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From Variable Inputs to Consistent Outputs: A DSP Playbook for Fermentation & Upcycling

Presented by

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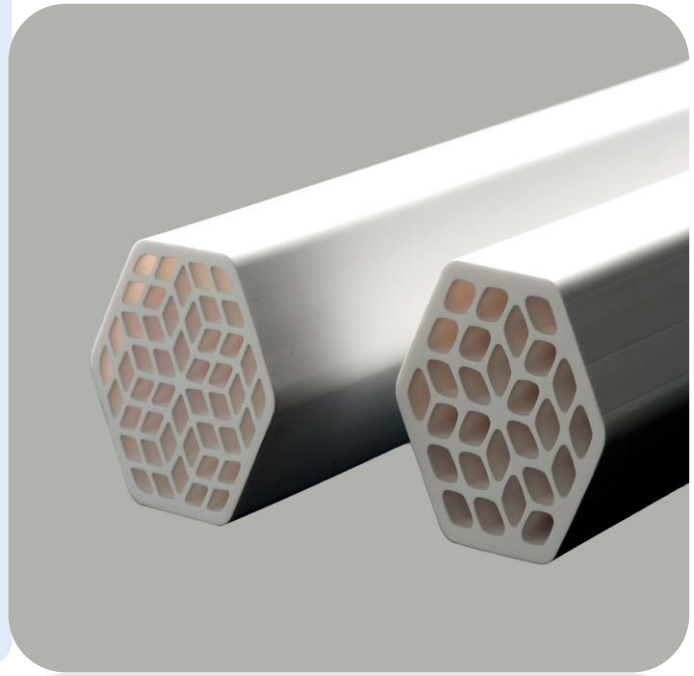
What you will walk out with

- Why fermentation and upcycling converge on the same DSP challenge
- Where scale actually fails
- Redefining circularity
- A decision framework to de-risk manufacturing early



PALL CORPORATION

About Pall

Pall is a **global leader in high-tech filtration, separation and purification,** serving the diverse needs of customers across a wide range of applications.

As a global provider of filtration and separation science that enables cutting edge technology we deliver:

- Deep customer application knowledge with **dedicated experts**
- World-class **engineering capability**
- Global reach, with **local support**
- **Innovative process solutions** to solve the most complex challenges across a range of industries from microelectronics, aerospace and food and beverage to petrochemical and power generation.

Markets Served

Microelectronics

Markets

Semiconductors
Electronic Components
Data Storage
Displays
Graphic Arts

Focus Areas

Wet, Etch & Clean
Lithography
Dry Processing
Chemical Filtration
Gas Purification & Filtration
Chemical Mechanical Polishing

Energy+

Markets

Chemicals
Oil & Gas
Polymers
Refineries
Nuclear/Fossil
Hydrogen
Carbon Capture
Biofuels
Energy Storage
Industrial Water
Mining
Auto/In-plant
Primary Metals
Pulp & Paper
OEMs (Mining, In-plant Turbines)

Focus Areas

Fluid and Gas Filtration
Separations/ Coalescers
Lube & Hydraulics
Mobile & In-plant OEMs
Gasification
Industrial Water
Rentals and Service

Aerospace

Markets

Aircraft
Helicopters
Gas Turbine Engines
Marine
Space

Focus Areas

Air
Coolants
Fuel
Hydraulic
Lubrication
Water
Electric-Hybrid & Hydrogen powered engines

Food & Beverage

Markets

Beer
Wine & Spirits
Cider
Food Ingredients
Dairy
Non-Alcoholic Drinks

Emerging Focus Areas

Alternative Proteins

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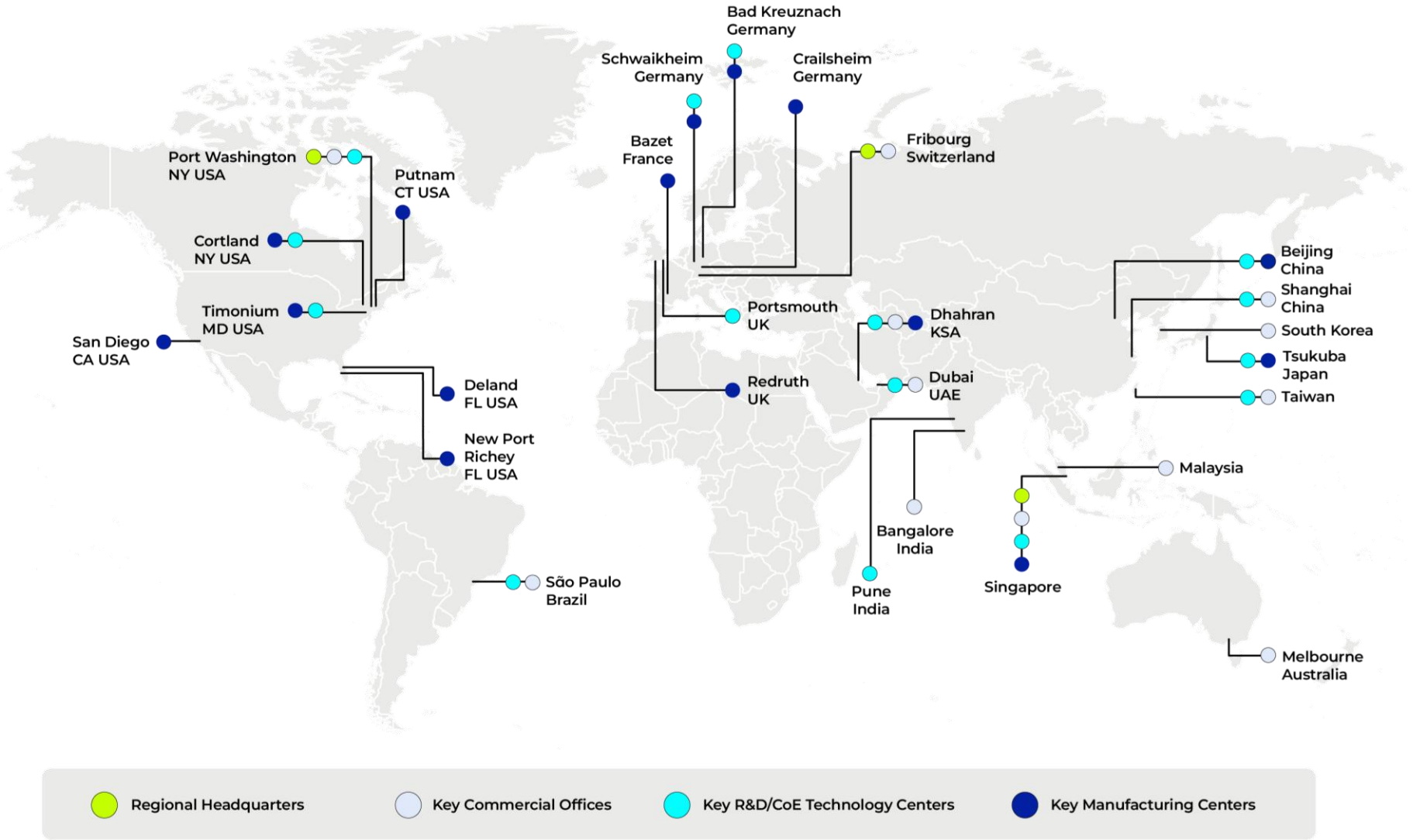
Global Footprint



Pall Food & Beverage Applications

Traditional Markets

- **Alcoholic Drinks** Wine, Beer, Cider, Beer, Spirits
- **Alcohol-Free Beverages** Bottled Water, Soft Drinks, Cold Brew Coffee, Juices, Tea, Functional Beverages
- **Utilities**

Food & Dairy Markets

Milk fractionation

Enzymes

Yeast extracts

Amino acids

Sweeteners / Sugars

Flavors

Distillers dried grains with solubles from thin stillage

Emerging Markets

Alternative proteins

Upcycling

Plant based

Fermentation

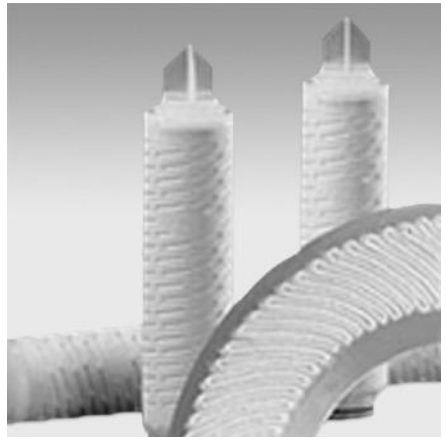
Cellular agriculture

Food & Beverage
Products

To support a global focus on food safety and stricter regulations, Pall has qualified a specific range of food contact compliant Pall Solutions to cover a broad range of applications from coarse clarification to sterilizing filtration with documentation readily available on our website.

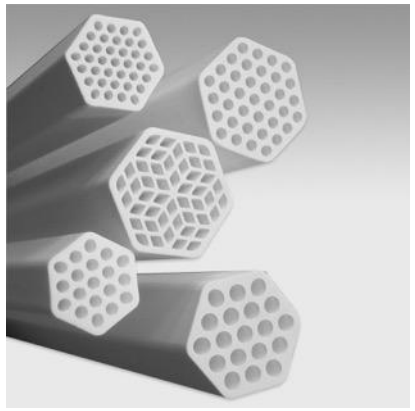
SUPRApak™ Modules are a cost-effective alternative to flat sheet filtration for distilled spirits, beer & food ingredients.

Ultipleat® High Flow Elements with laid over pleat design allow particle removal in high flow rate applications.



Fuente II filter cartridges are high area final filters developed for bottled water to give longer life and lower filtration costs.

The Palltronic Compact Touch is an automated pressure decay integrity test device. to confirm that filters are working as expected.



Membralox® Ceramic Modules for treatment of large volumes with high throughput for dairy products, sweeteners, food ingredients & beverages.

Profile® Star cartridges have a star pleat construction of melt blown media delivering the benefits of both traditional pleated and depth style filters.

Food & Beverage
Systems

As customers increase their production volumes, they often look towards more automated solutions to improve product quality, efficiency, consistency and yield.

Pall systems for clarification, stabilization and microorganism removal allow food and beverage producers to optimize their processes at the lowest total cost of ownership.

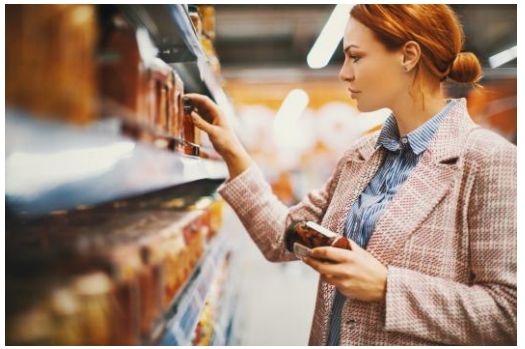
Membralox systems utilize ceramic membranes for high-solids applications across food and beverages

Pall's CFS NEO is a membrane filter system for the final filtration of beer directly upstream the filling line

Pall's **PROFi membrane systems** are modern and sustainable, DE-free filtration systems for beer clarification that minimize operational costs, waste, water usage and energy consumption

Oenoflow™ PRO system takes wine clarification digital. In addition to providing predictive analytics and remote operation, our 1st IoT enabled system is equipped with our proprietary algorithms based on years of operating experience to maximize run time and cost

B2F Reality Check



What Consumers Feel, DSP Controls!

Taste consistency: variable DSP creates off-flavors and batch-to-batch drift that kills repurchase

Texture & mouthfeel: over-processing strips body; under-processing leaves grit

Color & appearance: turbidity and browning signal “unnatural” in an already skeptical market

Clean label: Some processes enable “minimally processed” claims while others don’t

Purchase is driven by curiosity and marketing;

Repurchase is driven by manufacturing consistency.

Two Different Upstream Worlds: One Common Goal

Upcycling

- Variable & heterogenous side stream

  E.g.: beer spent grain, spent yeast, starch side streams, fish stick water

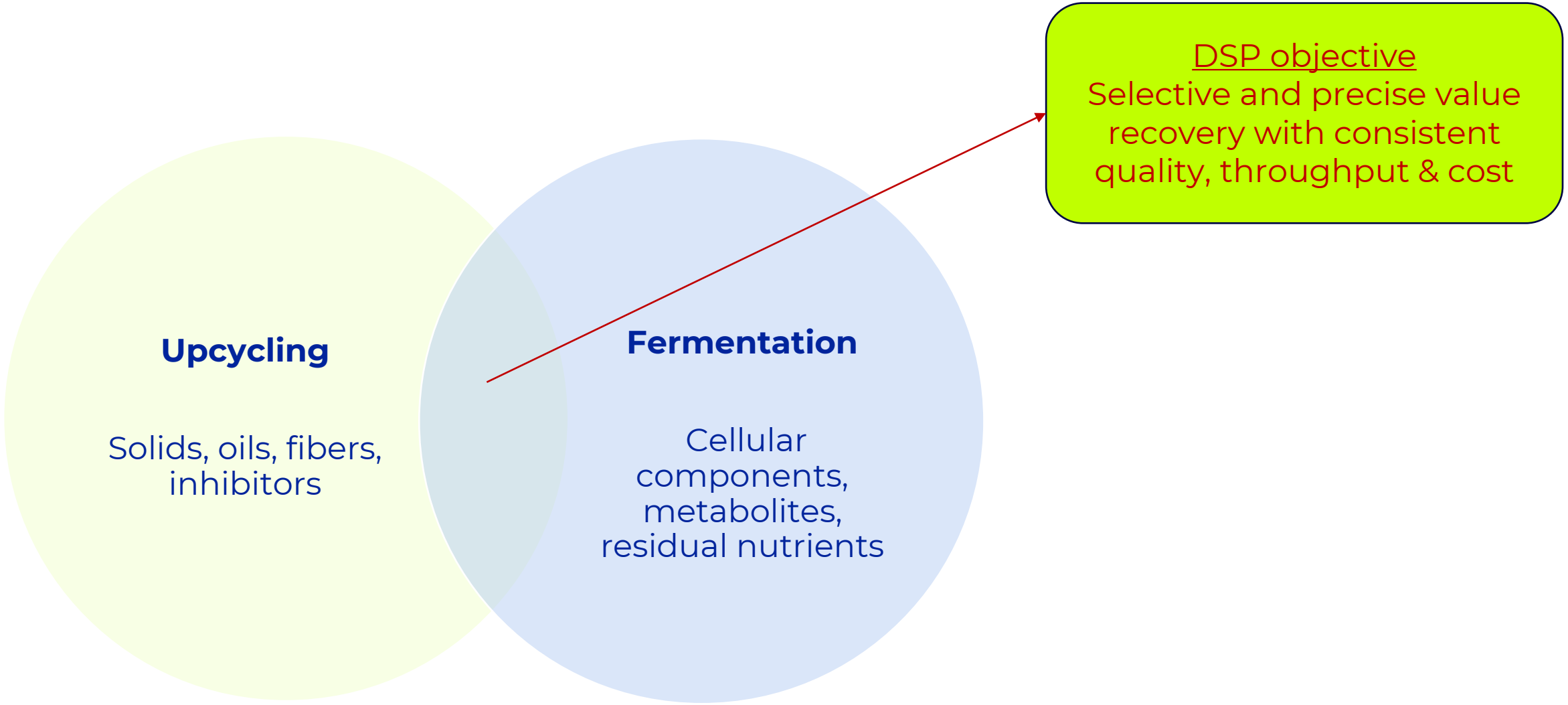
Fermentation

- Variable biology

  E.g.: host microbe (bacteria vs. yeast vs. fungi), intracellular Vs. extracellular, monomer Vs. complex polymer

Shared goal: Selectively separating value from complexity!

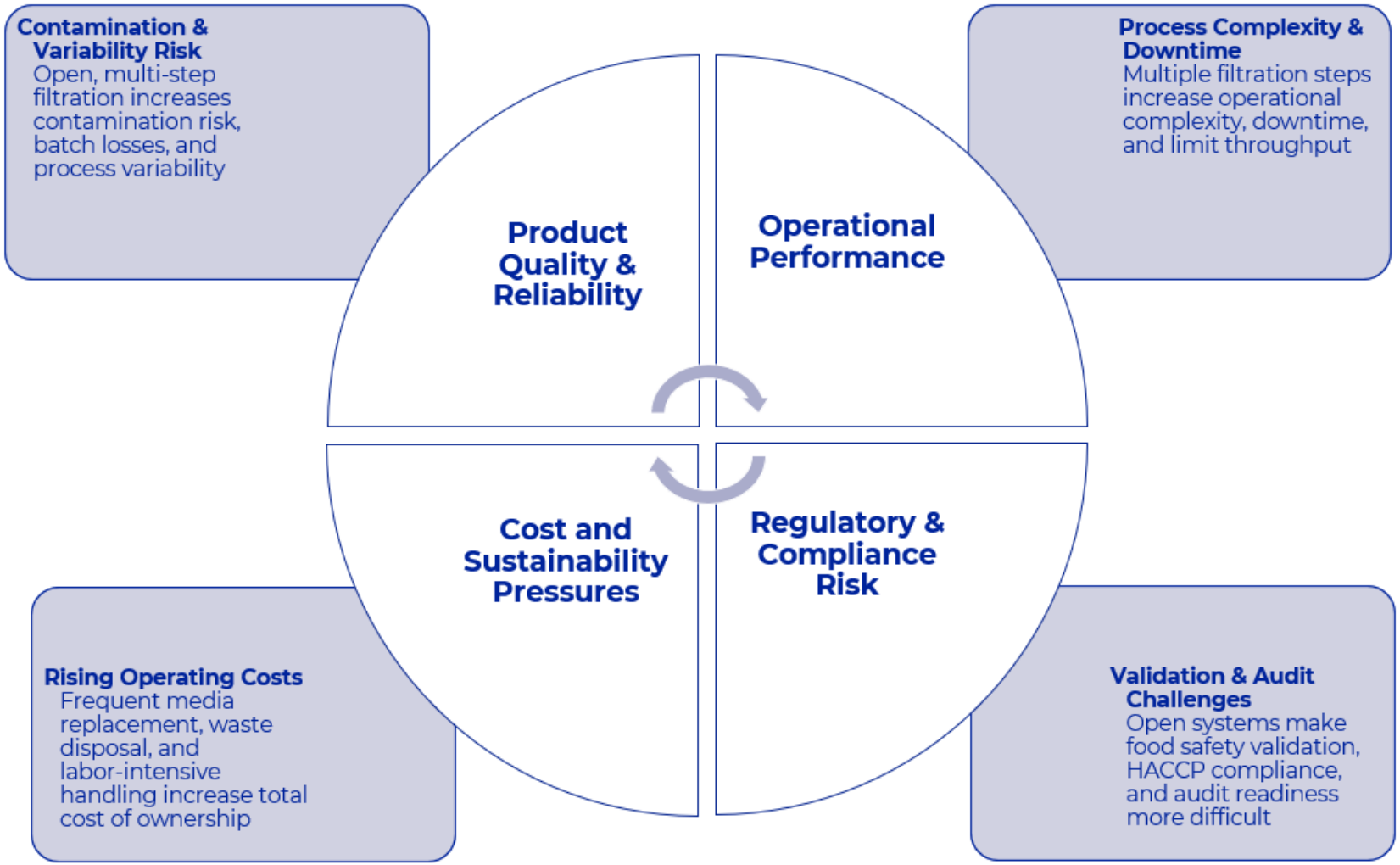
Same DSP Logic. Different Root Causes.



Why Scale Fails

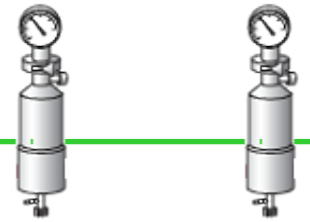
Downstream instability often arises when fine solids bypass clarification; often invisible at lab scale

Common Pain Points



Utilities are Often Overlooked

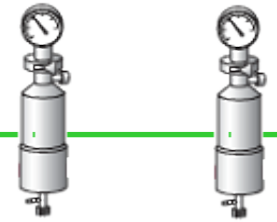
Air, liquid & steam



Prefilter

Sterilizing Grade Filter

Exhaust



Prefilter

Sterilizing Grade Air Filter

Media/Nutrients

Additives
Vitamins
Anti Foam
pH Regulator

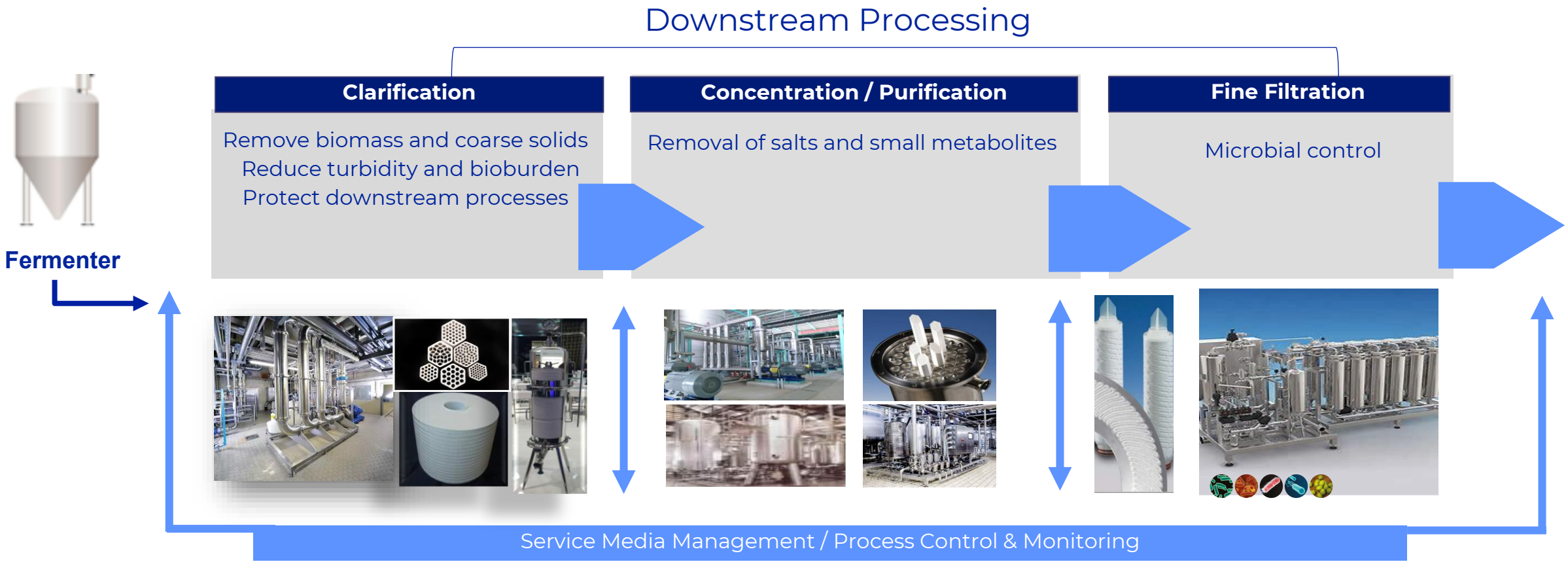
Particle Removal

Sterilizing Grade Filtration

Fermenter

Air Sparging

Downstream Processing Enabled by Filtration



Clarification Isn’t a Step- It’s the Strategy!

- Manage solids early
- Control emulsified oils, fibers, microbial load
- Protect yield without thermal or chemical over processing
- **Crossflow clarification** enables stable operation under high solids load and process variability

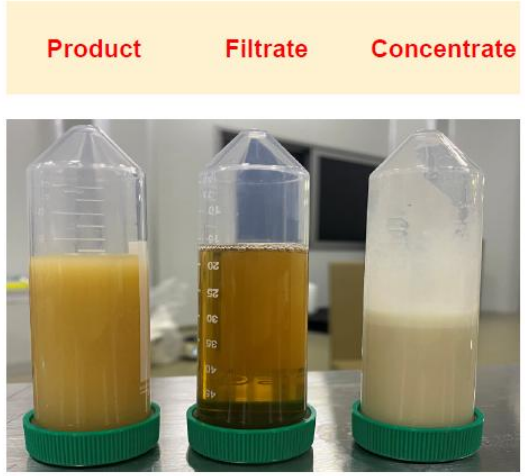
Microfiltration- Crossflow Filtration

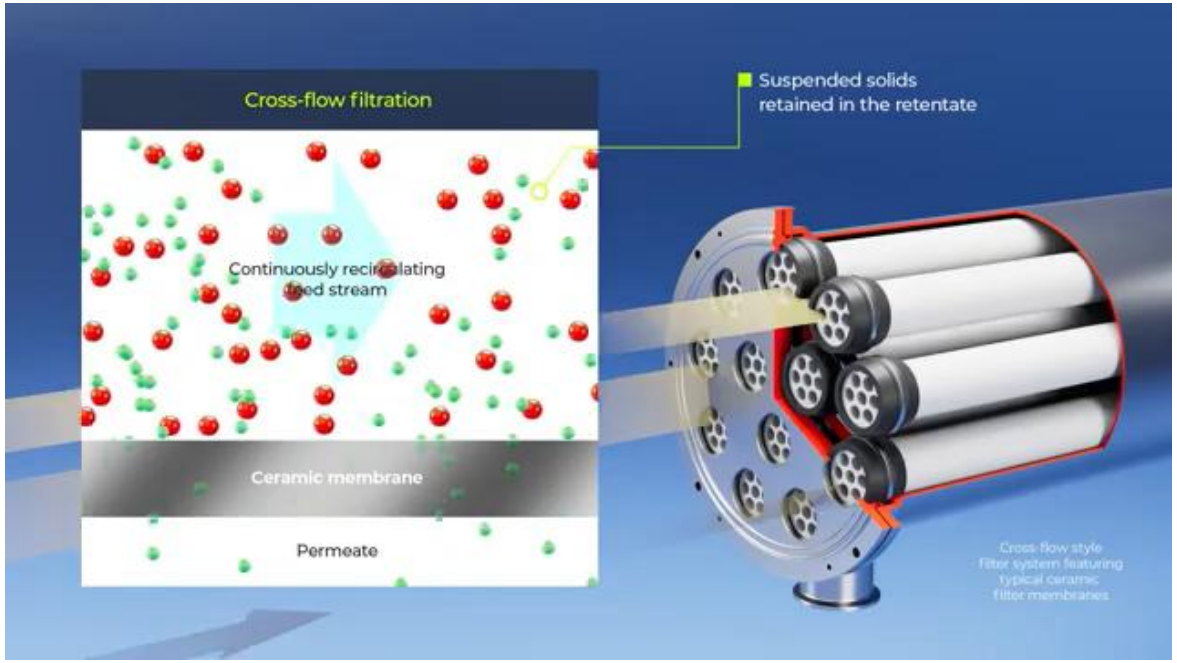
Critical for microfiltration applications:

- Clarification
- Retains suspended solids
- Reduce Bioburden
- Transfers dissolved solids

Most influential processing parameters:

- Crossflow **velocity**
- Transmembrane pressure (**TMP**)

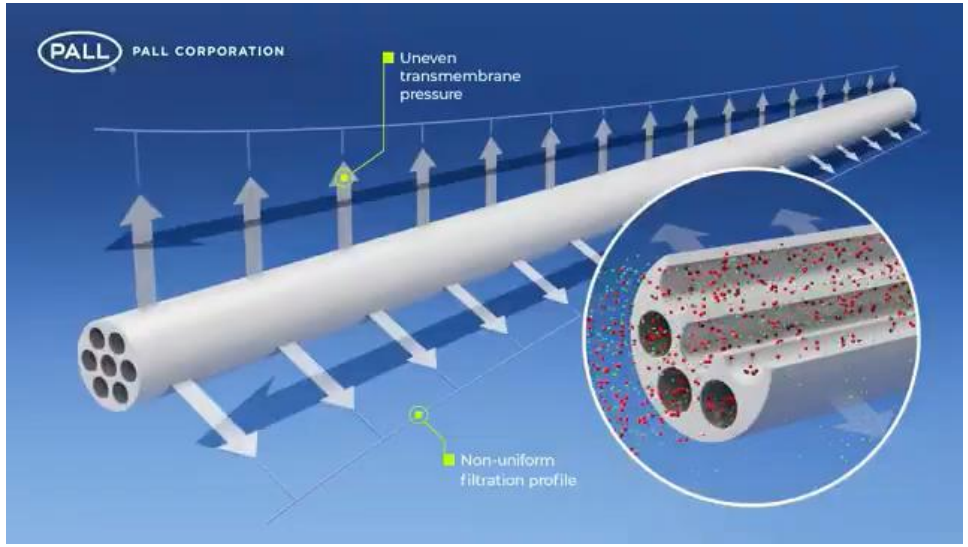


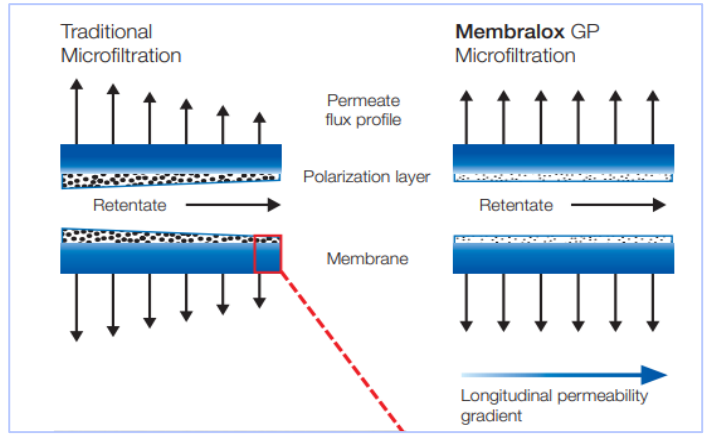


Crossflow Filtration

Transmission and Flux Dictate Yield

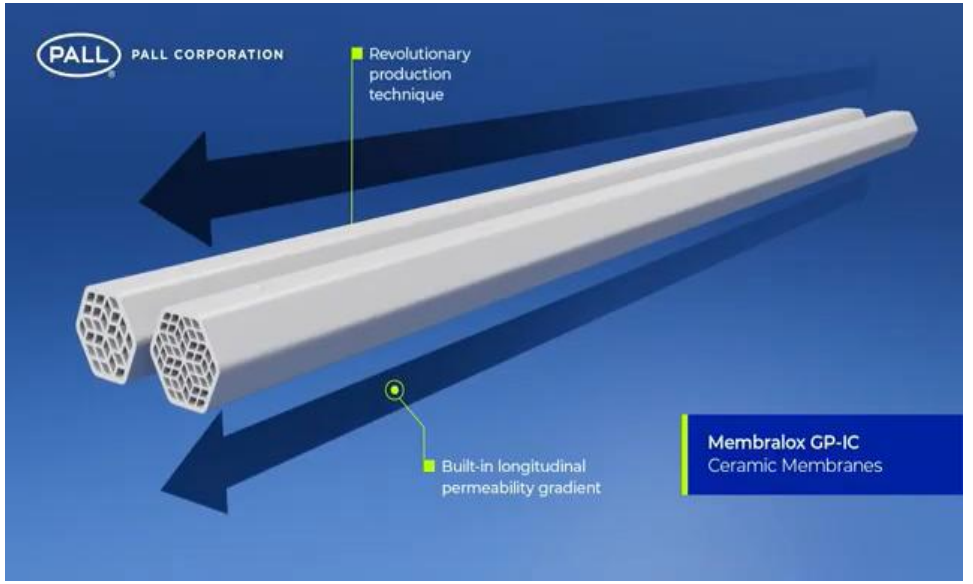
Transmission and flux challenges





Membralox GP ceramic membranes with longitudinal permeability gradients allow an efficient control of microfiltration regime for higher performance

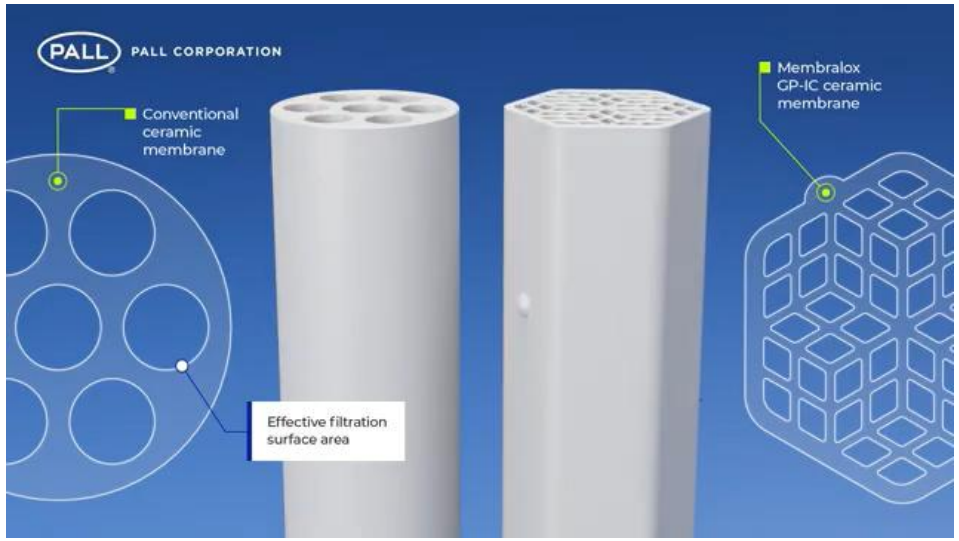
- Precisely calibrated flux
- Controlled selectivity all along the membrane
- Hydrodynamically optimized



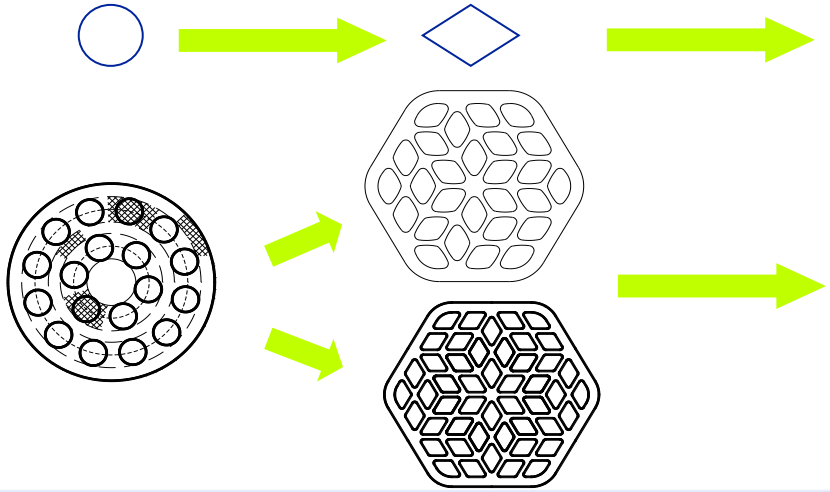
Gradient Permeability (GP)

Footprint Matters

- Diamond shape **c**hannels arrangement in **i**ntermingled rings
- Resulting in **~ 45% higher membrane surface area**



Concentric rings **IC design**



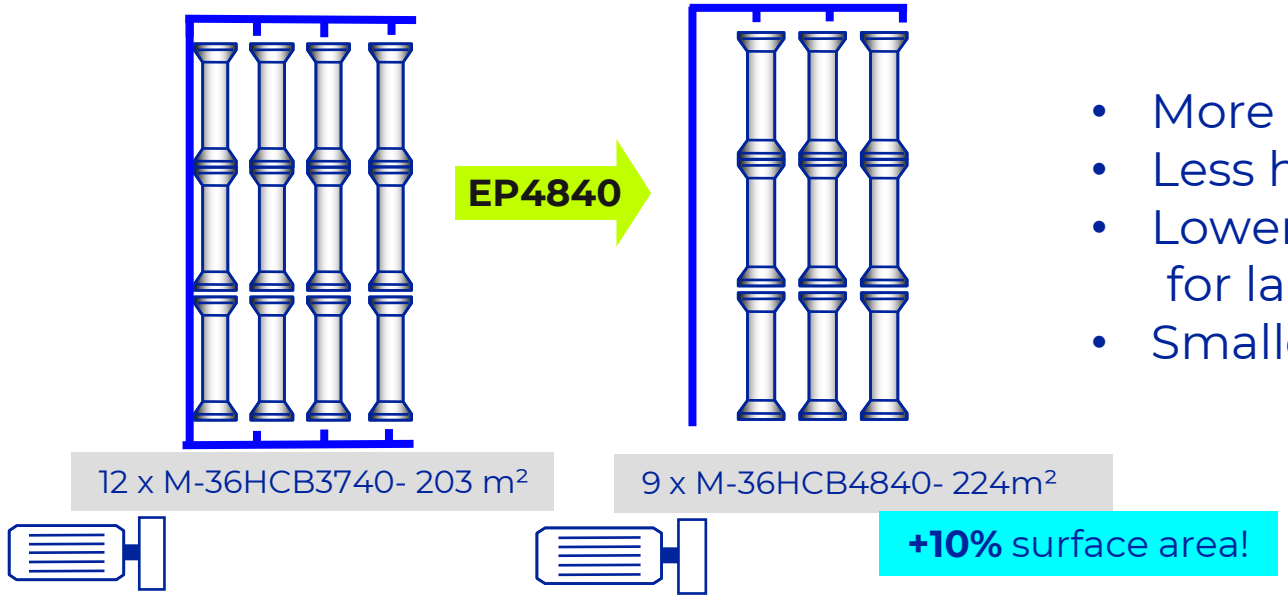
Perimeter increase = surface area increase with same cross section

More channels packed in the same element

Impact of the GP-IC on System Design

GP-IC: Combination of two proven technologies!

More membrane area into fewer housings compared to traditional round shaped ceramics



- More compact systems
- Less hardware
- Lower number of loops for large plants
- Smaller footprint

Capex savings on modules
Energy cost savings*
Chemical + water savings

* Assuming same crossflow pump and permeate throughput per loop

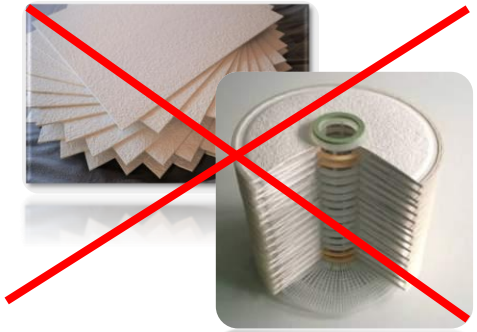
Process Improvement Scenarios

Processes with filter presses

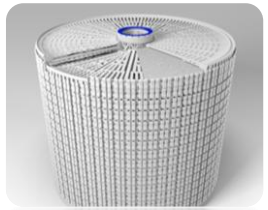
SUPRApak Modules

SUPRAdisc II Modules

Depth filter sheets or classic lenticulars



SUPRApak Modules



SUPRAdisc II Modules

Powdered Activated Carbon (PAC)

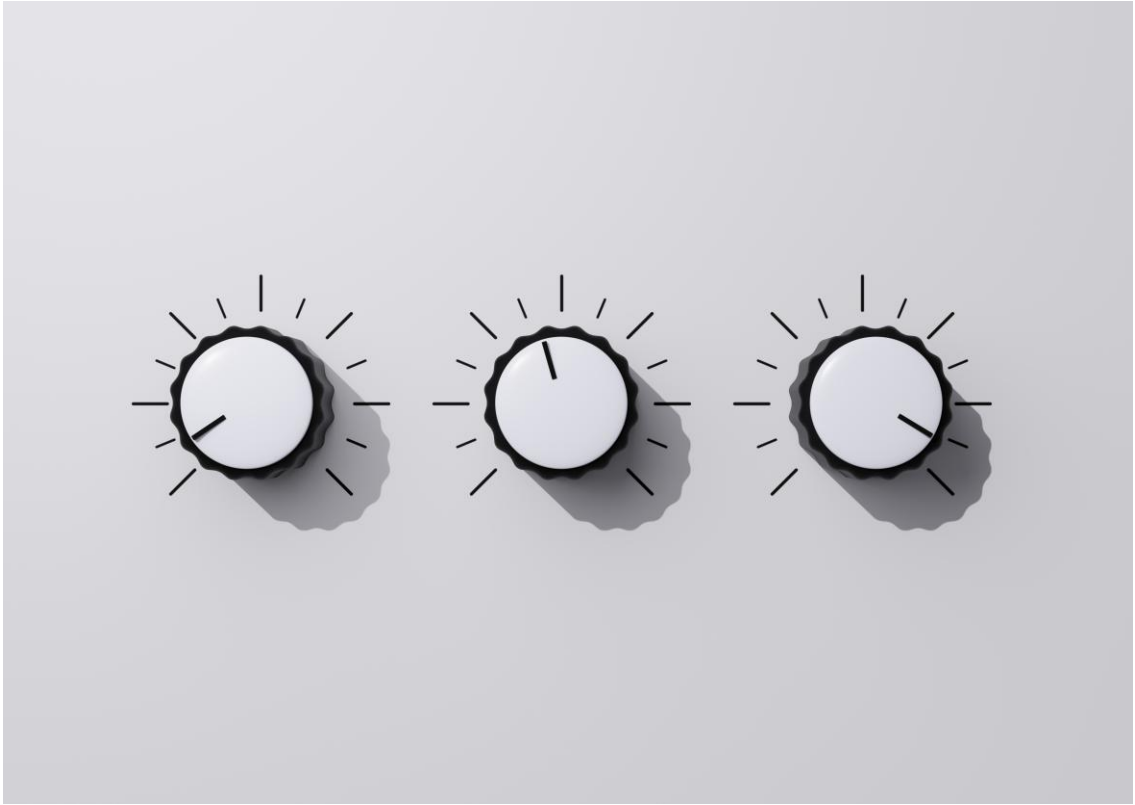
SUPRAdisc AKS FB Modules

Diatomaceous Earth (DE) or Perlite with Centrifuge

Membralox Crossflow Systems

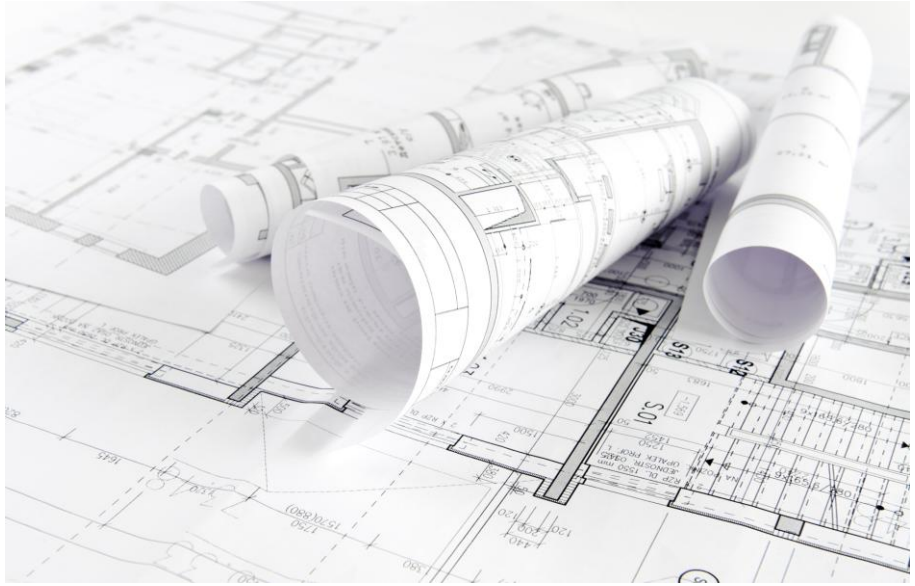
A Decision Framework to Find the *True* Bottleneck

- Define what value must be recovered
- Characterize real variability
- Select fit-for-purpose unit operations & windows
- De-risk scale up: yield, consistency and throughput



DSP Isn’t a CapEx Add-on, It Sets the Ceiling

- Design for variability from day one
- Clarification choices define scalability, cost and quality
- Use a decision framework to de-risk manufacturing early



Circularity Reframed

- Circularity fails without separation discipline
- Circularity depends on efficient recovery and reuse
- Over-processing destroys functionality and economics
- DSP choices directly affect water, energy and consumables

Takeaways

- Scale-up failures often come from downstream constraints, not upstream innovation
- DSP and filtration are not add-ons: they determine scalability, cost, and ingredient quality across both platforms
- Circularity is not only about inputs- it’s about how efficiently value is separated, recovered, and reused

Thank You

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