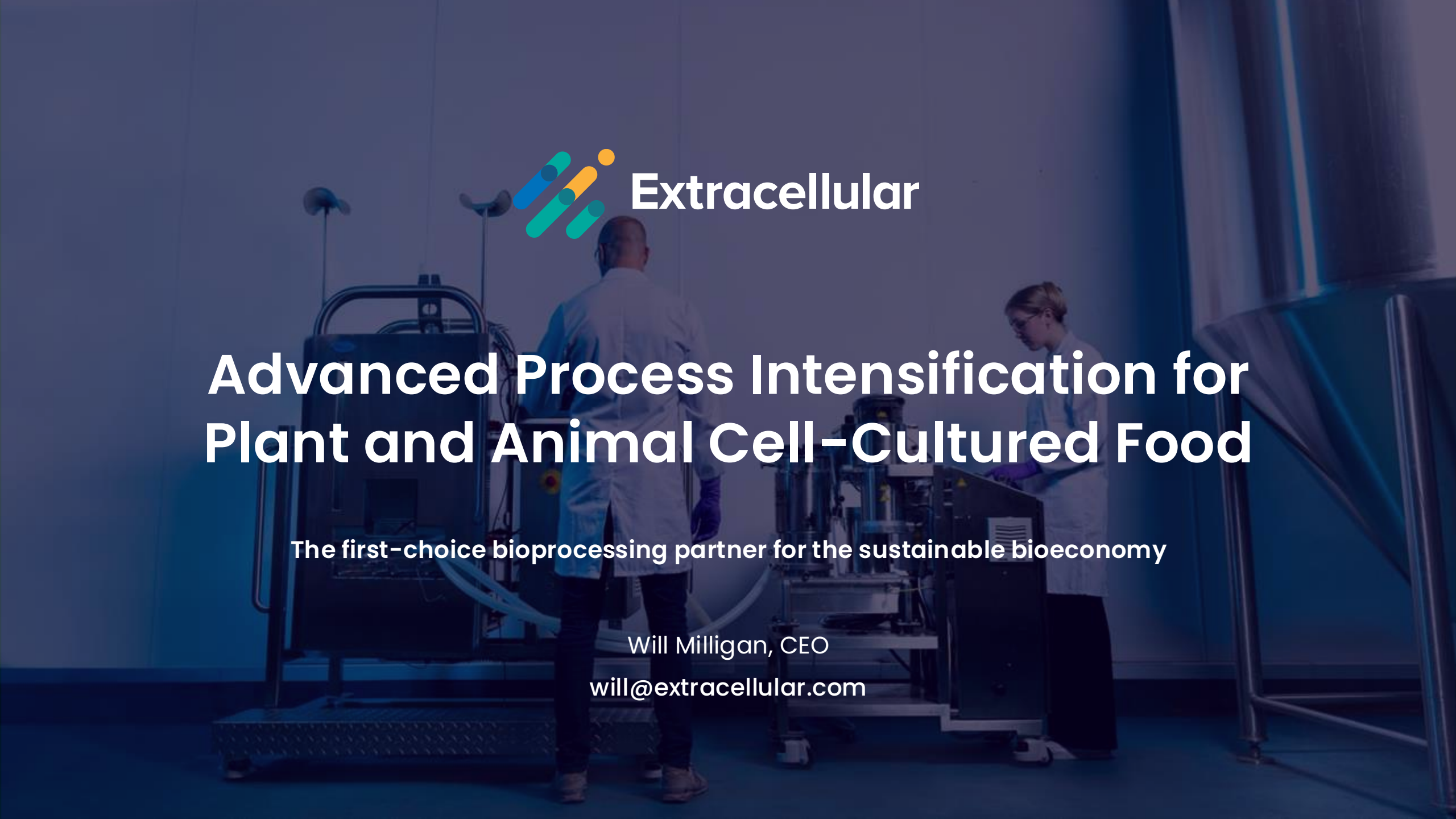


Extracellular

Advanced Process Intensification for Plant and Animal Cell-Cultured Food

The first-choice bioprocessing partner for the sustainable bioeconomy

Will Milligan, CEO

will@extracellular.com

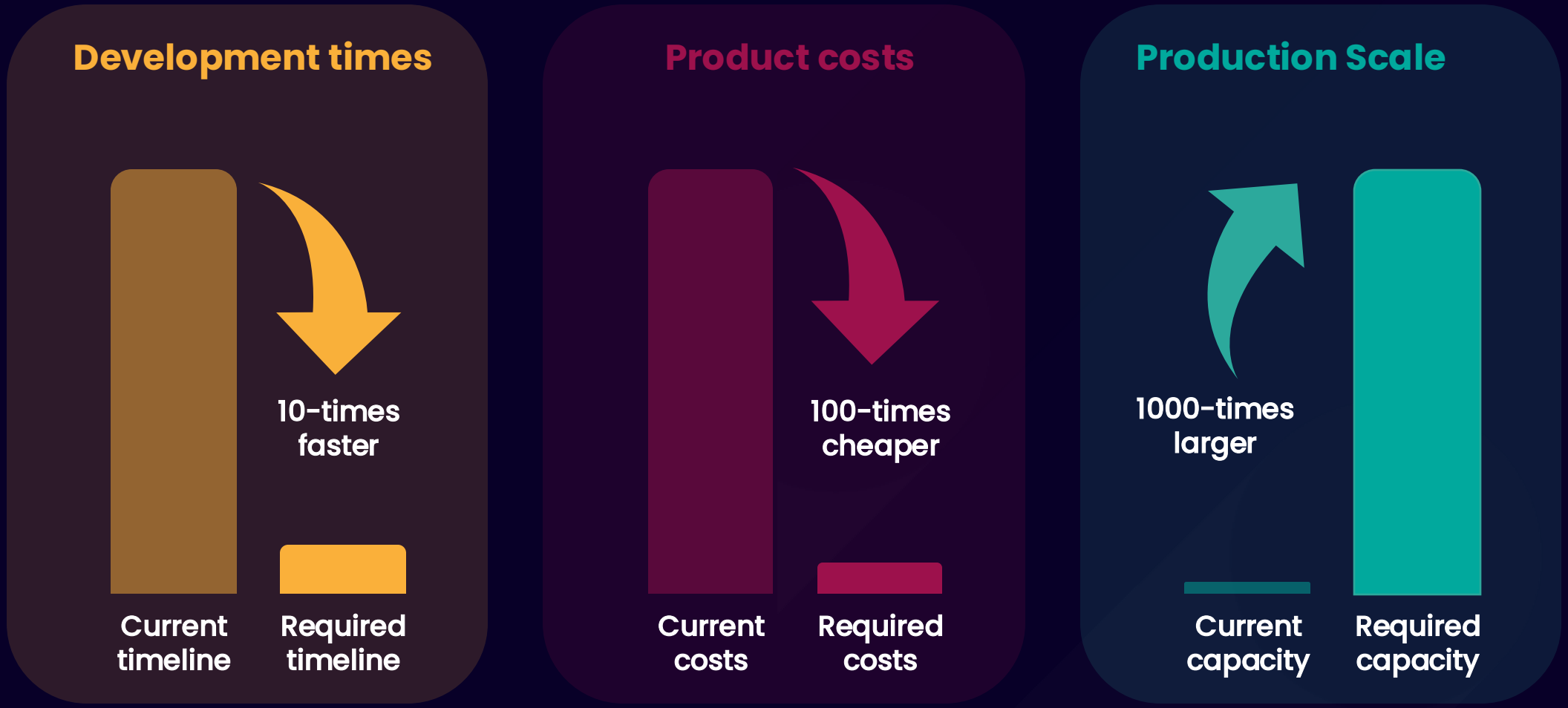

Cultivated
Meat & Seafood


Cultivated
Plant Ingredients

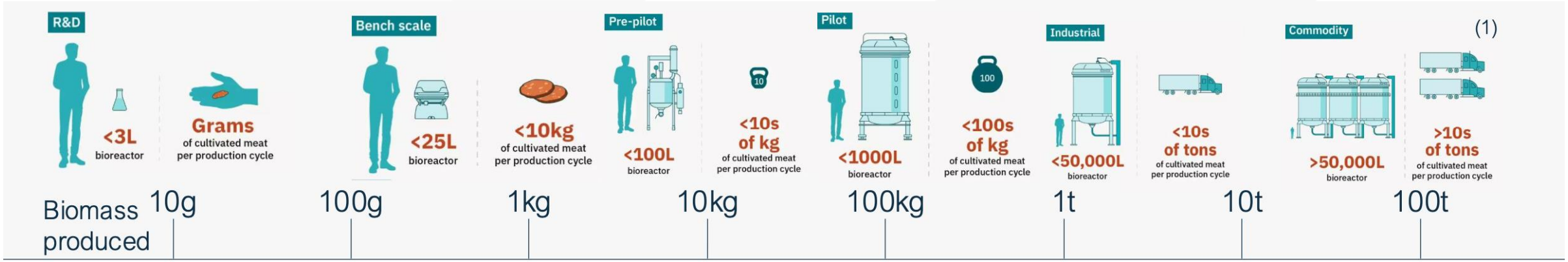

Cell-Derived
Food Ingredients


Personal Care
Ingredients

The Problem –sustainable cell-culture ingredients face immense commercialisation challenges



The Scaling Requirements for Cell-Based Products



R&D labs	Pilot Scale Facility	Pre-commercial	Commercial

Development Strategy → Process Development → Commercial Manufacturing

Source: GFI

Developing A Robust Commercialisation Strategy

Key considerations when starting to develop a commercialization strategy:

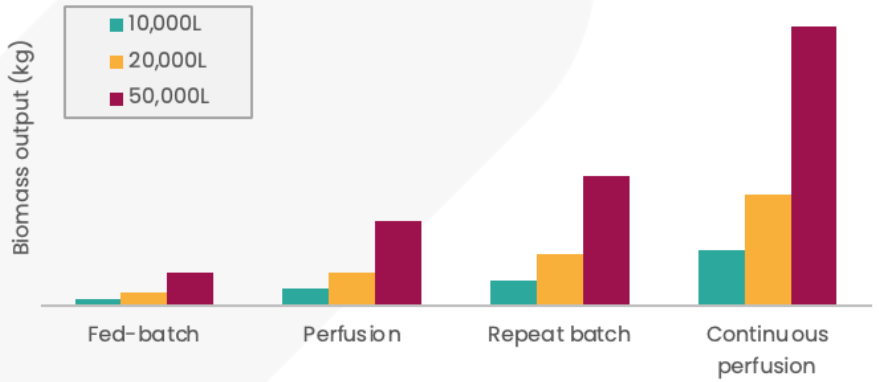
How much product is needed, at **what price point**, and **when**.

- Commercial goals
- Manufacturing options
- Cost drivers
- Development priorities
- Product development integration

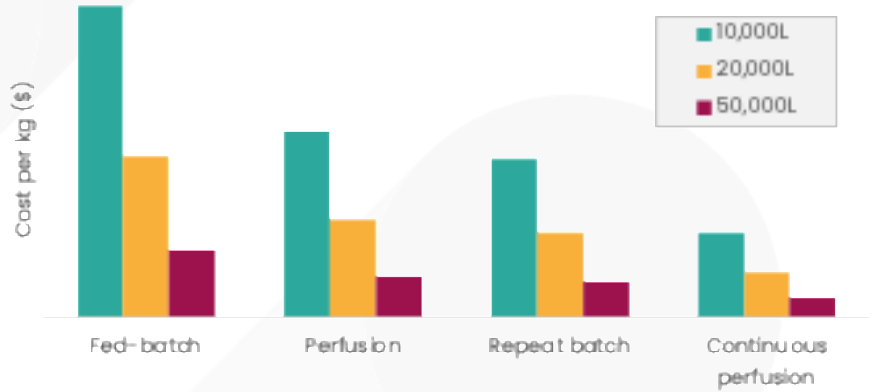
Cost of Goods Modelling Informs Manufacturing Strategy

Understanding the overall cost of goods is necessary early on to achieve commercial goals:

- Process yield varies depending on the process modes and scale of operation selected, which should align with commercial goals.
- Cost of goods can be reduced >90% through optimized process modes and operating scales.
- Continuous processes require more development, so achieving significant cost reduction requires investment and time.
- Commercialisation strategy may require a phased development and manufacturing plan.
- Continuous processes aren't always cheaper: significantly impacted by process titres and media costs.



Annual biomass output per process mode and bioreactor scale

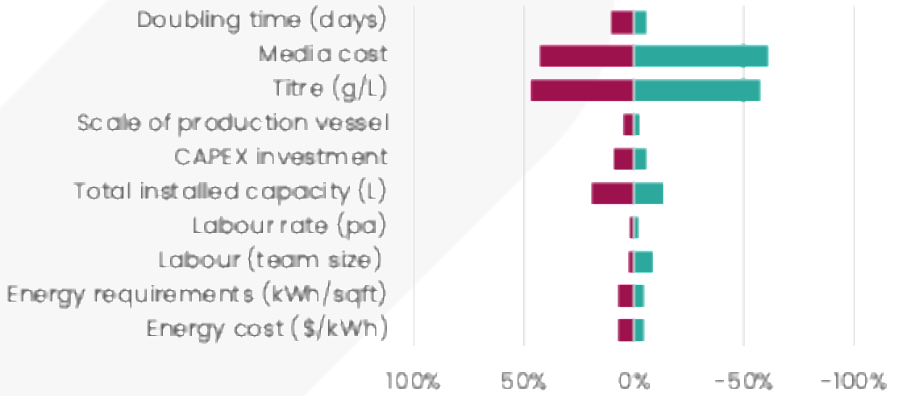


Representative cost per kg of product per process mode and bioreactor scale for animal cell culture

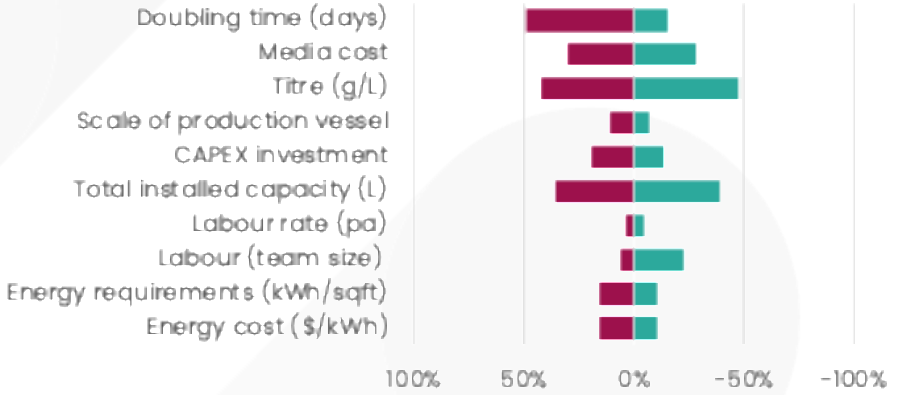
Sensitivity Analysis Informs Development Strategy

Robust understanding of variables impacting cost of goods aids prioritization for development studies

- Baseline assumptions significantly impact sensitivity analysis. Industry standard benchmarks and baseline data are essential for useful outputs.
- Cost of goods sensitivity output differs based on process mode and assumptions for each variable.
- Due to the differing characteristics of animal and plant cell cultures, requirements for each cell type vary significantly



*Sensitivity analysis of manufacturing variables (+/-50%) on cost of goods for **animal cell culture***

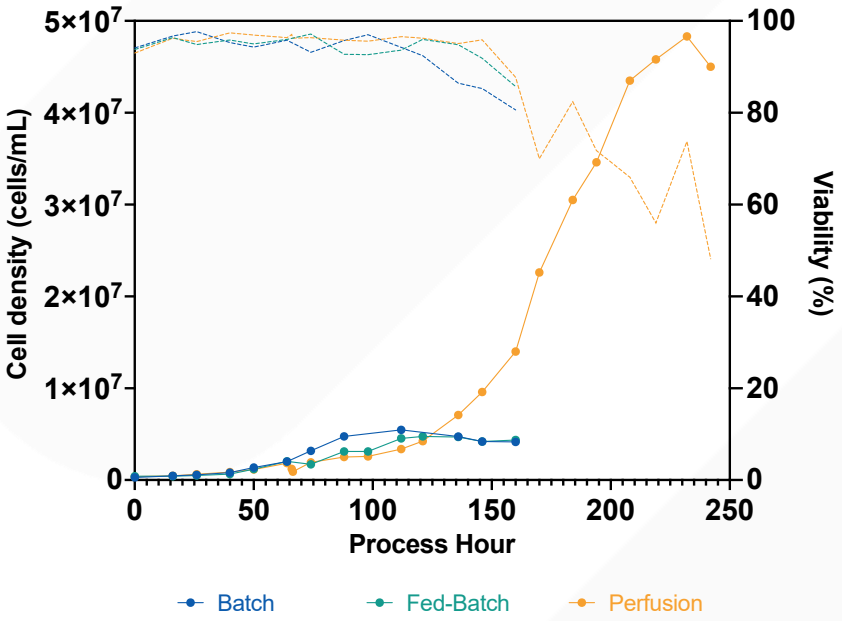


*Sensitivity analysis of manufacturing variables (+/-50%) on cost of goods for **plant cell culture***

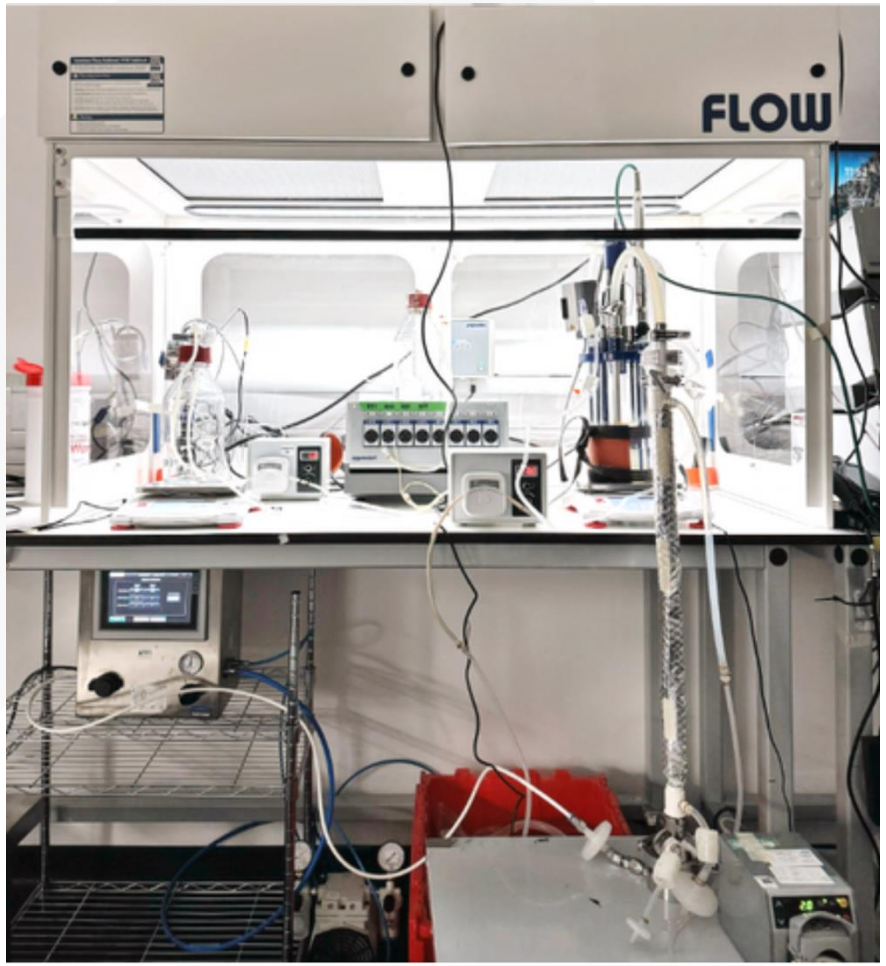
Process Baselining Supports Development Strategy

Typical baselining of non-continuous processes are often the starting point for future continuous processes.

- Perfusion processes can reach **10x cell density** than batch and fed-batch.
- **3x monthly output** with perfusion process

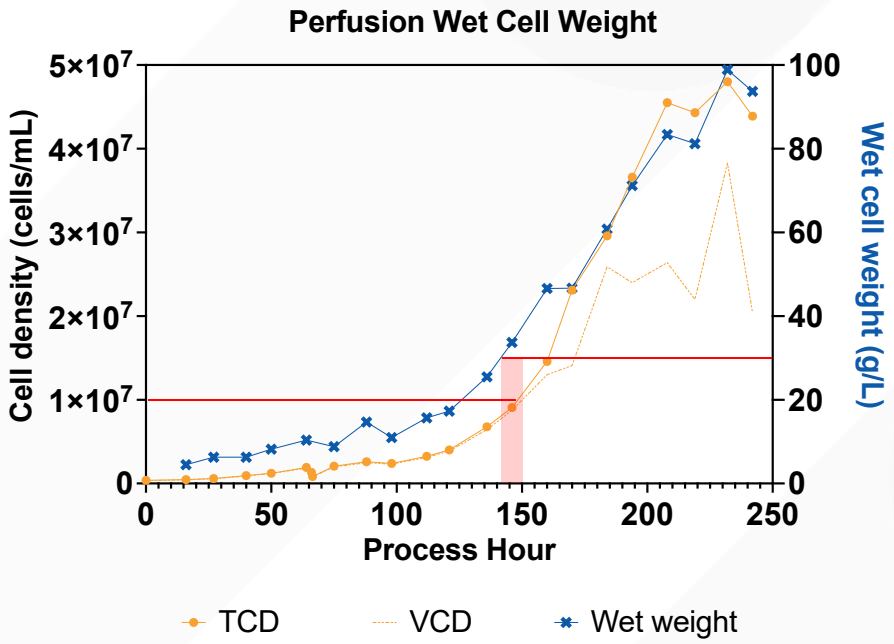


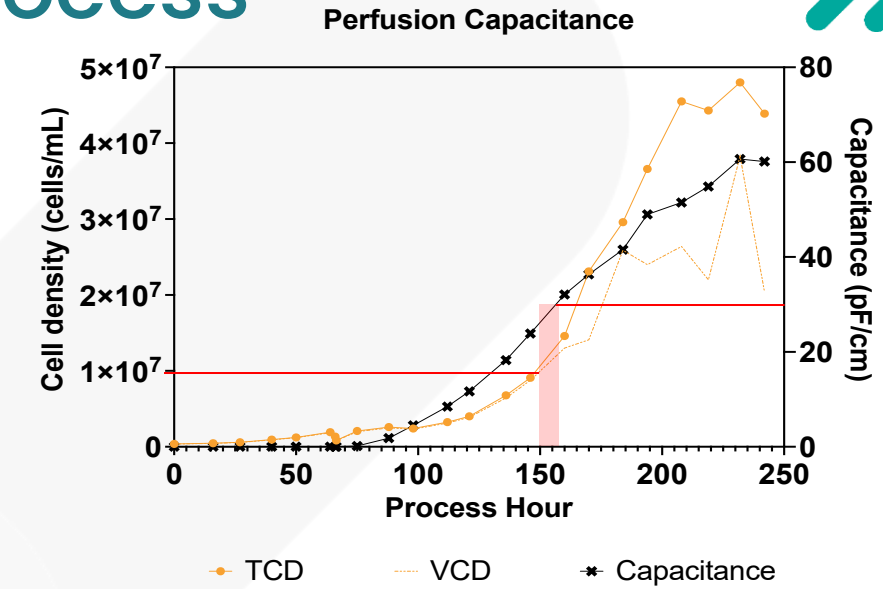
Process Mode	Monthly output per L_{wv}
Batch	128 g
Fed batch	104 g
Perfusion	296 g

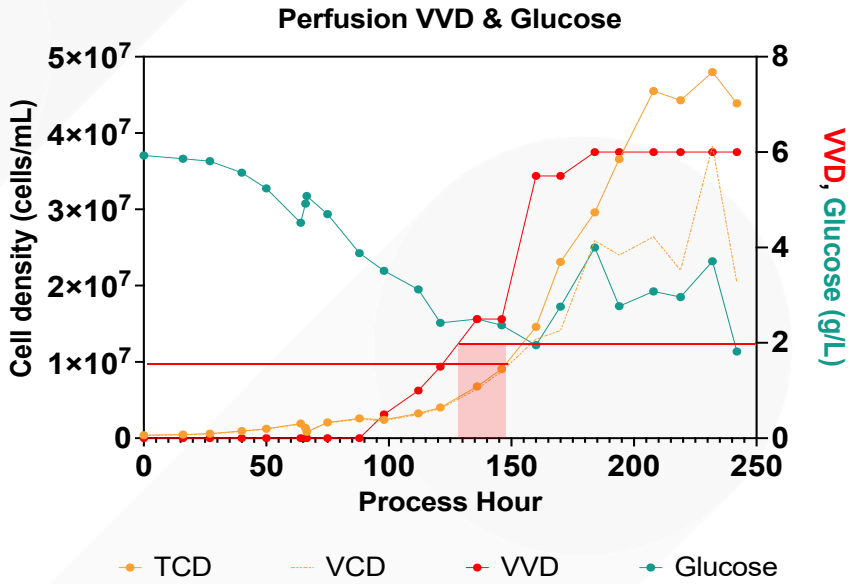


Development of a continuous process

Perfusion data provided key insights into defining sustainable set points for continuous process:







WCW: **30 g/L**

VVD **< 2**

Cell density: **1.00E+07**

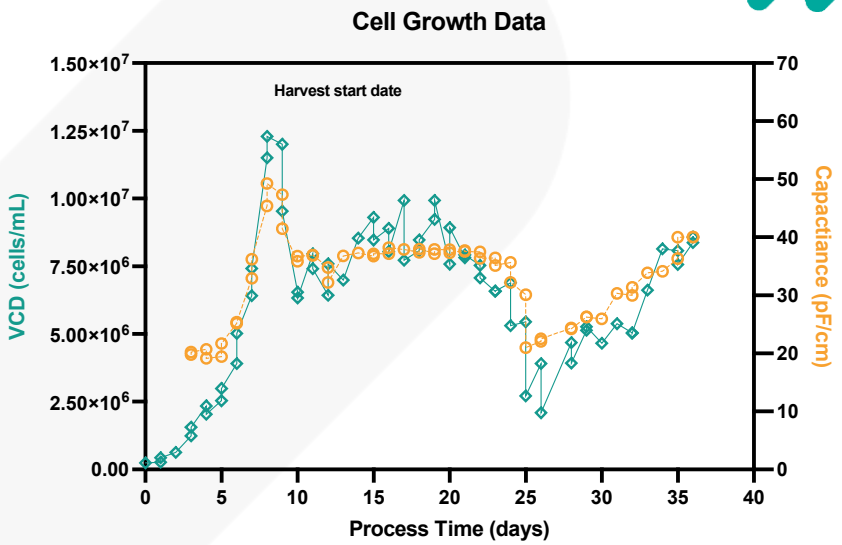
Glucose **> 1 g/L**

Capacitance: **30 pF/cm**

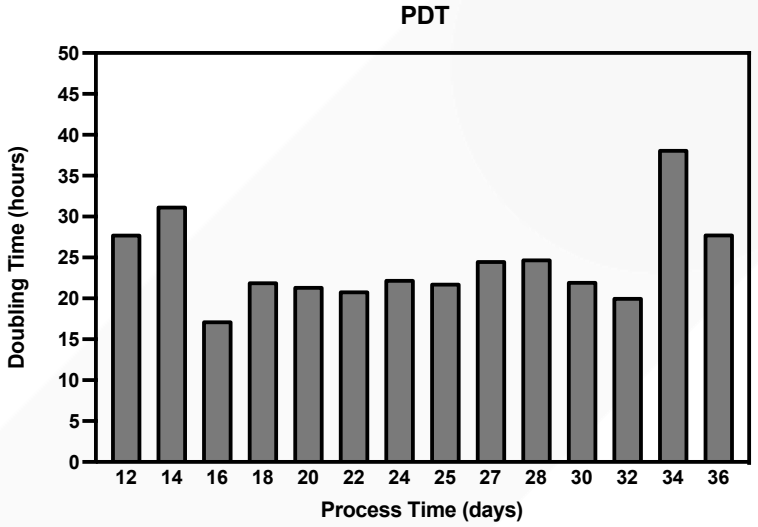
Development of a continuous process

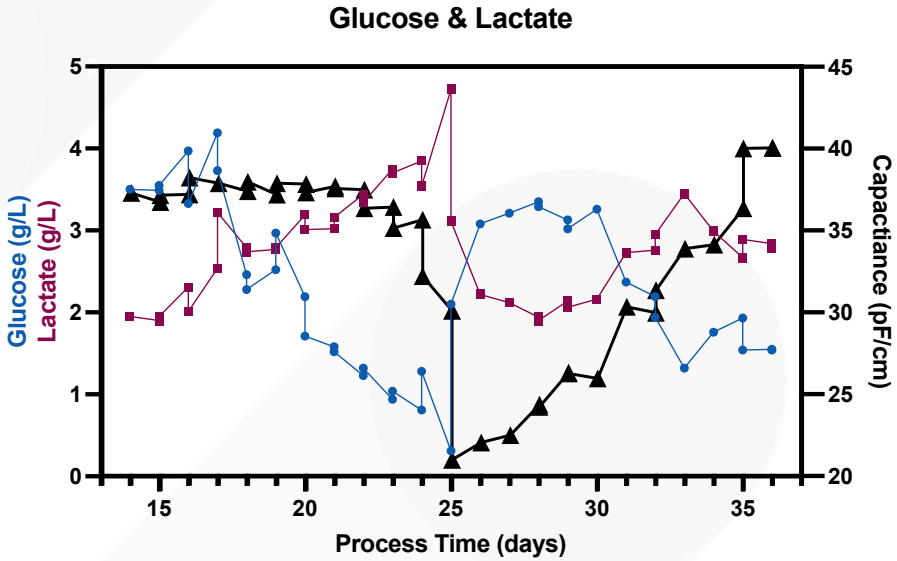
Continuous processes require advanced process monitoring and control

- Biomass concentration
- Nutrient and metabolite profile
- Predictive modelling



Process Mode	Monthly output per L_{wv}
Batch	128 g
Fed batch	104 g
Perfusion	296 g
Continuous	**401 g**





Comparing animal plant (and microbial) cell culture

Animal and plant cell cultures present unique challenges over precision fermentation which require dedicated infrastructure and operating philosophies

Feature	Microbial Fermentation	Animal Cell Culture	Plant Cell Culture
Cell Wall / Membrane	Rigid cell wall	Flexible phospholipid membrane	Rigid cellulose-based cell wall
Cell Size	Small (~1–10 µm for bacteria, ~5–10 µm for yeast)	Medium (~10–30 µm)	Medium to large (~20–100 µm)
Speed of Growth	Very fast (doubling in 20 min to few hours)	Slow (doubling in 16–48+ hours)	Slow to moderate (doubling in days)
Nutrient Requirements	Simple media (carbon source, salts, nitrogen)	Complex media (amino acids, vitamins, growth factors, supplements)	Complex media (sugars, vitamins, hormones)
Physicochemical Requirements	Wide pH band (4–9); High oxygen demand (especially aerobic microbes); Tolerates high agitation	Narrow pH range (eg 7.2–7.4); 37°C (mammalian cells); Sensitive to shear stress	pH ~5.5–6.0; Temperature ~25°C; Sensitive to shear stress; Lower oxygen requirements
Culture Format	Batch, fed-batch, continuous fermentation; Bioreactors scalable to 100,000+ L	Adherent or suspension culture; Limited scale (typically up to 20,000 L)	Suspension or callus culture; Less scalable industrially
Contamination Risk	Relatively low if sterile techniques maintained	High – susceptible to microbial and viral contamination	Medium – mostly fungal/microbial contamination

Contract Manufacturing

Extracellular operates Europe's largest contract pilot facility for cell-based novel food production.

Dedicated food-grade space for cell-based products with:

- 2,000L & multiple 200L single-use bioreactors installed.
- Batch, fed-batch & continuous process modes
- Up to 40,000L total bioreactor capacity planned to support food, materials and personal care ingredients

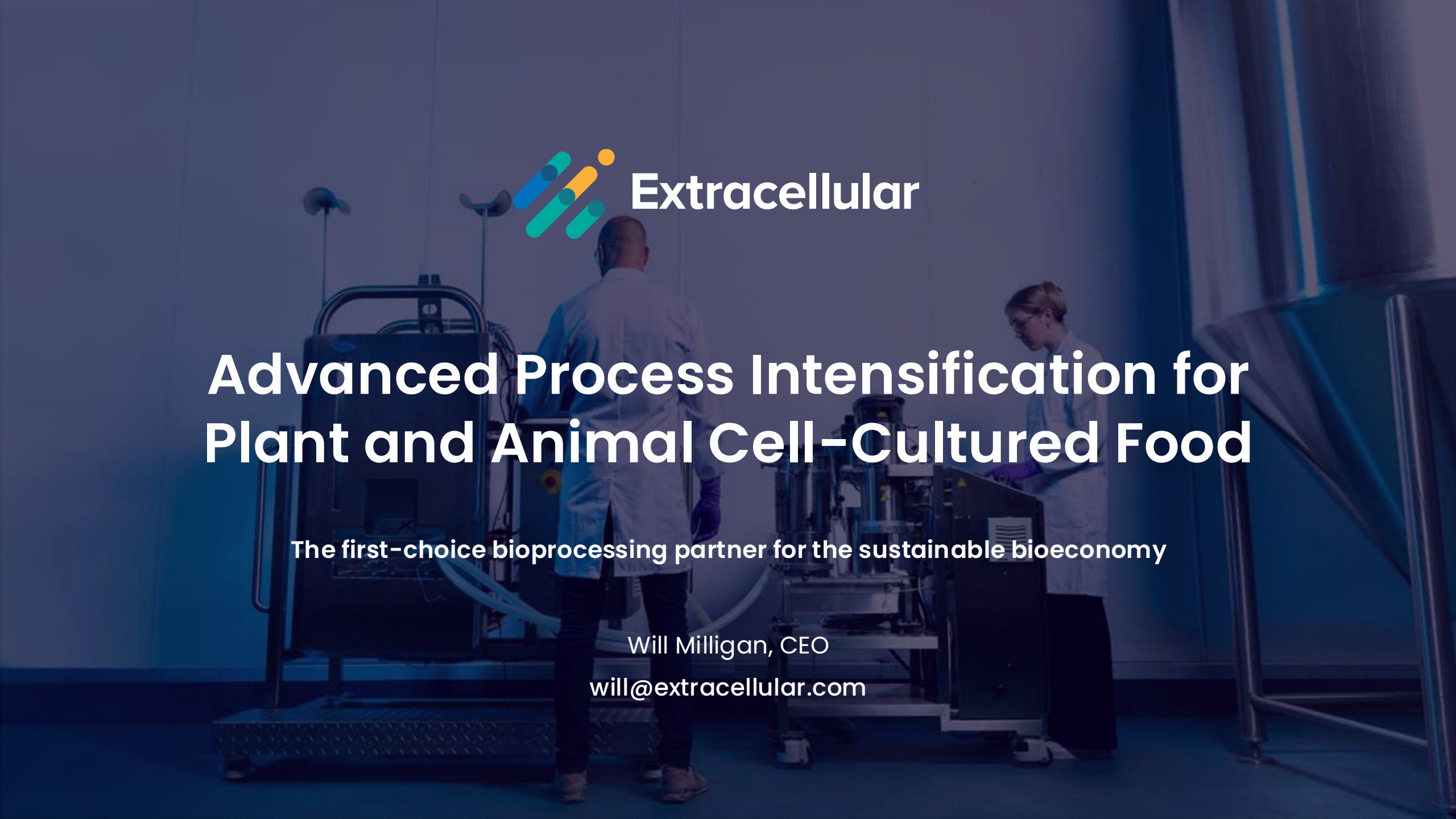
Extracellular supports product developers and large corporate partners with expert capabilities for cell-based products

Media Development

Cell Development

Process Development

Contract Manufacturing



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