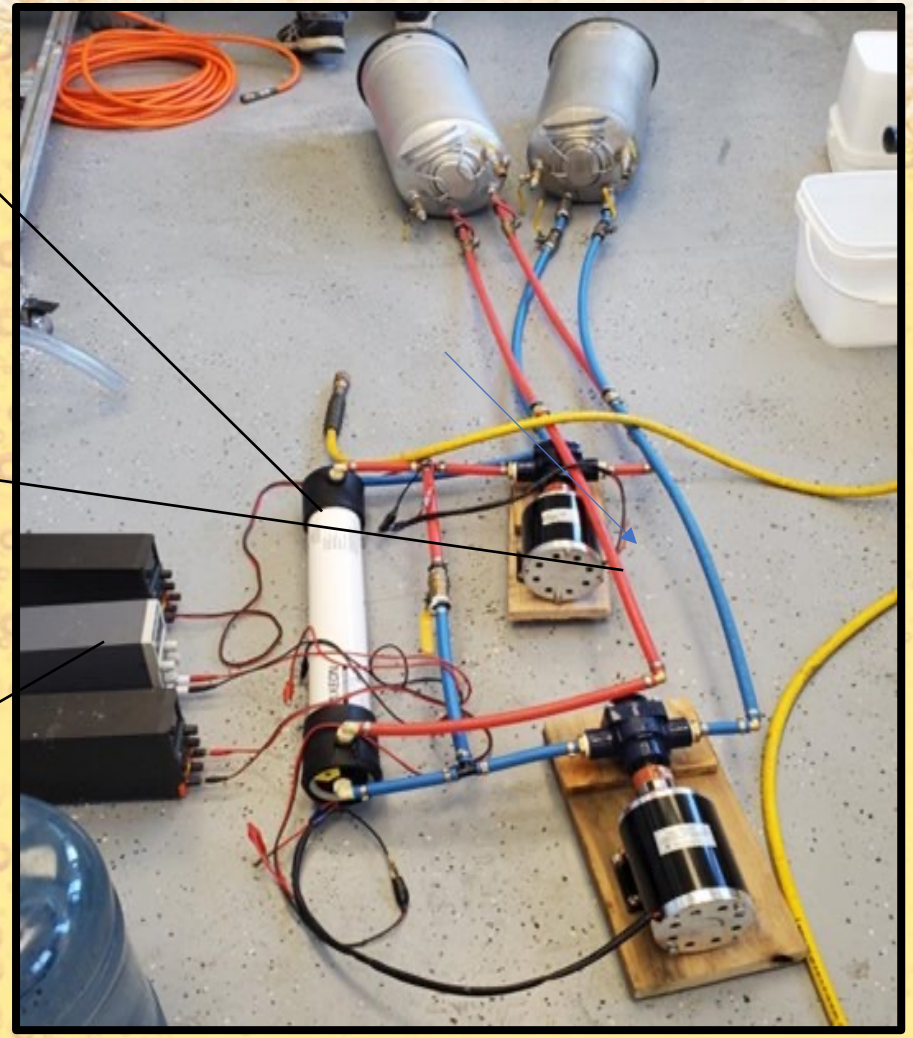
Grace

The Product Experimental Setup

Membrane Housing

Tubing

Power Source



Grace

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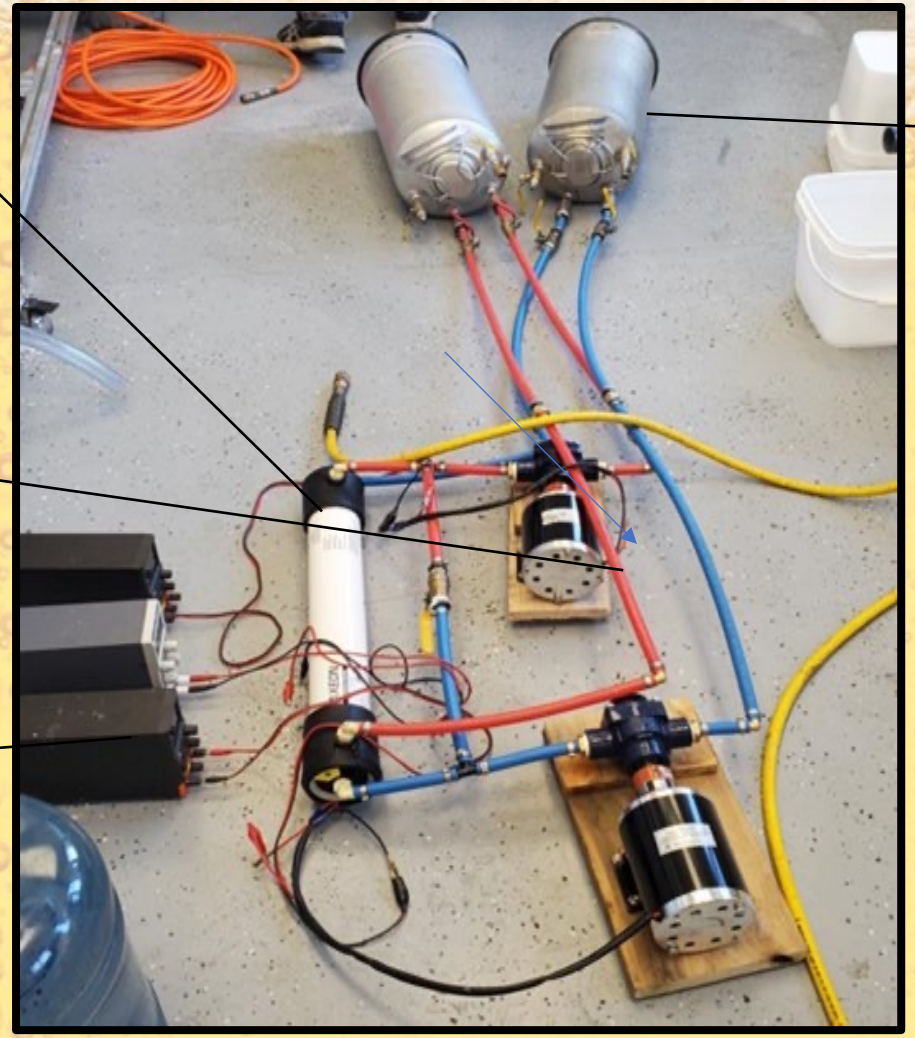
The Product Experimental Setup

Membrane Housing

Tubing

Power Source



Pressurized tanks

Grace

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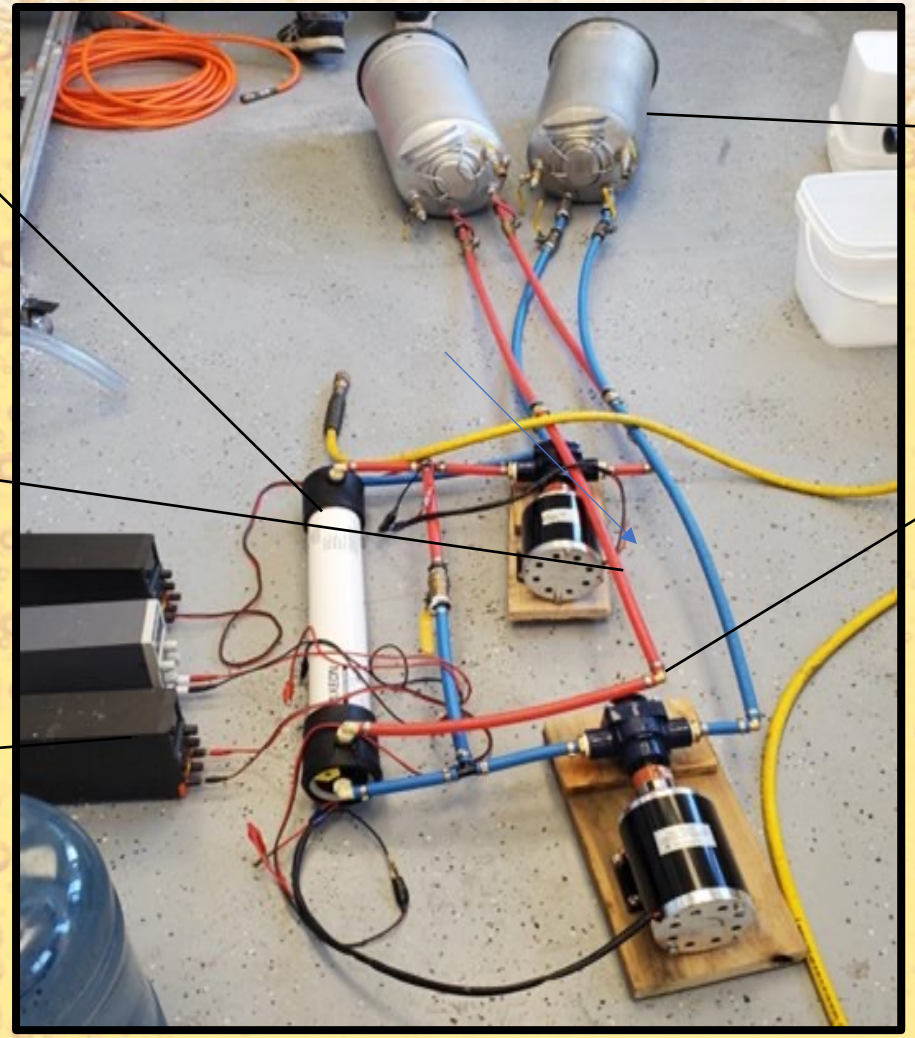
The Product Experimental Setup

Membrane Housing

Tubing

Power Source



Pressurized tanks

Fittings

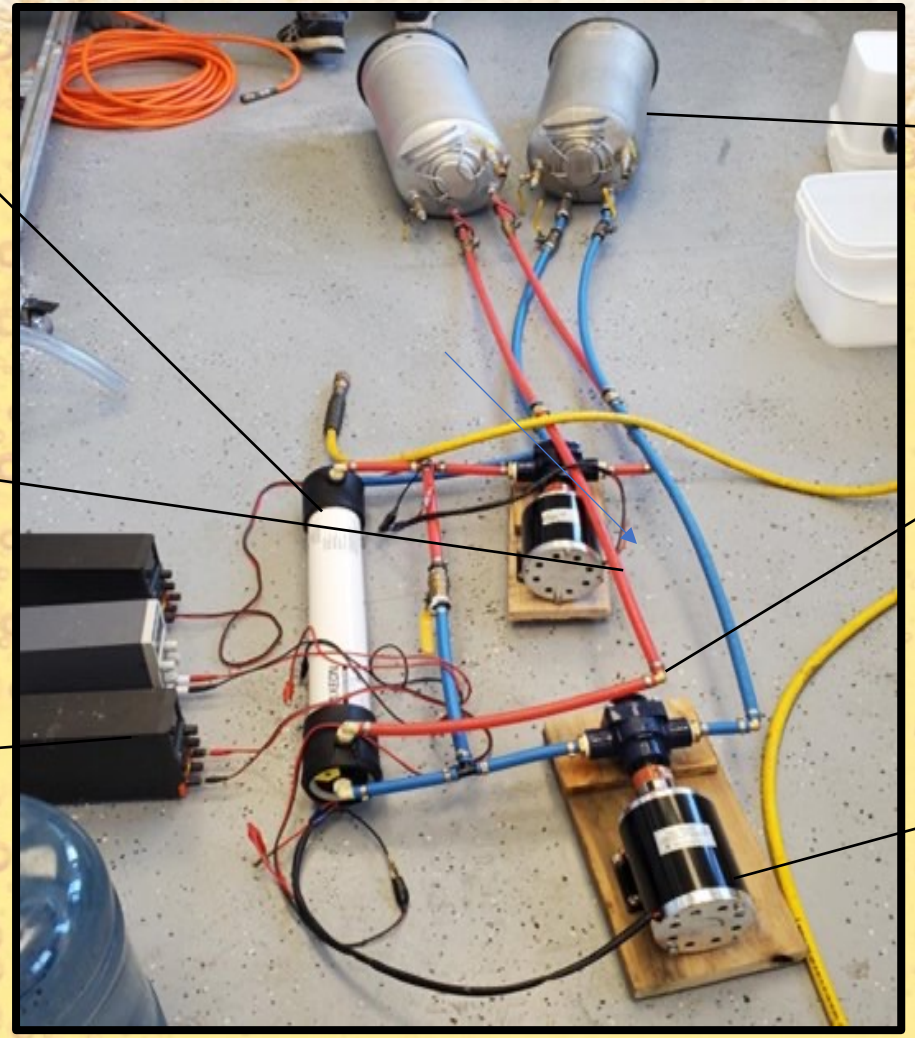
Grace

The Product Experimental Setup

Membrane Housing

Tubing

Power Source



Pressurized tanks

Fittings

Pump

Grace

The Product Requirements

Alcohol Content

- Below 0.5% ABV

Grace

The Product Requirements

Alcohol Content

- Below 0.5% ABV

Acidity

- pH between 3-5.6

Grace

The Product Requirements

Alcohol Content

- Below 0.5% ABV

Acidity

- pH between 3-5.6

No O2/Taste Retention

- Oxidation alters taste

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The Product Requirements

Alcohol Content

- Below 0.5% ABV

Acidity

- pH between 3-5.6

No O2/Taste Retention

- Oxidation alters taste

CO_2 Limits

- 1.0-2.6 Volumes of CO_2

Grace

The Product Requirements

Alcohol Content

- Below 0.5% ABV

Acidity

- pH between 3-5.6

No O2/Taste Retention

- Oxidation alters taste

CO2 Limits

- 1.0-2.6 Volumes of CO2

Sanitary Tubing & Fittings

- 3-A sanitary Standards

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The Product Requirements

What are the 3-A sanitary Standards ?

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The Product Requirements

What are the 3-A sanitary Standards ?

Large inventory of design criteria for equipment and processing systems developed using modern consensus process-based requirements accepted by FDA, USDA, and State regulatory authorities

Grace

The Product Requirements

Stainless Steel

Grace

The Product Requirements

Most common used in sanitary piping

Stainless Steel

Grace

MAGFO

The Product Requirements

Most common used in sanitary piping

Stainless Steel

Corrosion Resistant

Grace

MAGFO

The Product Requirements

Most common used in sanitary piping

Stainless Steel

Corrosion Resistant

High durability

Grace

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The Product Requirements

Stainless Steel

- Most common used in sanitary piping
- Corrosion Resistant
- High durability
- Less Expensive

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The Product Requirements

National Sanitary Parts Suppliers

Grace

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The Product Testing

Alcohol Elimination Service (AES)

Grace

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The Product Testing

Draw Solution

$Mg(OH)_2$

Grace

MAGFO

The Product Testing

Draw Solution

$Mg(OH)_2$ → Sugar solution

Grace

The Product Testing

Draw Solution

$Mg(OH)_2$ → Sugar solution

Grace

The Product Testing

Draw Solution

$Mg(OH)_2$ → Sugar solution

Pouches act as a membrane

- Cellulose Triacetate FO Membrane

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The Product Testing

Ben Bailey, QA Manager at Tröegs Brewing Co.

Grace

The Product Testing

Grace

The Product Testing

2 sugar Pouches

Each has 90 grams of fructose/glucose blend

Pouch/Membrane size: 6.5” x 4”

Fill Volume: 400 ml

Grace

The Product Testing

2 sugar Pouches

Each has 90 grams of fructose/glucose blend

Pouch/Membrane size: 6.5” x 4”

Fill Volume: 400 ml

900 ml of a 7.39 % Alc. IPA beer

Grace

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Experiment Results

Sample	Temperature	pH	Alcohol % V/V	Duration	% Alcohol Removed
Sample IPA beer	68 degrees F	4.84	7.39	-	-
Dealcoholized beer	68 degrees F	4.78	6.57	7 days	0.82
Dealcoholized beer	68 degrees F	4. 75	5.24	12 days	2.15

Grace

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Experiment Results

Sample	Temperature	pH	Alcohol % V/V	Duration	% Alcohol Removed
Sample IPA beer	68 degrees F	4.84	7.39	-	-
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Grace

Experiment Results

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Grace

Experiment Results

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Next Steps

To reach target alcohol content

< 0.5% ABV

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Next Steps

To reach target alcohol content

< 0.5% ABV

- Increase Draw solution
- Increase the membrane size

Grace

Next Steps

To reach target alcohol content

< 0.5% ABV

- Increase Draw solution
- Increase the membrane size

To retain taste/flavor

Grace

Next Steps

To reach target alcohol content

< 0.5% ABV

→

- Increase Draw solution
- Increase the membrane size

To retain taste/flavor

→

- Special Recipes for NA beer before dealcoholization

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Next Steps

To reach target alcohol content
< 0.5% ABV

→ - Increase Draw solution
- Increase the membrane size

To retain taste/flavor

→ - Special Recipes for NA beer before dealcoholization

To avoid microbial contamination and oxidation

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Next Steps

To reach target alcohol content < 0.5% ABV	- Increase Draw solution - Increase the membrane size
To retain taste/flavor	- Special Recipes for NA beer before dealcoholization
To avoid microbial contamination and oxidation	- Use proper sanitary parts and fittings

Grace

Introduction & Market Research
Alex Romanowski

Industry Research
Jack Lee

Market Opportunity
Ethan Hughes

Customer Needs
Austin McCullough

The AES Product
Grace Kuzwa

Business Model
Janik Wing

Marketing
Marina Mendez

Financials & Next Steps
Anna Harvey

MAGFO

Business Model – Mobile Dealcoholization Service for Breweries

Janik

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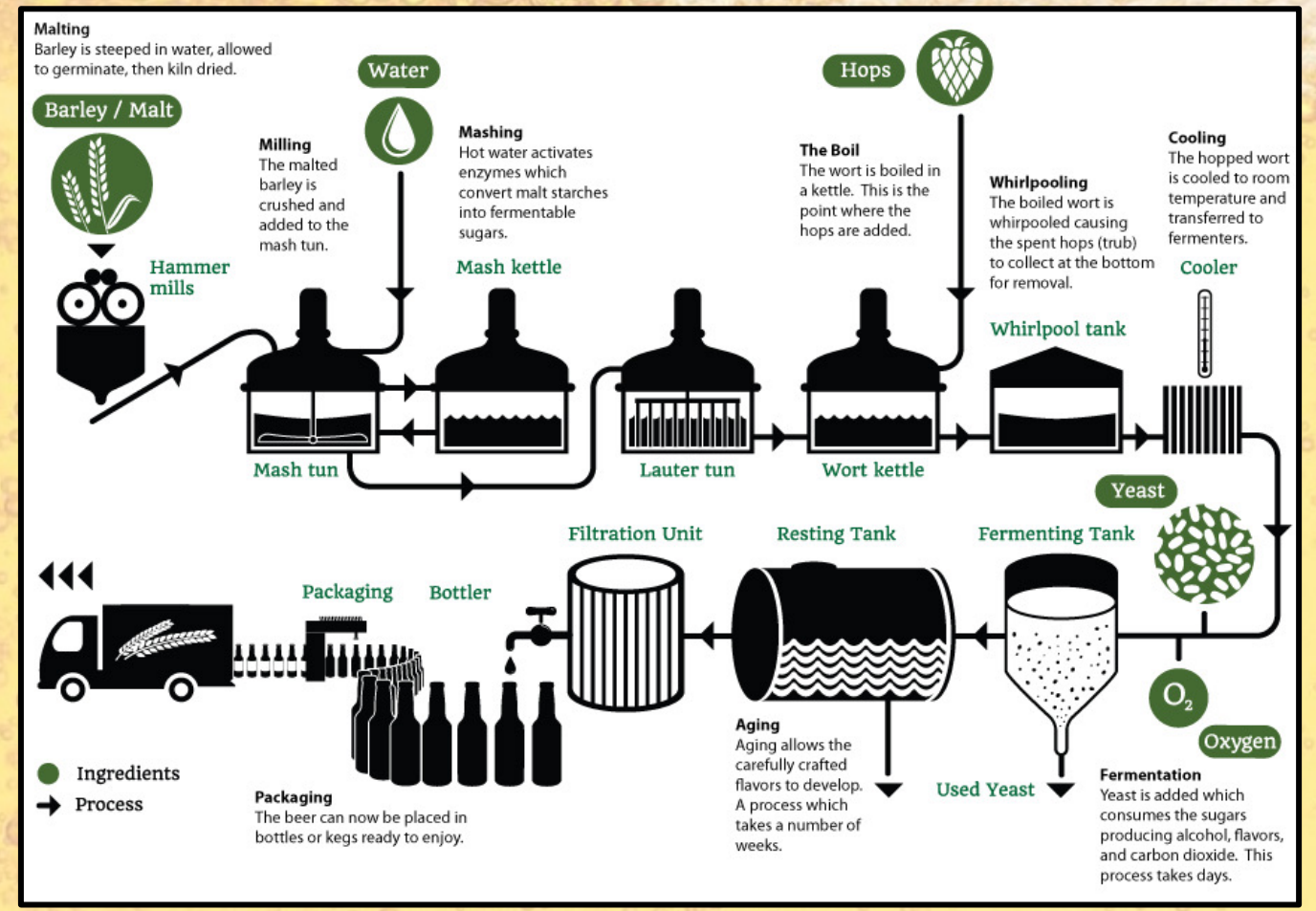
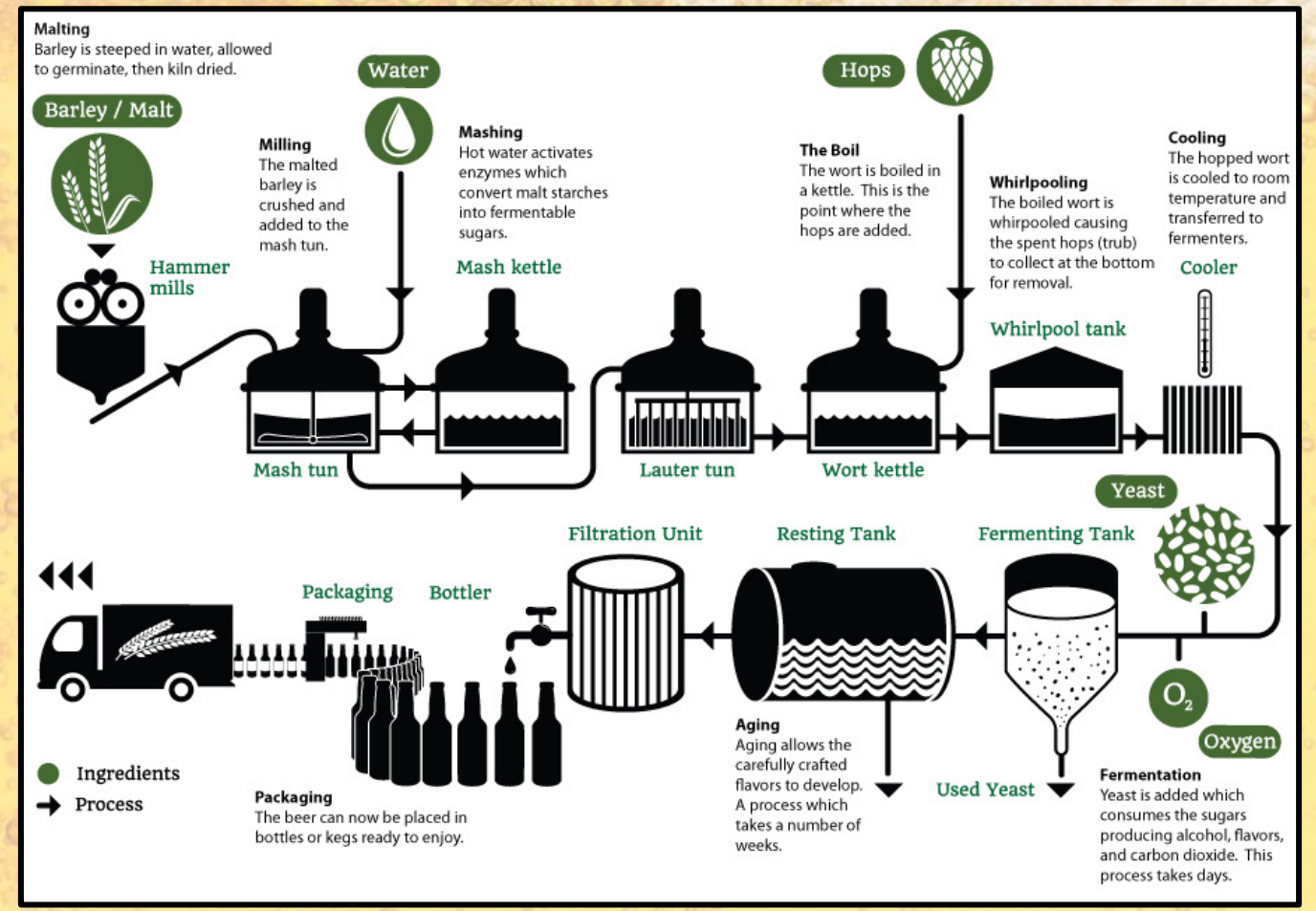
Integration



Delicate process for flavor balance

Janik

Integration

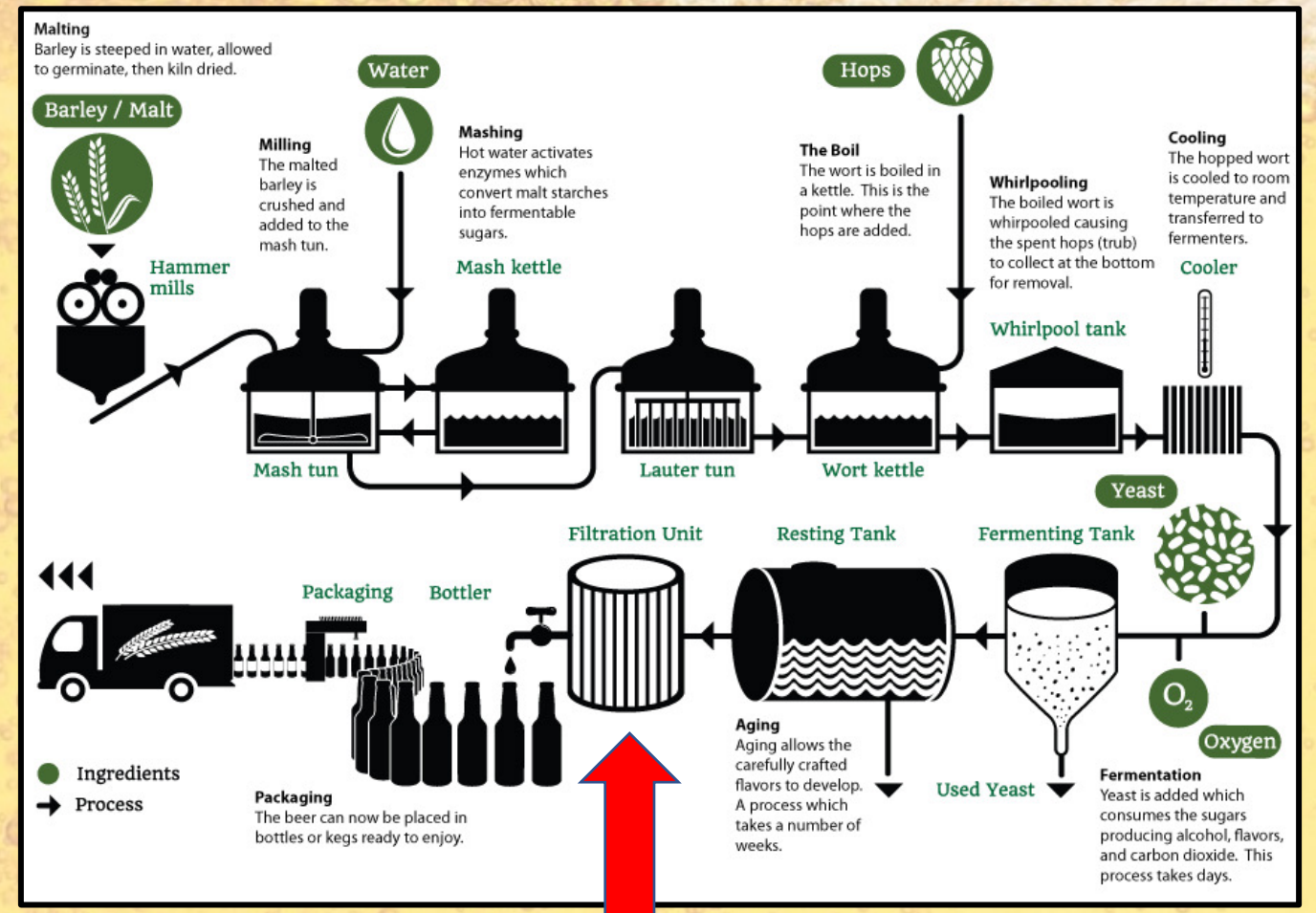


Delicate process for flavor balance

Low microbial stability in NA beer

Janik

Integration



Delicate process for flavor balance

Low microbial stability in NA beer

Seamless integration needed

Janik

AES

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The Skid

Tow Truck

Trailer

Janik

The Skid

Mobile System

Janik

Business Case - Tröegs

Produces 100k+ barrels annually

Janik

Business Case - Tröegs

Produces 100k+ barrels annually

Looking to expand into the NA market

Janik

Business Case - Tröegs

Produces 100k+ barrels annually

Looking to expand into the NA market

Manage risk and capital expenditure

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Test Your Order

Run demos with AES and experiment flavors

Janik

MAGFO

Test Your Order

Run demos with AES and experiment flavors

Test market with flexible order volume

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Orders

Quote: $3/gallon
Trucking: $4/mile
Fixed: $250

Janik

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Orders

Quote: $3/gallon
Trucking: $4/mile
Fixed: $250

500 gal minimum

90-day basis

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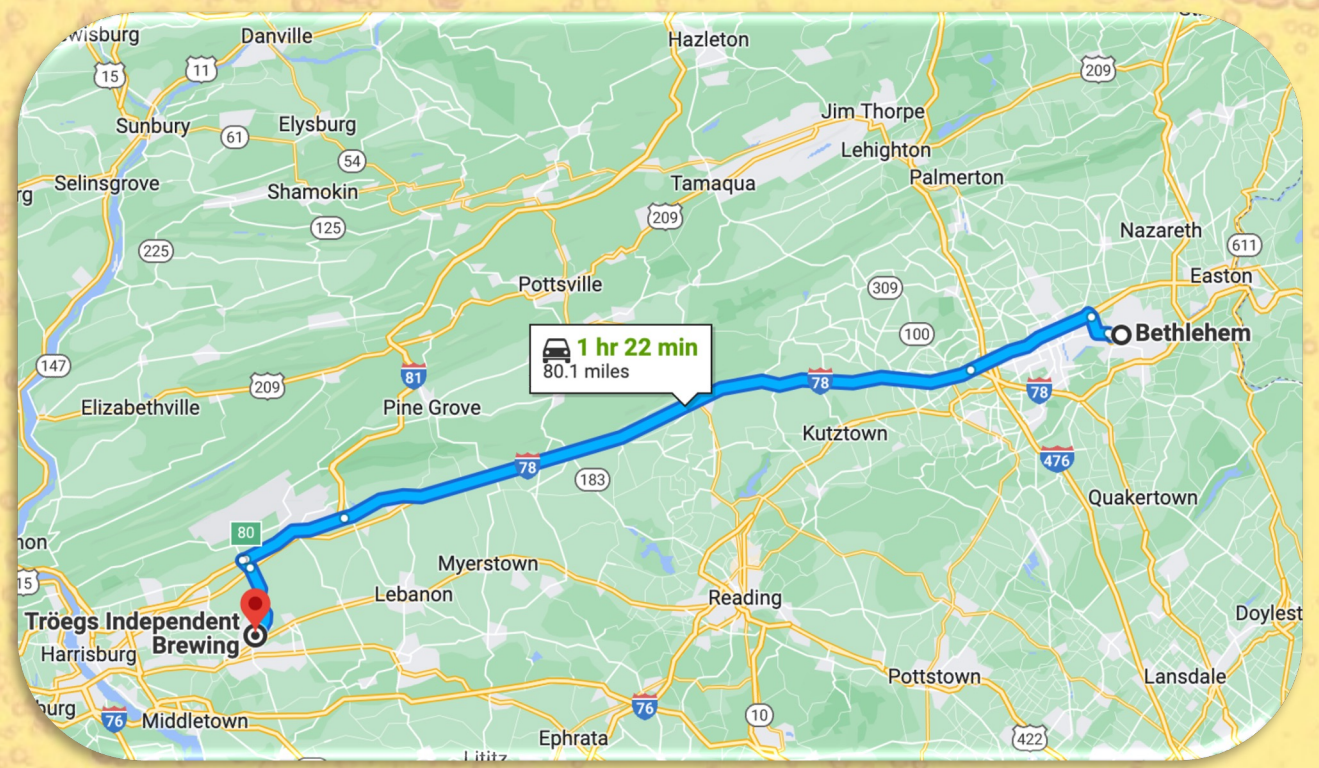
Order Example - Tröegs



- 80 miles
- 1,000 gallons

Quote: $3,000

Additional: $890

Janik

Setup and Running

1-2 hours for both setup and teardown

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Setup and Running

1-2 hours for both setup and teardown

300 gallons/hour filtered

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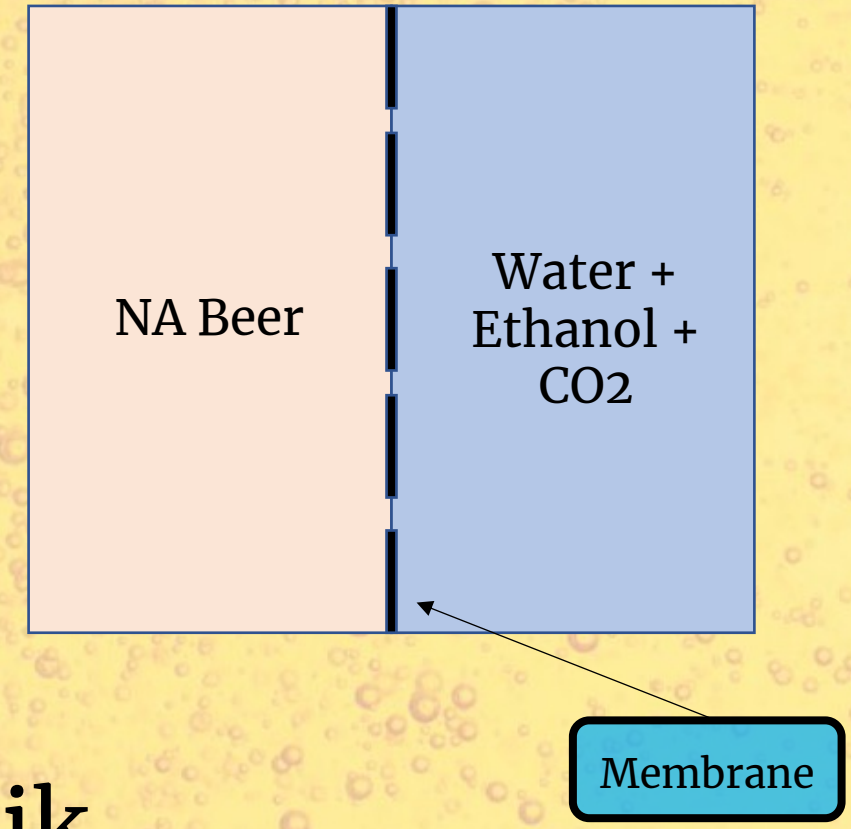
Byproduct



Seltzer Base

Business value

Janik

MAGFO

The Solution

AES (MagFO)

Austin

The Solution

AES (MagFO)

Forward Osmosis

Austin

The Solution

AES (MagFO)

Forward Osmosis

Alcohol Removal

Austin

The Solution

AES (MagFO)

Forward Osmosis

Alcohol Removal

Scalable

Austin

The Solution

AES (MagFO)

- Forward Osmosis
- Alcohol Removal
- Scalable
- Service Model

Austin

The Solution

AES (MagFO)

Taste & Aroma R etention	
Cost Effective	
Space Saving	
Flexible	
Hands-off	

Austin

The Solution

AES (MagFO)

Taste & Aroma R etention	
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Austin

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Marketing

Marina

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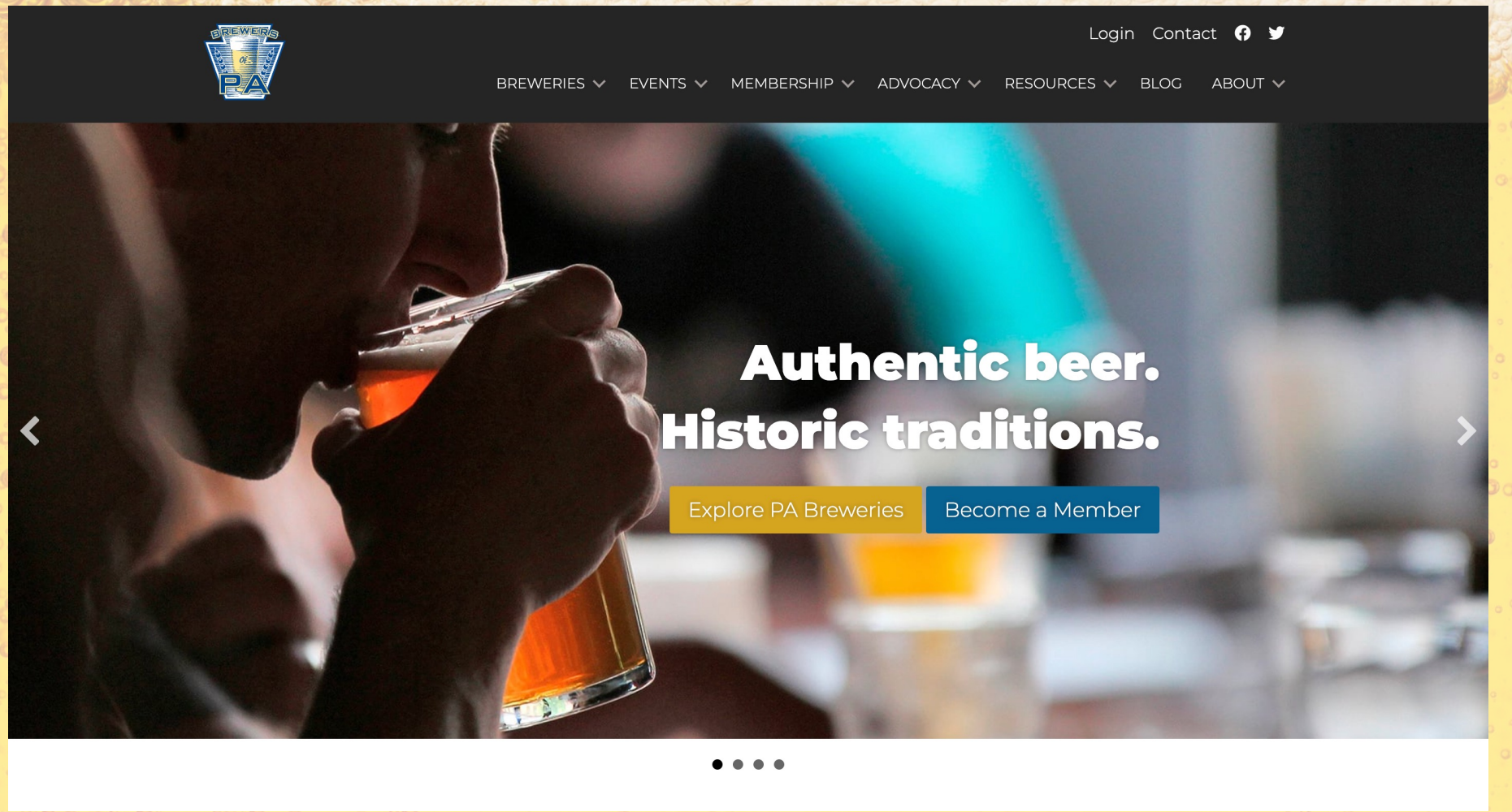
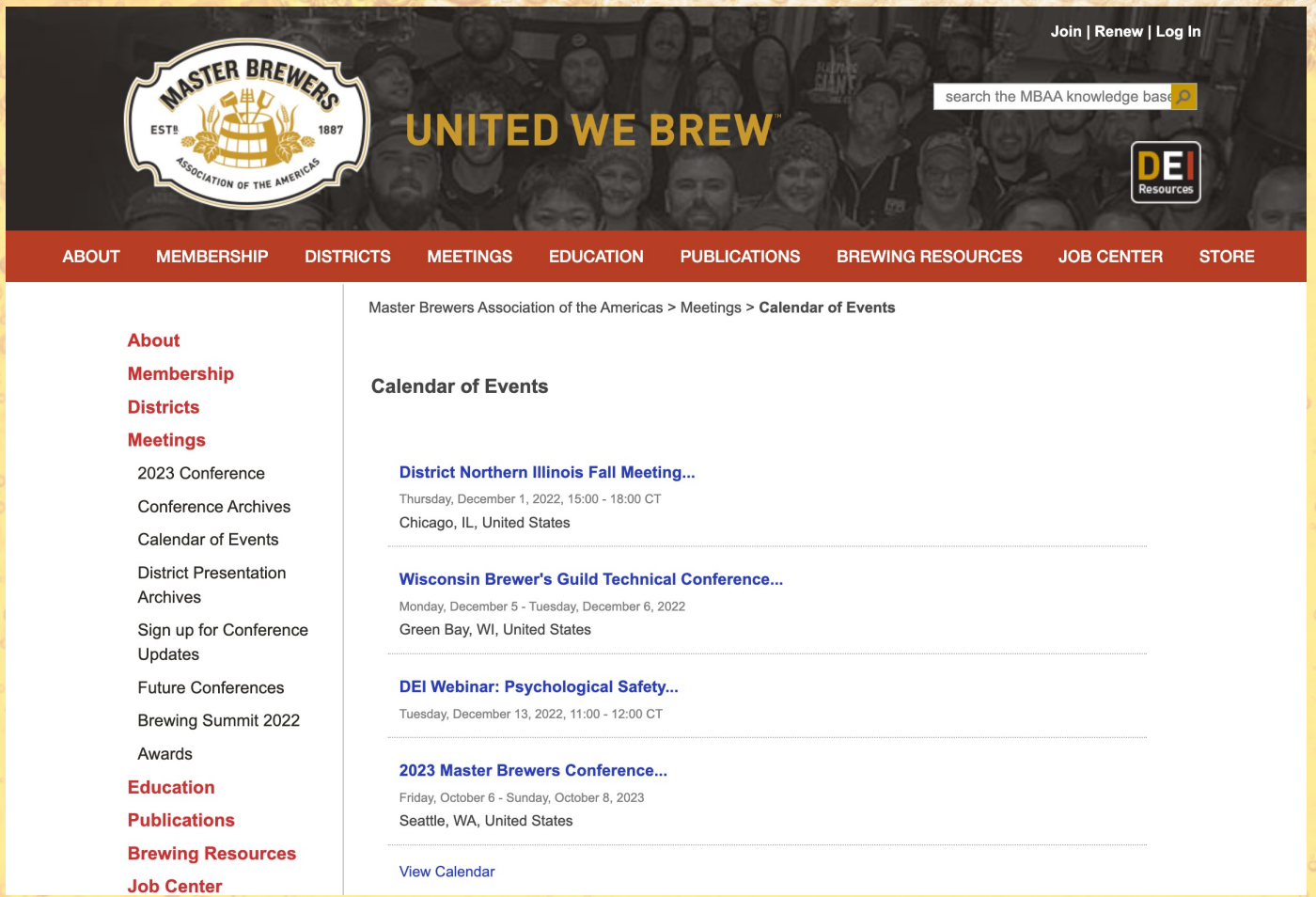
Brewers of PA



Marina

Master Brewers Association Of The Americas



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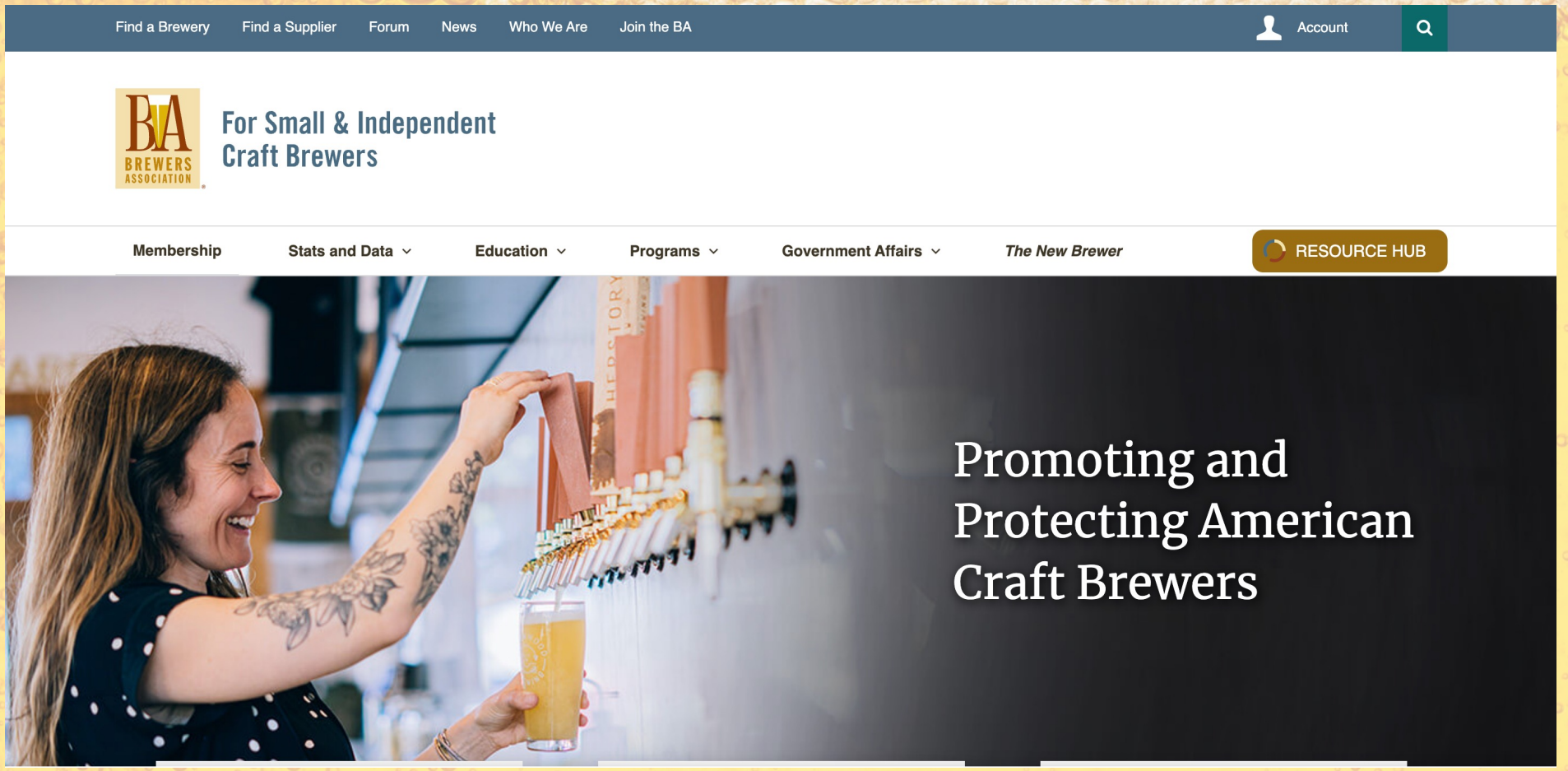
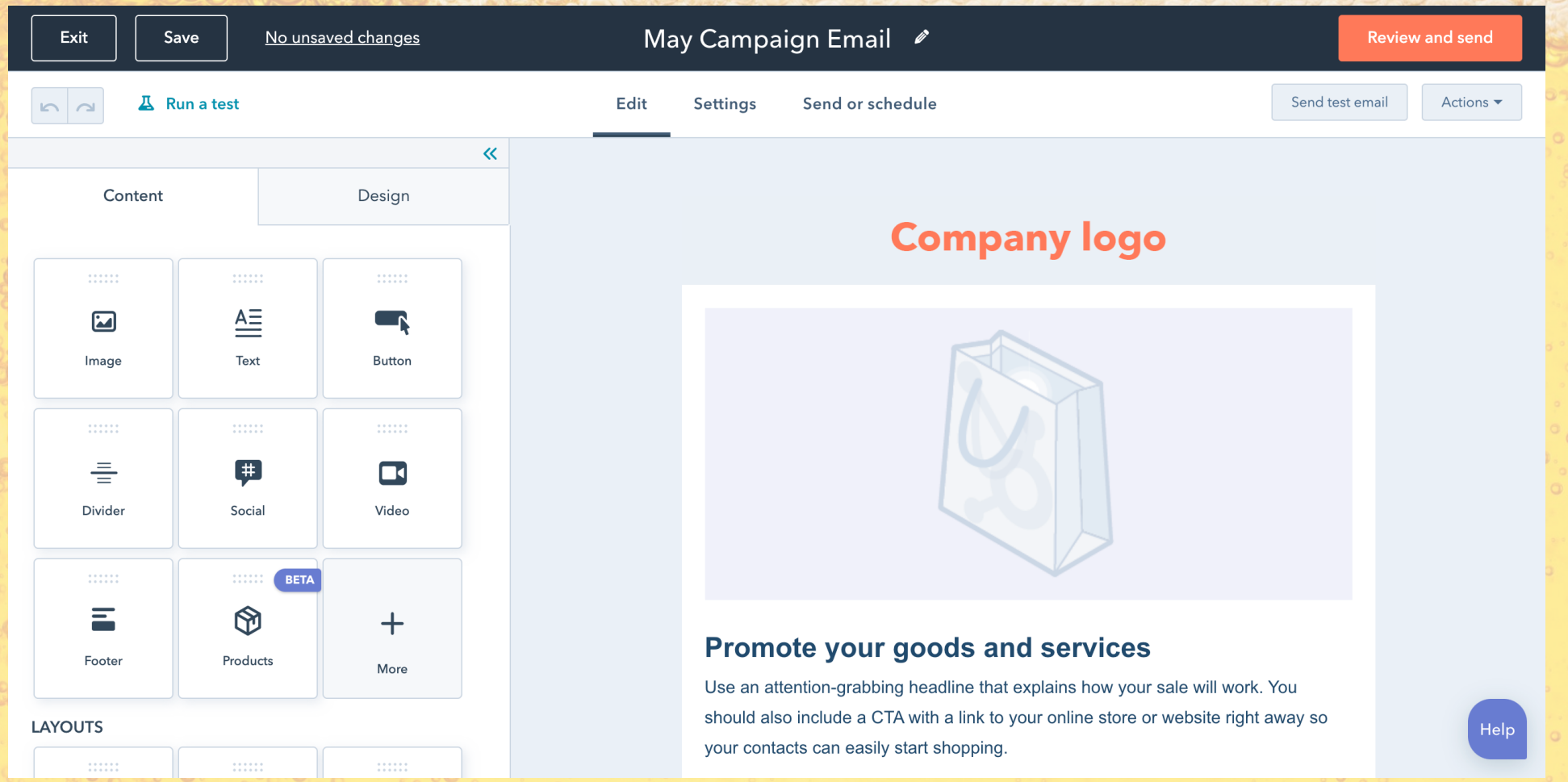
Brewers Association



Marina

Email Campaign



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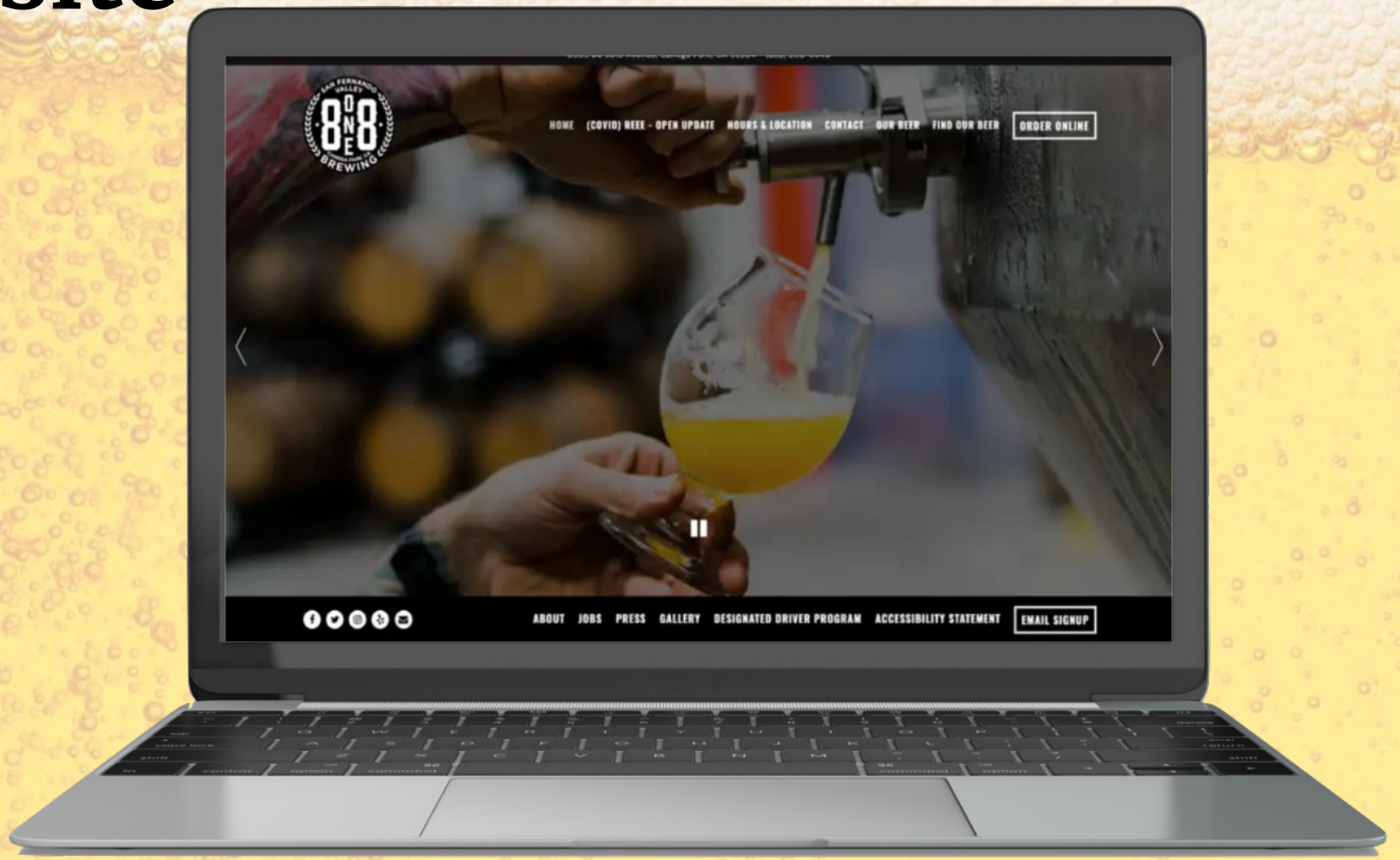
Website



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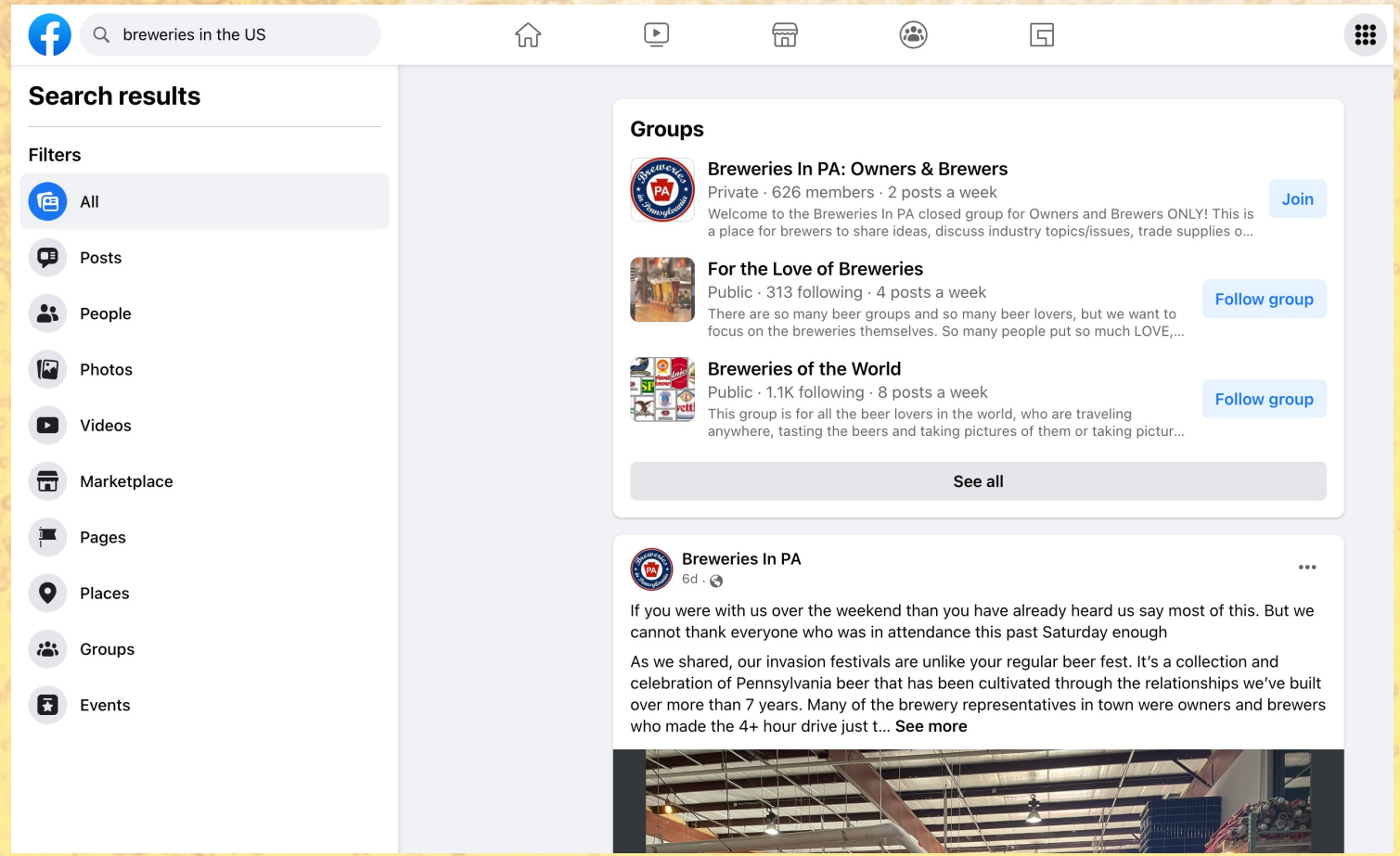
Facebook Groups



Marina

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Financials & Next Steps
Anna Harvey

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Financials

Anna

Tröegs

$12.49

Anna

Non-Alcoholic Market

Non-Alcoholic	Avg Price/12 oz
Heineken Lager 0.0	$1.99
Lagunitas IPNA	$2.49
Coors Edge	$1.28
Sam Adams just the haze	$2.49
Miller Sharps	$1.49
Budweiser zero	$1.59
Busch NA	$1.08

Anna

Non-Alcoholic Market

Non-Alcoholic	Avg Price/12 oz	Alcoholic	Avg Price/12 oz
Heineken Lager 0.0	$1.99	Heineken Lager	$1.29
Lagunitas IPNA	$2.49	Lagunitas IPA	$1.69
Coors Edge	$1.28	Coors	$1.25
Sam Adams just the haze	$2.49	Sam Adams	$1.79
Miller Sharps	$1.49	Miller Lite	$1.29
Budweiser zero	$1.59	Budweiser	$1.29
Busch NA	$1.08	Busch	$0.83

Anna

Non-Alcoholic Market

Non-Alcoholic	Avg Price/12 oz	Alcoholic	Avg Price/12 oz	Diff/12 oz	Percent Difference
Heineken Lager 0.0	$1.99	Heineken Lager	$1.29	$0.700	54.26%
Lagunitas IPNA	$2.49	Lagunitas IPA	$1.69	$0.800	47.34%
Coors Edge	$1.28	Coors	$1.25	$0.037	2.95%
Sam Adams just the haze	$2.49	Sam Adams	$1.79	$0.700	39.11%
Miller Sharps	$1.49	Miller Lite	$1.29	$0.200	15.50%
Budweiser zero	$1.59	Budweiser	$1.29	$0.300	23.26%
Busch NA	$1.08	Busch	$0.83	$0.250	30.06%

Anna

Non-Alcoholic Market

Non-Alcoholic	Avg Price/12 oz	Alcoholic	Avg Price/12 oz	Diff/12 oz	Percent Difference
Heineken Lager 0.0	$1.99	Heineken Lager	$1.29	$0.700	54.26%
Lagunitas IPNA	$2.49	Lagunitas IPA	$1.69	$0.800	47.34%
Coors Edge	$1.28	Coors	$1.25	$0.037	2.95%
Sam Adams just the haze	$2.49	Sam Adams	$1.79	$0.700	39.11%
Miller Sharps	$1.49	Miller Lite	$1.29	$0.200	15.50%
Budweiser zero	$1.59	Budweiser	$1.29	$0.300	23.26%
Busch NA	$1.08	Busch	$0.83	$0.250	30.06%

30.35%

Anna

6-Pack Analysis

6-Pack
$12.49

Anna

6-Pack Analysis

6-Pack
$12.49

30%

Anna

6-Pack Analysis

6-Pack
$12.49

30%

NA 6-Pack
$16.24

Anna

6-Pack Analysis

6-Pack
$12.49

30%

NA 6-Pack
$16.24

Anna

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Profit for Tröegs

Flat Fee of $3/gallon

Anna

Profit for Tröegs

*1000 gallons = 1778 6pks

Flat Fee of $3/gallon

1000 gallons of regular beer

1000 gallons of NA beer

Anna

Profit for Tröegs

*1000 gallons = 1778 6pks

Flat Fee of $3/gallon

1000 gallons of regular beer → 1778 6pks x $12.49 = $22,207

1000 gallons of NA beer → 1778 6pks x $16.24 = $28,875

Anna

MAGFO

Profit for Tröegs

*1000 gallons = 1778 6pks

Flat Fee of $3/gallon

1000 gallons of regular beer → 1778 6pks x $12.49 = $22,207

1000 gallons of NA beer → 1778 6pks x $16.24 = $28,875

$6668 - $3000 = $3668

Anna

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AES Financials

Cost of System:

Anna

Cost Estimate

Type	Item	Name	Material	Size	Unit	Quantity	Unit Price	Total Cost	Make/Model
Membranes (*1) (*2)	1	FO Spiral Element	Membrane	8040	in	10	$1,500.00	$15,000.00	Fluid Technology Solutions
Pressure Vessels (*3)	1	FO Element Housing	Fiberglass	20	bar	10	$650.00	$6,500.00	Firstline F80-300S-5W 4" Port
Pumps	3	FO Booster Pump @ 30 m head	Polypropylene	55	m^3/h	1.00	$18,000.00	$18,000.00	
Instrumentation	1	Conductivity transmitter	Corrosion Resistant	200	mS/cm	3.00	$548.34	$1,645.02	+GF Signet Conductivity 3-2850-52-42
	2	Flow transmitter	Corrosion Resistant	50	m^3/h	3.00	$917.95	$2,753.85	+GF Signet Magmeter 3-2551-TO-12
	3	Flow Indicator	Corrosion Resistant	5	m^3/h	4.00	$1,270.00	$5,080.00	GPI SS
	5	pH electrode	Corrosion Resistant	7	pH	4	$428.40	$1,713.60	+GF Signet pH Electrode 3-2724-00
	6	pH transmitter	Corrosion Resistant	7	pH	4	$466.20	$1,864.80	+GF Signet pH Transmitter 3-2750-2
	7	Level transmitter	Corrosion Resistant	3	m	4	$486.78	$1,947.12	+GF Signet Tank Level 3-2250-21U
	8	Pressure transmitter	Corrosion Resistant	7	bar	3.00	$74.40	$223.20	Dwyer Instruments 628-10-GH-P1-E1-S1
	9	Pressure transmitter	Corrosion Resistant	100	bar	4.00	$144.28	$577.12	Dwyer Instruments 626-19-GH-P1-E1-S1
	10	Pressure indicator	Corrosion Resistant	7	bar	3.00	$33.48	$100.44	Kodiak SS Gauge KC301L25E
	11	Pressure indicator	Corrosion Resistant	100	bar	4.00	$33.48	$133.92	Kodiak SS Gauge KC301L25P
	12	High pressure switch	Corrosion Resistant	90	bar	6.00	$312.81	$1,876.86	Omega Pressure Switch PSW-245D
	13	Low pressure switch	Corrosion Resistant	2	bar	6.00	$476.90	$2,861.40	Omega Pressure Switch PSW-226
	14	Temperature Transmitter	Corrosion Resistant	100	C	6.00	$228.00	$1,368.00	+GF Signet Temp 3-2350-3

Anna

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Cost Estimate

Type	Item	Name	Material	Size	Unit	Quantity	Unit Price	Total Cost	Make/Model
Tank	3	Tank	Polypropylene	2	m^3	2	$2,500.00	$5,000.00	JTI - 3 bulkheads
Valves	1	Ball valve	PVC	0.25	in	12	$6.69	$80.28	McMaster-Carr Compact 45975K63
	2	Ball+check valve	PVC	0.5	in	4	$10.93	$43.72	Deluxe SK-GS-005 + SK-TUBC-S-005
	3	Ball valve	PVC	0.75	in	12	$2.41	$28.92	Deluxe Compact Valve SK-GS-007
	4	Ball valve	PVC	1.5	in	4	$6.03	$24.12	Deluxe Compact Valve SK-GS-015
	5	Manual 3-way valve	PVC	1.5	in	4.00	$150.37	$601.48	Hayward 3-way Valve
	6	Check valve	PVC	1.5	in	4.00	$59.52	$238.08	Industrial Check Valve SK-CTUBC-S-015
	8	Air-operated valve	PVC	1.5	in	4.00	$432.00	$1,728.00	+GF Type 233 Pneumatic Valve 199233108
	9	Air-operated valve	PVC	2	in	4.00	$709.20	$2,836.80	+GF Type 233 Pneumatic Valve 199233110
	10	Air-operated 3-way valve	PVC	1.5	in	4.00	$700.00	$2,800.00	S&K Automation
Vent	3	FO Booster Pump @ 30 m head	Corrosion Resistant	7.5	kW (10 HP)	1.00	$1,500.00	$1,500.00	Teco Westinghouse - EQ7-4020-C
Controls and Electrical	1	Control Panels (Main HMI)	Corrosion Resistant	-	-	1	$21,500.00	$21,500.00	Superior Controls - prewiring
	3	Power Panels	Corrosion Resistant	-	-	1	$6,500.00	$6,500.00	Superior Controls - prewiring
	4	Wiring - labor	Corrosion Resistant	-	-	1.00	$15,500.00	$15,500.00	Electrical Contractor (Olssen)
	5	Wiring - materials	Corrosion Resistant	-	-	1.00	$4,500.00	$4,500.00	Platt Electric
	6	Engineering	Panel box layout	-	hr	80	$71.50	$5,720.00	Superior Controls Contractor / FTS
	7	Programming	Modify pilot program	-	hr	160	$71.50	$11,440.00	Fluid Technology Solutions

Anna

Cost Estimate

Type	Item	Name	Material	Size	Unit	Quantity	Unit Price	Total Cost	Make/Model
Misc.	1	System frame	Powder Coated Steel	-	-	1.00	$24,000.00	$24,000.00	Fluid Technology Solutions
	2	Piping Lot	PVC/CPVC	-	-	1.00	$7,500.00	$7,500.00	Fluid Technology Solutions
	4	CIP Cart	Various	-	-	1	$9,000.00	$9,000.00	Fluid Technology Solutions
Labor (*4)	1	Assembly	Lead Fabricator	-	hr	50	$61.60	$3,080.00	Fluid Technology Solutions
	2	Assembly	Floor Staff	-	hr	200	$38.50	$7,700.00	Fluid Technology Solutions
	3	Engineering	Project Management	-	hr	20	$71.50	$1,430.00	Fluid Technology Solutions
	4	Engineering	Junior Eng	-	hr	20	$71.50	$1,430.00	Fluid Technology Solutions
	5	Engineering Design	Senior Eng	-	hr	20	$154.00	$3,080.00	Fluid Technology Solutions

Total		$198,906.73
OH	31%	$61,661.09
Project	Total	$260,567.82

Anna

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Cost Estimate

Type	Item	Name	Material	Size	Unit	Quantity	Unit Price	Total Cost	Make/Model
Misc.	1	System frame	Powder Coated Steel	-	-	1.00	$24,000.00	$24,000.00	Fluid Technology Solutions
	2	Piping Lot	PVC/CPVC	-	-	1.00	$7,500.00	$7,500.00	Fluid Technology Solutions
	4	CIP Cart	Various	-	-	1	$9,000.00	$9,000.00	Fluid Technology Solutions
Labor (*4)	1	Assembly	Lead Fabricator	-	hr	50	$61.60	$3,080.00	Fluid Technology Solutions
	2	Assembly	Floor Staff	-	hr	200	$38.50	$7,700.00	Fluid Technology Solutions
	3	Engineering	Project Management	-	hr	20	$71.50	$1,430.00	Fluid Technology Solutions
	4	Engineering	Junior Eng	-	hr	20	$71.50	$1,430.00	Fluid Technology Solutions
	5	Engineering Design	Senior Eng	-	hr	20	$154.00	$3,080.00	Fluid Technology Solutions

Total		**$198,906.73**
OH	**31%**	**$61,661.09**
Project	**Total**	**$260,567.82**

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AES Financials

Cost of System: $260,567

Additional Business Costs:

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Skid and Running Costs

Skid	Cost
FO System	260567
Trailer	$10,000.00
Tow Truck	$25,000.00

Total	Cost
Fixed Cost	295567
Add: Assembly Buffer	$10,000.00
Total	$305,567.00

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Skid and Running Costs

Skid	Cost
FO System	260567
Trailer	$10,000.00
Tow Truck	$25,000.00

Total	Cost
Fixed Cost	295567
Add: Assembly Buffer	$10,000.00
Total	$305,567.00

Cost / Job	Cost	Notes
Trucking Cost / Mile	$3	incurred by client
Cleaning System	$50	Incurred by client
Setup Cost at Location	$200	incurred by client (~4hours)

Annual Costs	Cost	Notes
Net	25000	Maintenance, Insurance, Marketing

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AES Financials

Cost of System: $260,567

Additional Business Costs: $70,000

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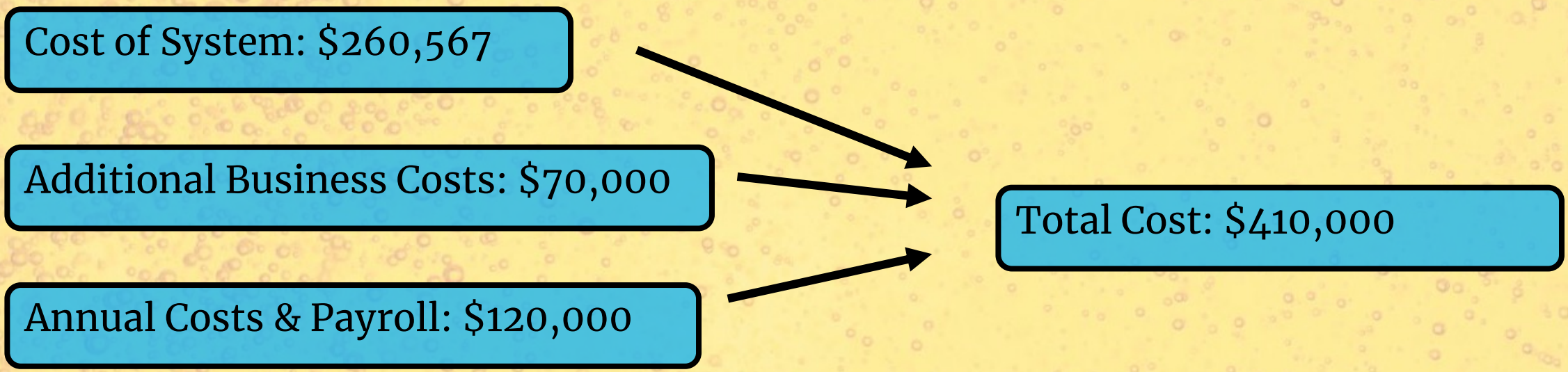
AES Financials



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Financing 7-Year Term

	Beginning Balance	Interest	Principal	Ending Balance
1	$410,000.00	$24,600.00	-$48,845.36	$361,154.64
2	$361,154.64	$21,669.28	-$51,776.08	$309,378.56
3	$309,378.56	$18,562.71	-$54,882.64	$254,495.92
4	$254,495.92	$15,269.76	-$58,175.60	$196,320.32
5	$196,320.32	$11,779.22	-$61,666.14	$134,654.18
6	$134,654.18	$8,079.25	-$65,366.11	$69,288.07
7	$69,288.07	$4,157.28	-$69,288.07	$0.00

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Break-Even Analysis

	+ Revenues	- (Loan Payment)	- (Wage Expense)	- (Annual Costs)	Net
Year 1		-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 2		-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 3		-$73,445.35	-$100,000.00	-$25,000.00	$0.00
Year 4		-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 5		-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 6		-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 7		-$73,445.35	-$100,000.00	-$25,000.00	$0.00
NPV					$0.00

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Break-Even Analysis

	+ Revenues	- (Loan Payment)	- (Wage Expense)	- (Annual Costs)	Net
Year 1	$198,445.36	-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 2	$198,445.36	-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 3	$198,445.35	-$73,445.35	-$100,000.00	-$25,000.00	$0.00
Year 4	$198,445.36	-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 5	$198,445.36	-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 6	$198,445.36	-$73,445.36	-$100,000.00	-$25,000.00	$0.00
Year 7	$198,445.35	-$73,445.35	-$100,000.00	-$25,000.00	$0.00
NPV					$0.00

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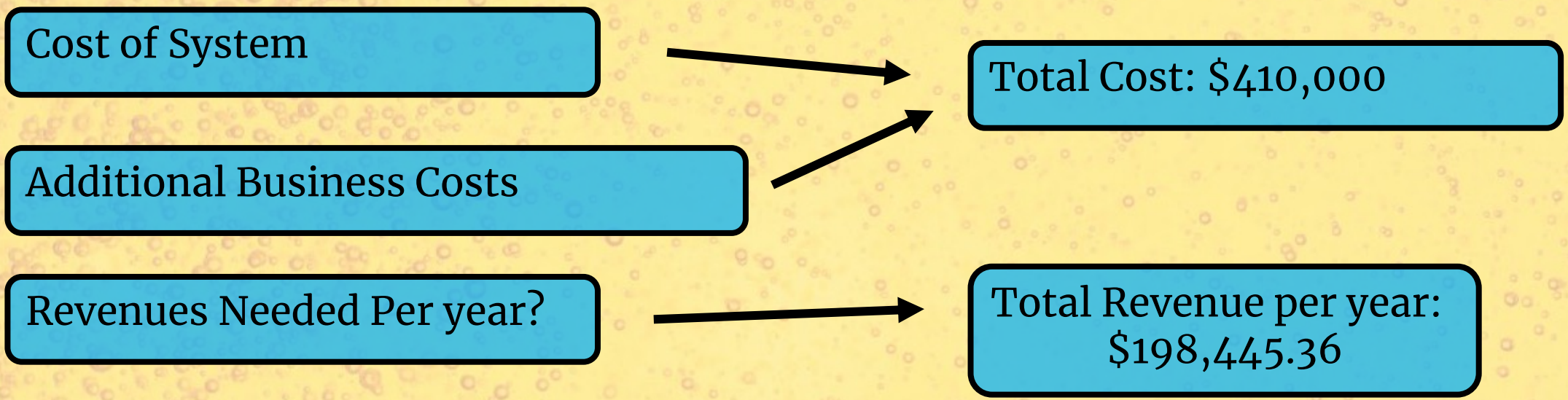
AES Financials



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AES Financials

Cost of System

Additional Business Costs

→ Total Cost: $410,000

Revenues Needed Per year? → Total Revenue per year: $198,445.36

Project Size Per Week? → 1300 gallons

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AES Financials

Cost of System

Additional Business Costs

→ Total Cost: $410,000

Revenues Needed Per year? → Total Revenue per year: $198,445.36

Project Size Per Week? → 1300 gallons

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Financials Summary

Profit for
NA > Traditional Beer

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Financials Summary

Profit for
NA > Traditional Beer

$3.00 Flat Fee

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Financials Summary

Profit for
NA > Traditional Beer

$3.00 Flat Fee

1300 Gallons/Week

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Recap

Untapped Service in the NA Beer Market

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Recap

Untapped Service in the NA Beer Market

$3.00 Flat Fee

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Recap

Untapped Service in the NA Beer Market

$3.00 Flat Fee

Turn-Key Service

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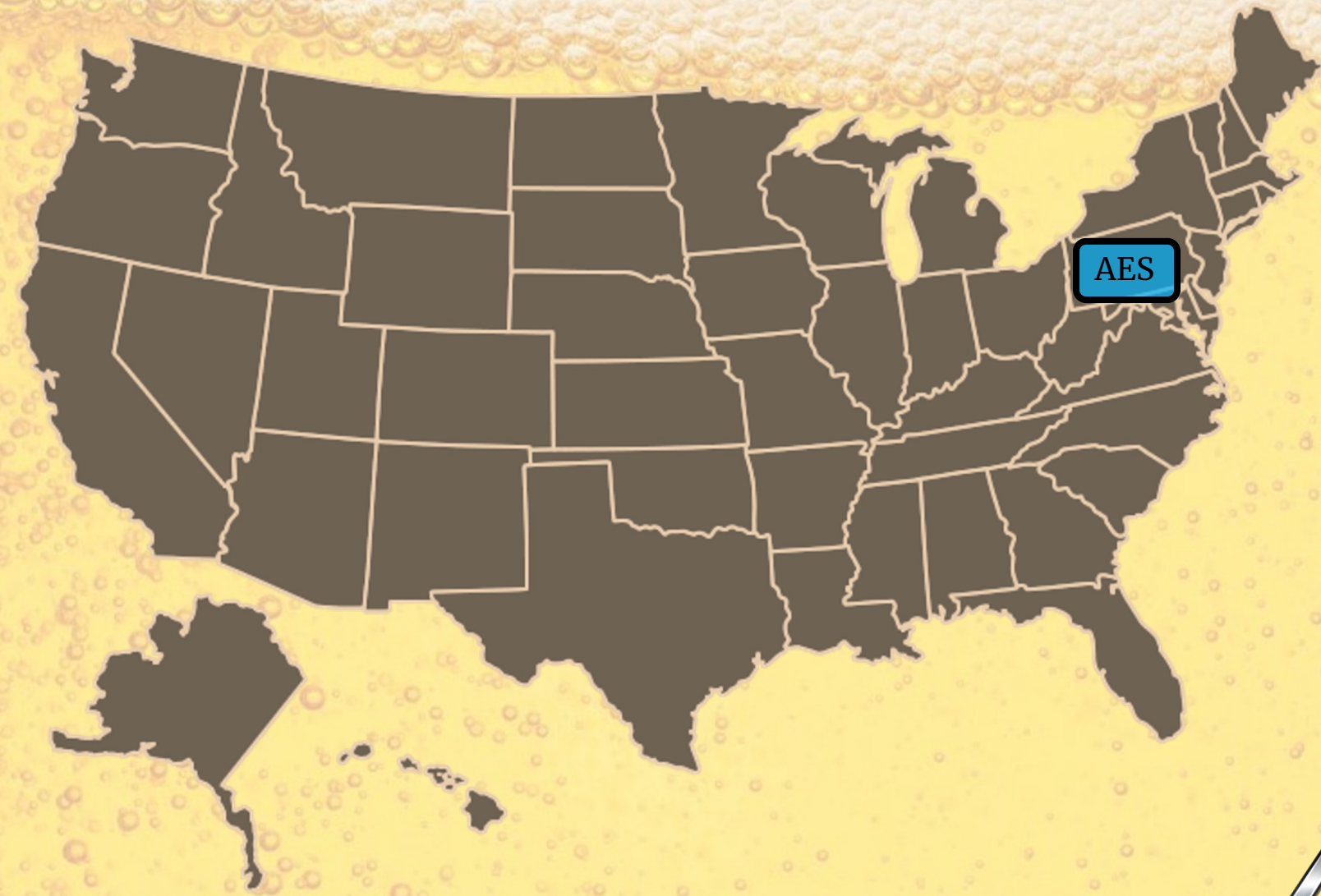
Next Steps

Top 5 States With Most Beer Production:



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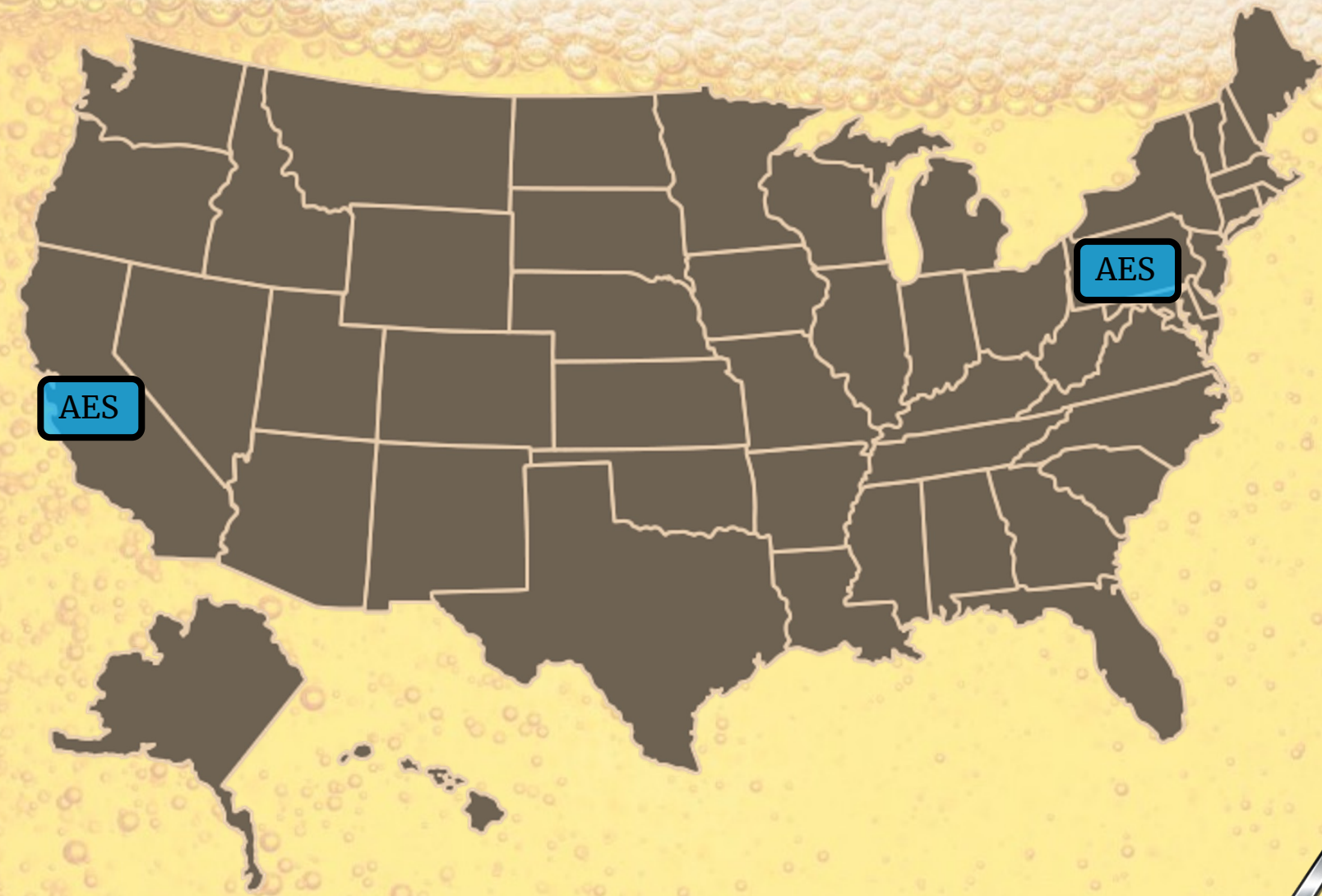
Next Steps

Top 5 States With Most Beer Production:

1. California



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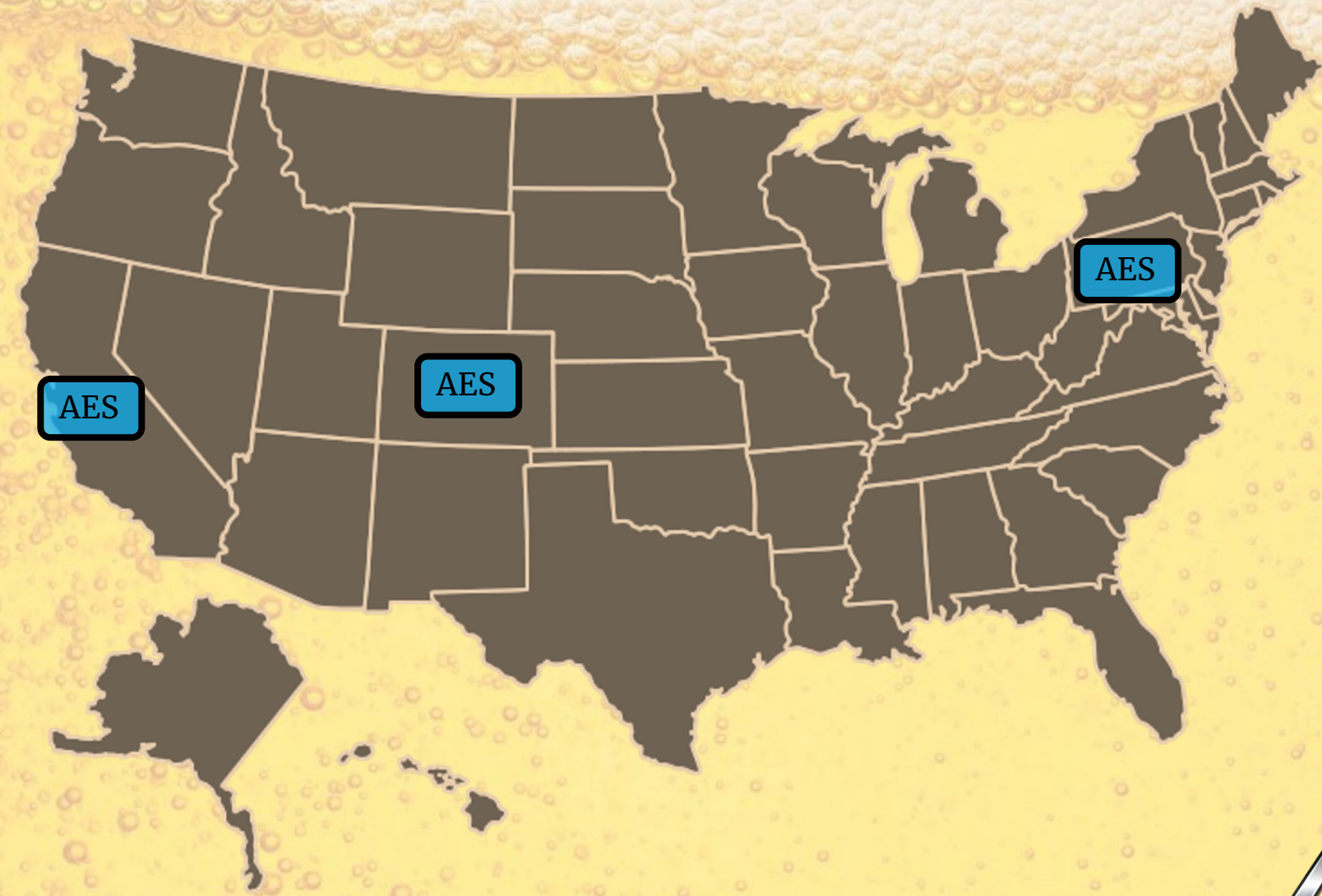
Next Steps

Top 5 States With Most Beer Production:

1. California
2. Colorado



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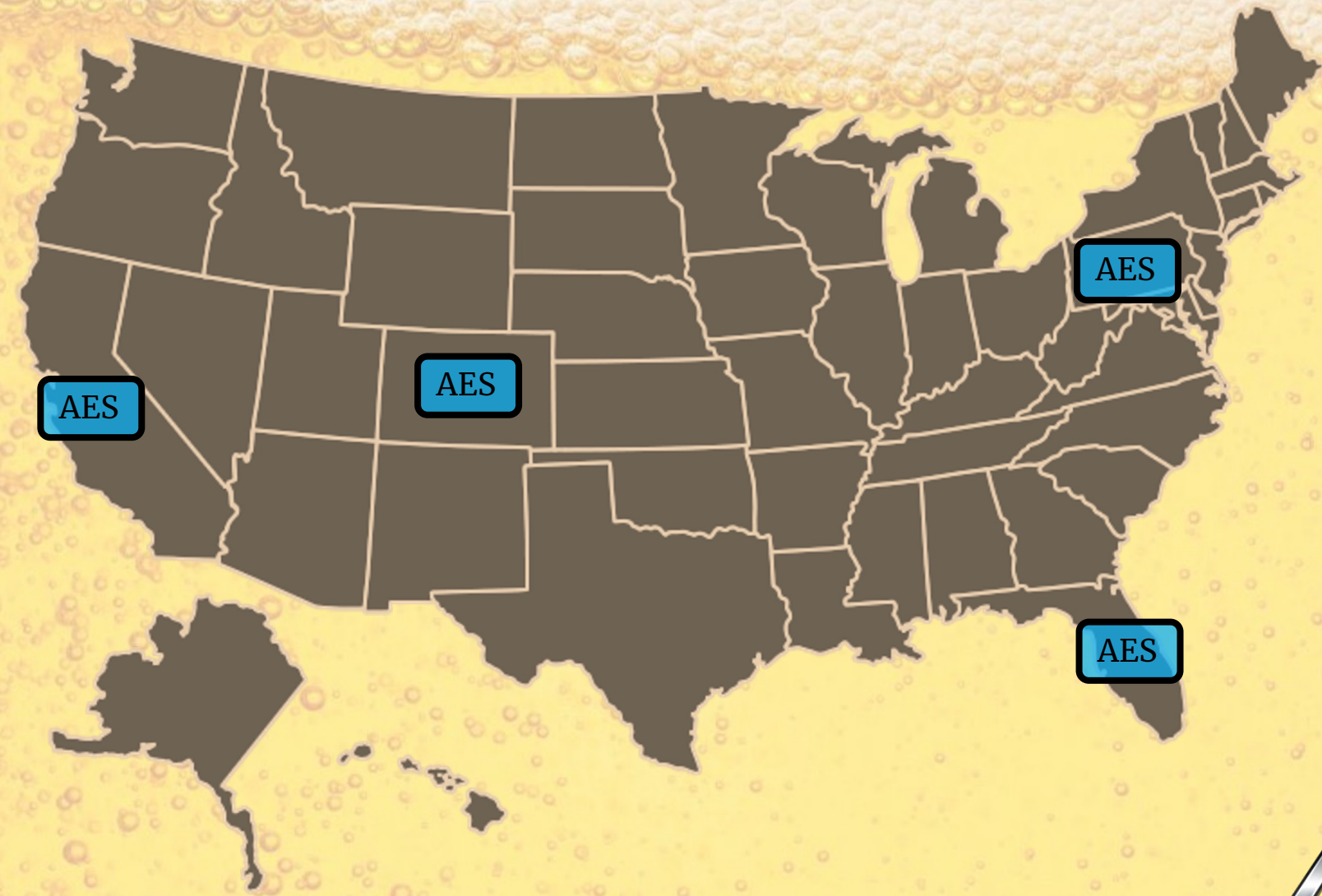
Next Steps

Top 5 States With Most Beer Production:

1. California
2. Colorado
3. Florida



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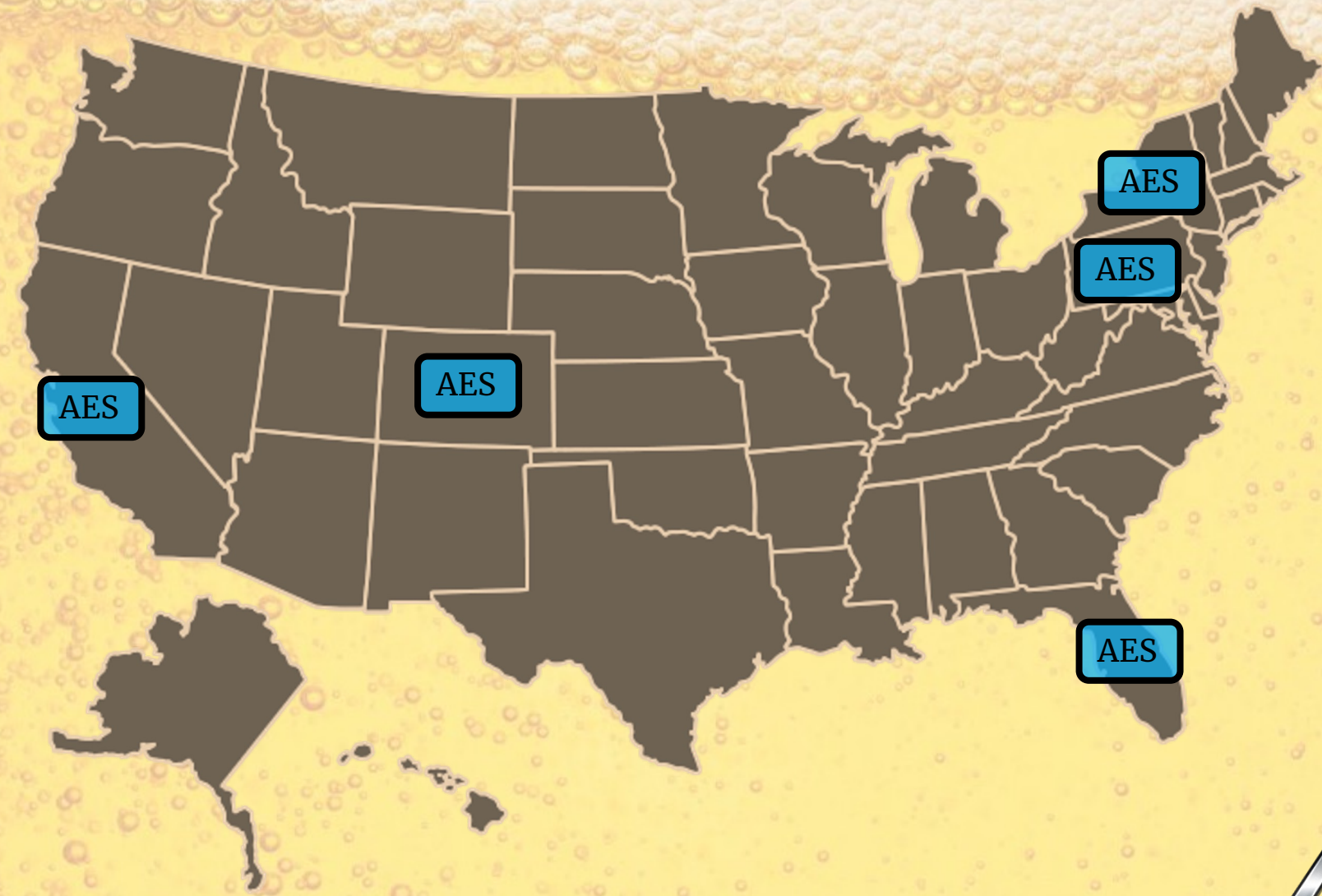
Next Steps

Top 5 States With Most Beer Production:

1. California
2. Colorado
3. Florida
4. New York



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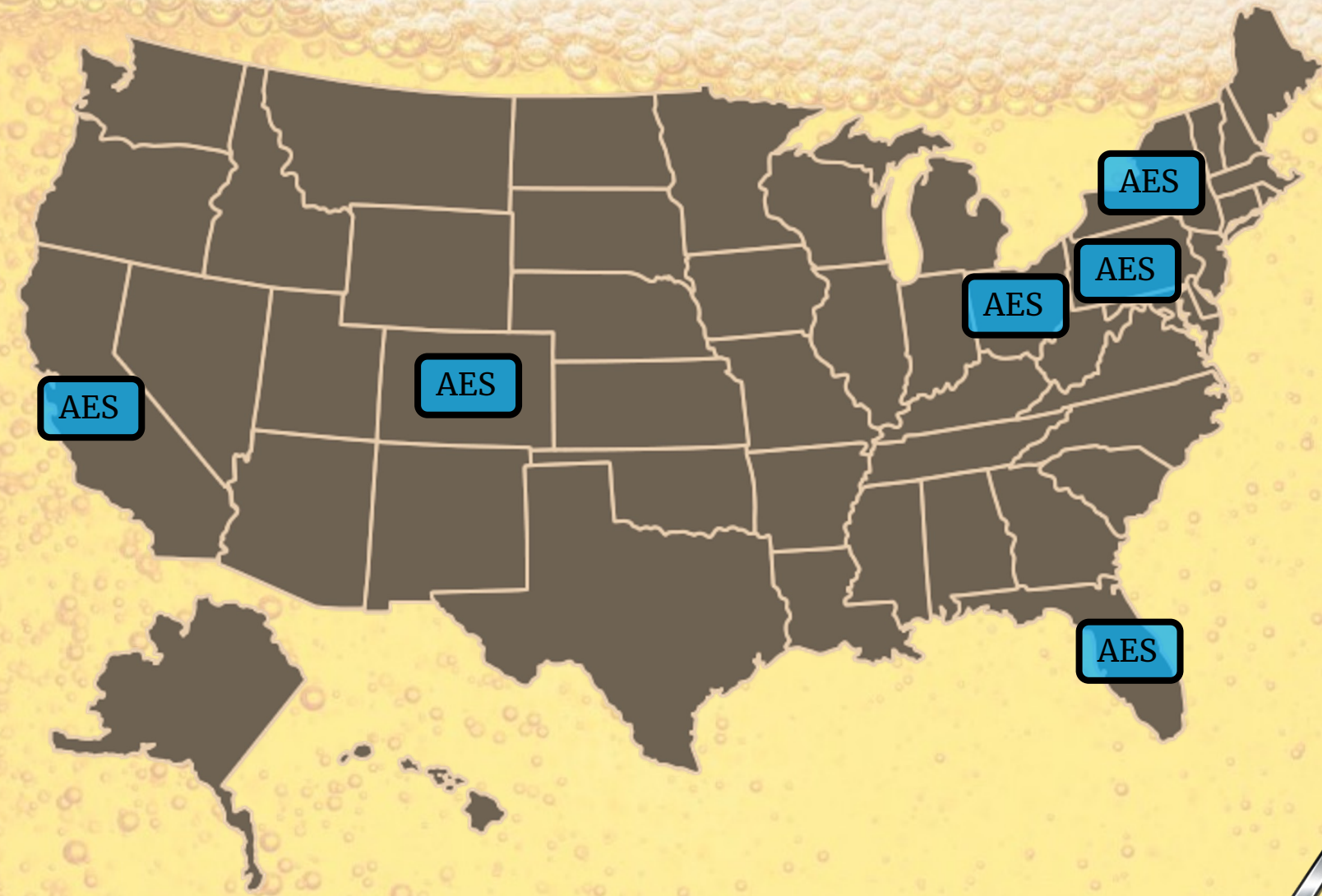
Next Steps

Top 5 States With Most Beer Production:

1. California
2. Colorado
3. Florida
4. New York
5. Ohio



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Acknowledgements

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- **Dr. Jennifer Klare** - Senior Director of Applications and Operations at Porifera
- **Rick Smith**- Director of Office of Technology Transfer Director
- **International Forward Osmosis Association**
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- **Bethlehem Landfill** (manager)
- **Marine Spill Response Corporation**
- **Valicor** (Leachate Treatment Facility)
- **Clear Creek** (Leachate Treatment Facility)
- **Lehigh County Authority Wastewater Treatment Plant** in Allentown
- **Russel Reid-**Plant Representative
- **Penn Argyl Landfill**
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- **Richard Weisman**-Water Resources Engineering at Lehigh
- **Aquaporin**
- **Alfa Laval**

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- **Seven Sirens Brewing Company**
- **F&A Grog House**
- **Sly Fox Brewing**
- **Brooklyn Brewing Company**
- **Sam Adams**
- **Tröegs Brewing**
  - Ben Bailey, QA Manager
  - Edward Yashinsky, VP of Operations
- **Fre Winery**
- **Ariel Winery**
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- **John Ioannou**, Process Manager at Alfa Laval
- **Shangy's Beer Distributor**
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- **Country Club Brewery**
- **Brewworks**
- **Flying Dog**
- **Athletic Brewing Company**
- **Super Beverage Warehouse**
- **Matt Cole**, Brewmaster at Fat Head's Brewery
- **Emma Hedrick**, Production Planning Manager at Victory Brewing Company
- **Scott Adams**, Co-owner at Funk Brewing

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Alex Romanowski
Market Reseach

Jack Lee
Industry Research

Ethan Hughes
Market Opportunity

Austin McCullough
Customer Needs

Grace Kuzwa
The Product

Janik Wing
Business Model

Marina Mendez
Marketing

Anna Harvey
Financials & Next Steps

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