



Stellenbosch

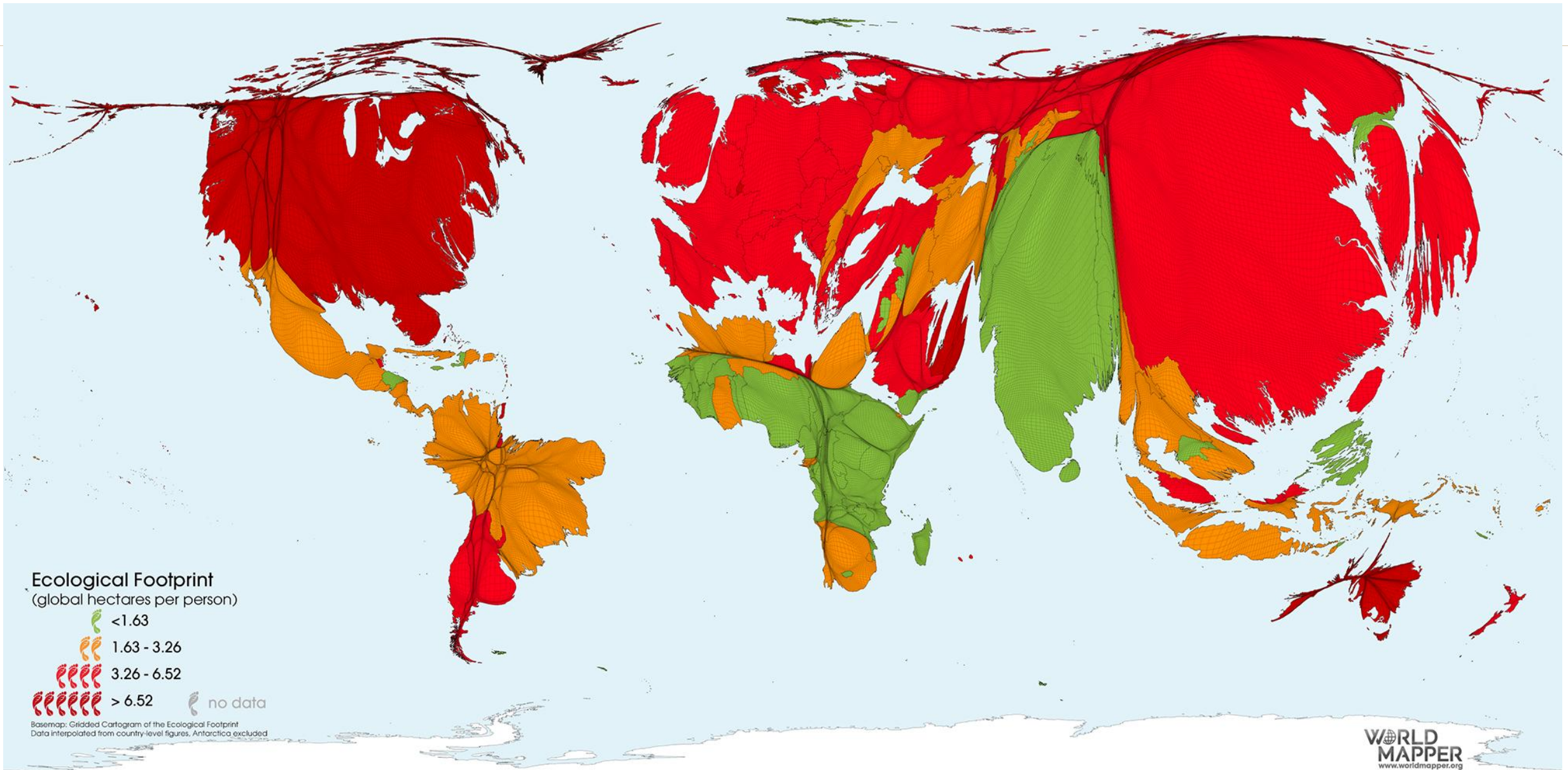
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IYUNIVESITHI
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forward together
sonke siya phambili
saam vorentoe

Developing Sustainably: Materials, Chemicals and Processes for a Circular Future

Department of Chemical Engineering

Ecological footprint - 2019



Changes in Global Investments and Trade



R/€ = 19.2946 ▼

R/\$ = 18.1706 ▼

Au 1845.69 \$/oz ▲

Pt 965.20 \$/oz ▼

iress

South Africa must prioritise decarbonisation, as \$1.5bn of exports to EU are at risk

2ND MARCH 2023

BY: SCHALK BURGER

ARTICLE ENQUIRY

SAVE THIS ARTICLE

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The Department's approaches to these issues:

Sustainable feedstocks



Sustainable electrons & carbon



Local biomass, agri-products, waste, e-waste, minerals



The Department's approaches to these issues:

Sustainable feedstocks



Advanced materials



**Biosurfactants in
Minerals processing**

Novel Bioprocesses

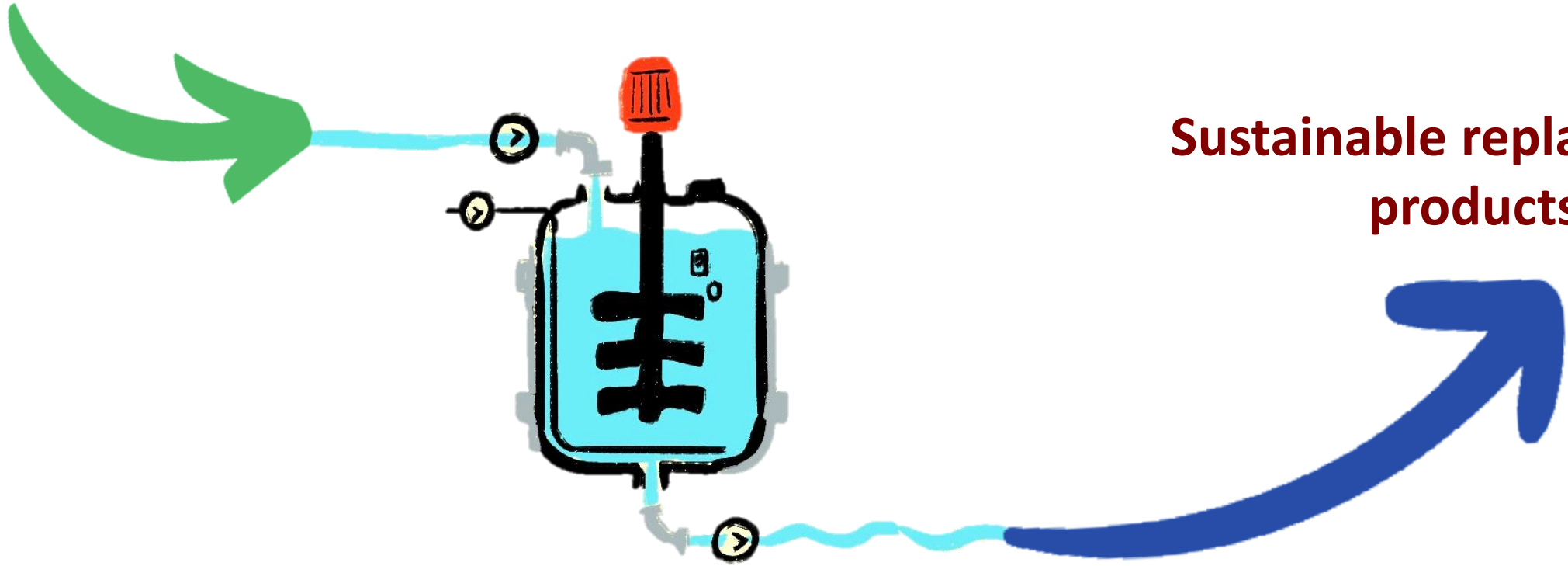
**Sustainable replacement
products**

**Replace traditional
C-intensive products**



Quantification of sustainability

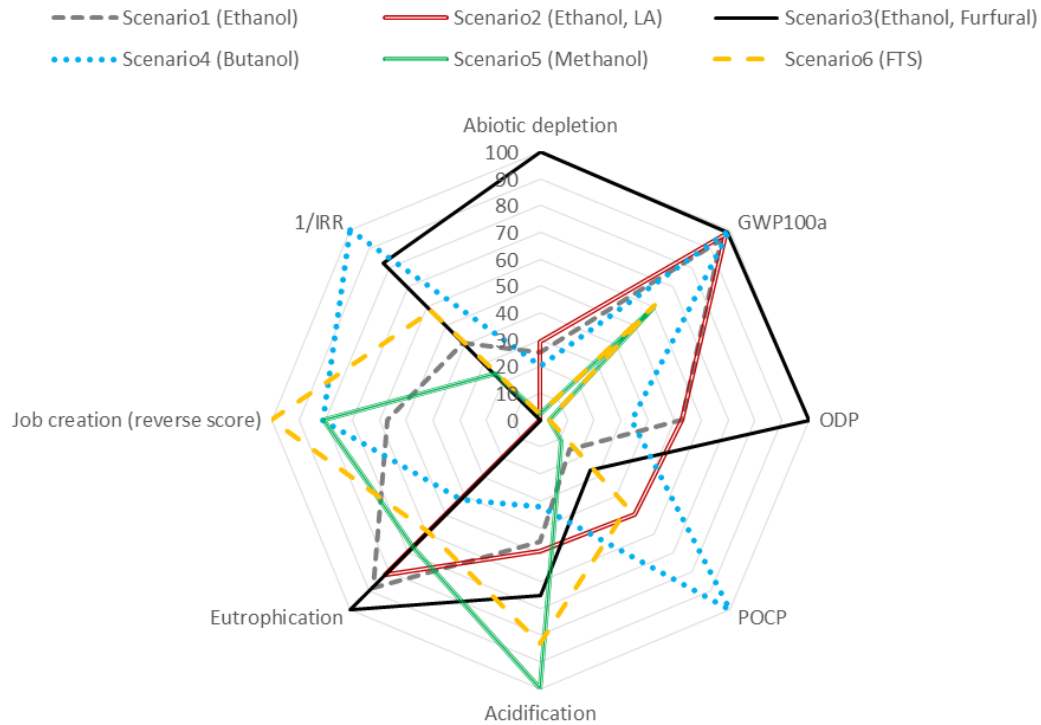
Sustainable feedstocks



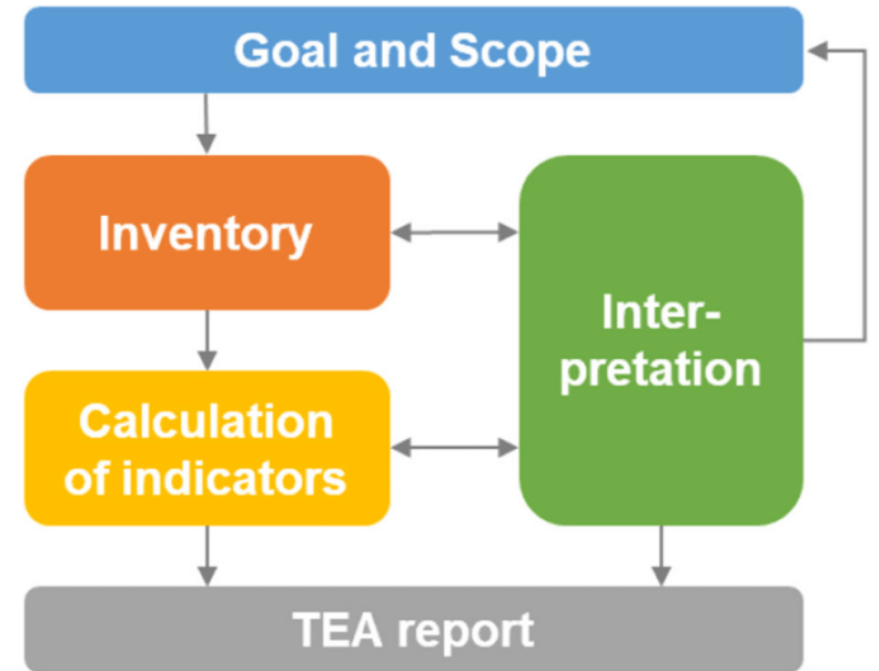
Sustainable replacement products

Novel Bioprocesses

Quantification of sustainability



Sustainability
Assessment LCA



Techno-economic
assessment

Need technologies that rise to the challenge:



Example projects

From our research portfolio



**Bioresource
Engineering**



**Extractive
Metallurgy**



**Machine
Learning**



**Separations
Technology**



**Waste
Valorisation**



**Sustainable Hydrogen
and Carbon Transitions**

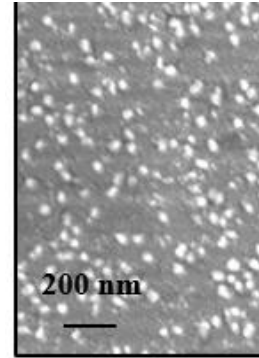


Advanced materials for biomedical applications



Functional properties:

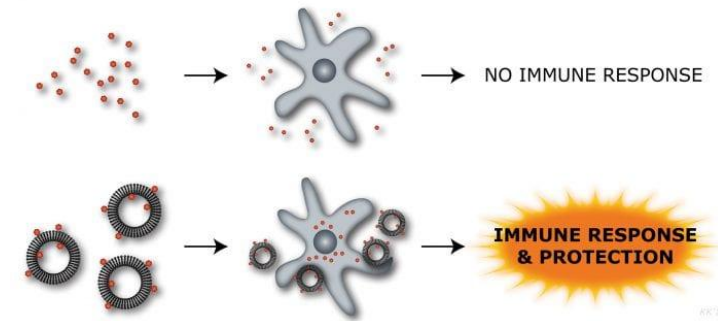
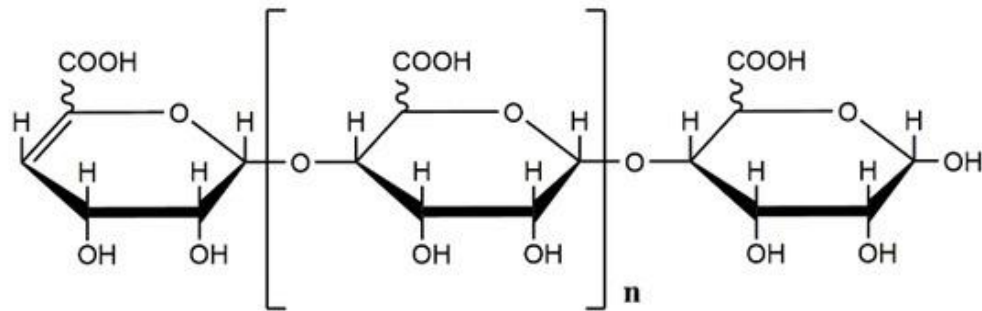
- biosensors
- Implantation matrix
- Encapsulation matrix
- Coatings
- Sorbents
- Emulsifiers
- Reinforcements
- Additives
- Fillers
- Film forming
- Barrier properties
- Tissue growth matrix
- 3-D printing



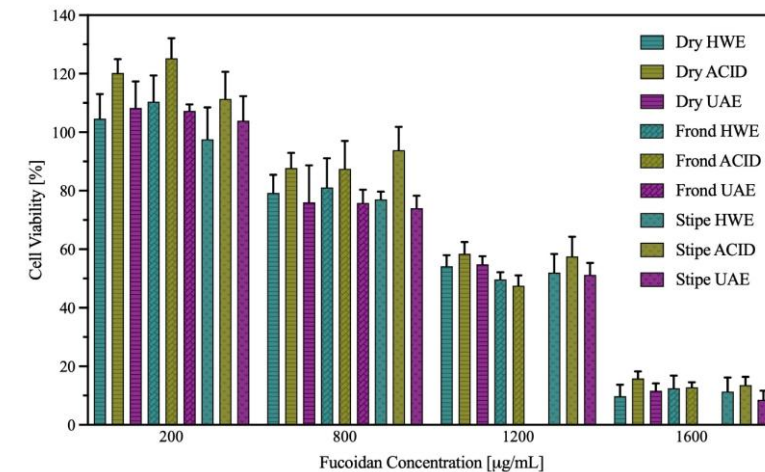
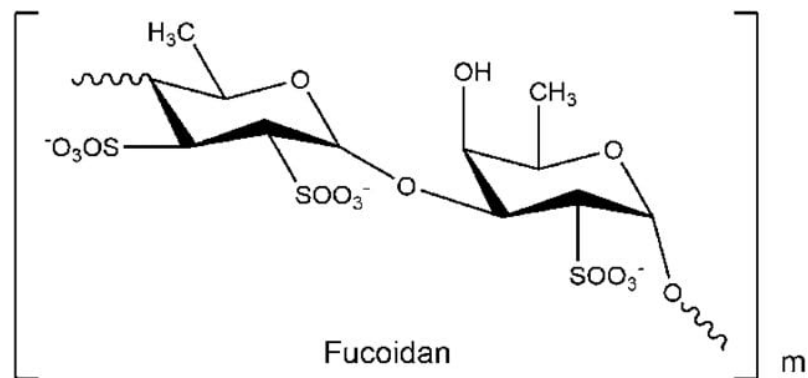
Coatings
Films
Hydrogels
Oleogels
Composites



Sustainable production of vaccine adjuvants



Fucoidan as anti-cancer and anti-diabetic compound



Designing Integrated Biorefineries for a Circular Bioeconomy- Example

Biorefineries Integrated into Cassava Starch Processing Maximizing
Resource Recoveries and Material Circularity

Cassava plant



Cassava tubers



Starch facility



Wastewater (CWW)



Stalks (CS)



Waste treatment / CHP



Power & heat



Biofertilizer



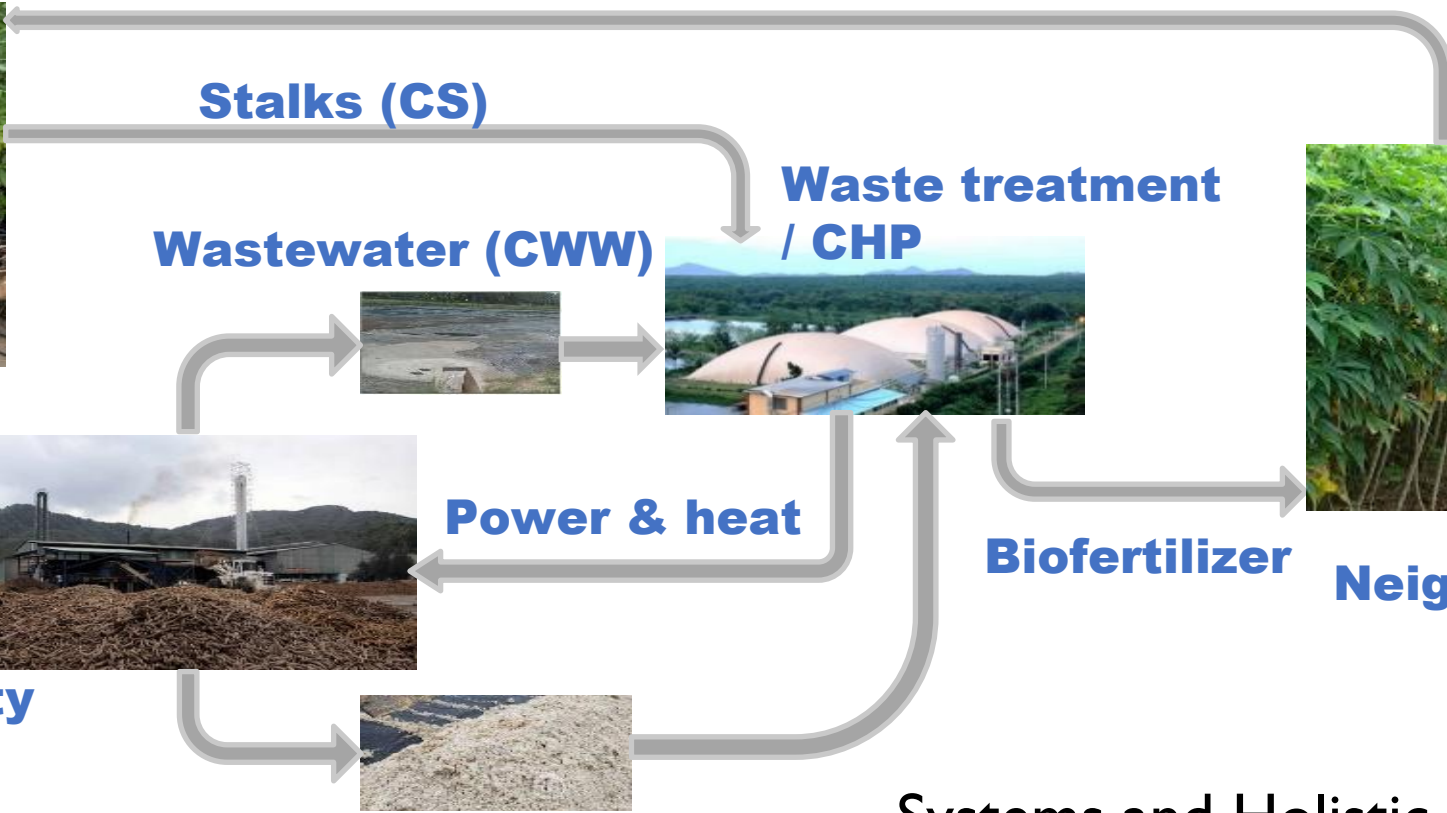
Neighboring cassava farms



Bagasse (CB) waste



Systems and Holistic Approach
Regeneration of Inputs



Mango waste (peels and seeds) circular biorefinery scenarios

1. Combined heat and power production only

2. Co-production of pectin and combined heat and power

3. Sequential recovery of pectin and polyphenols coupled with combined heat and power production

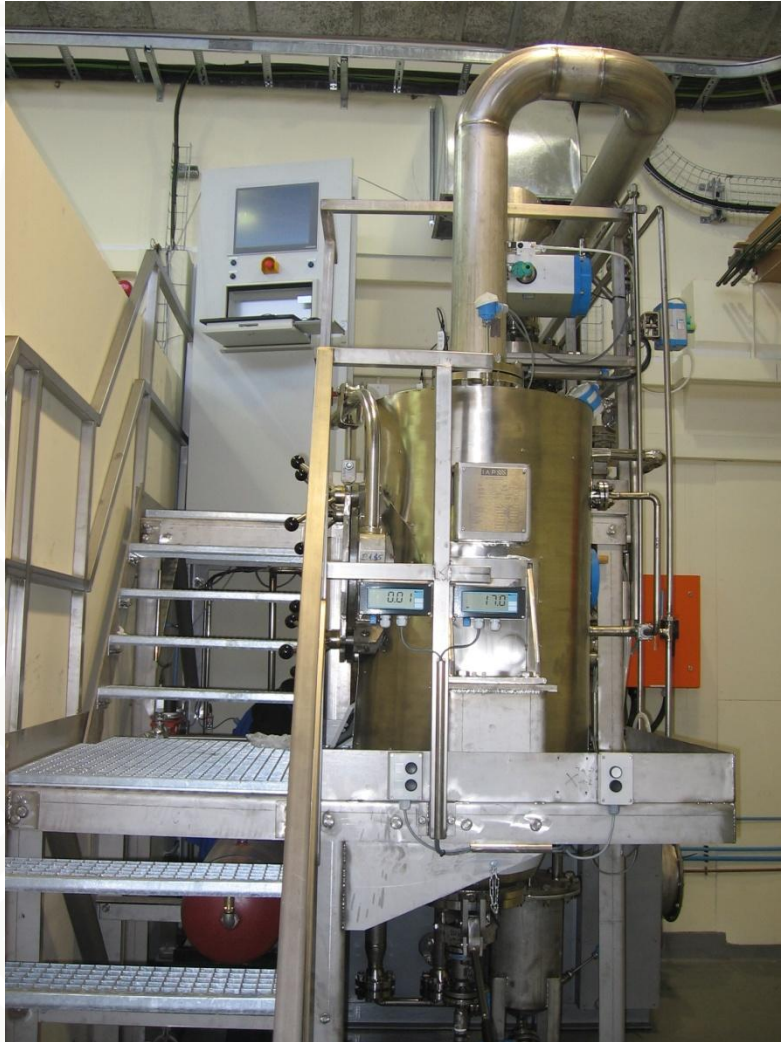
4. Co-production of pectin, ethanol and combined heat and power

5. Sequential recovery of pectin and polyphenols coupled with ethanol + combined heat and power production

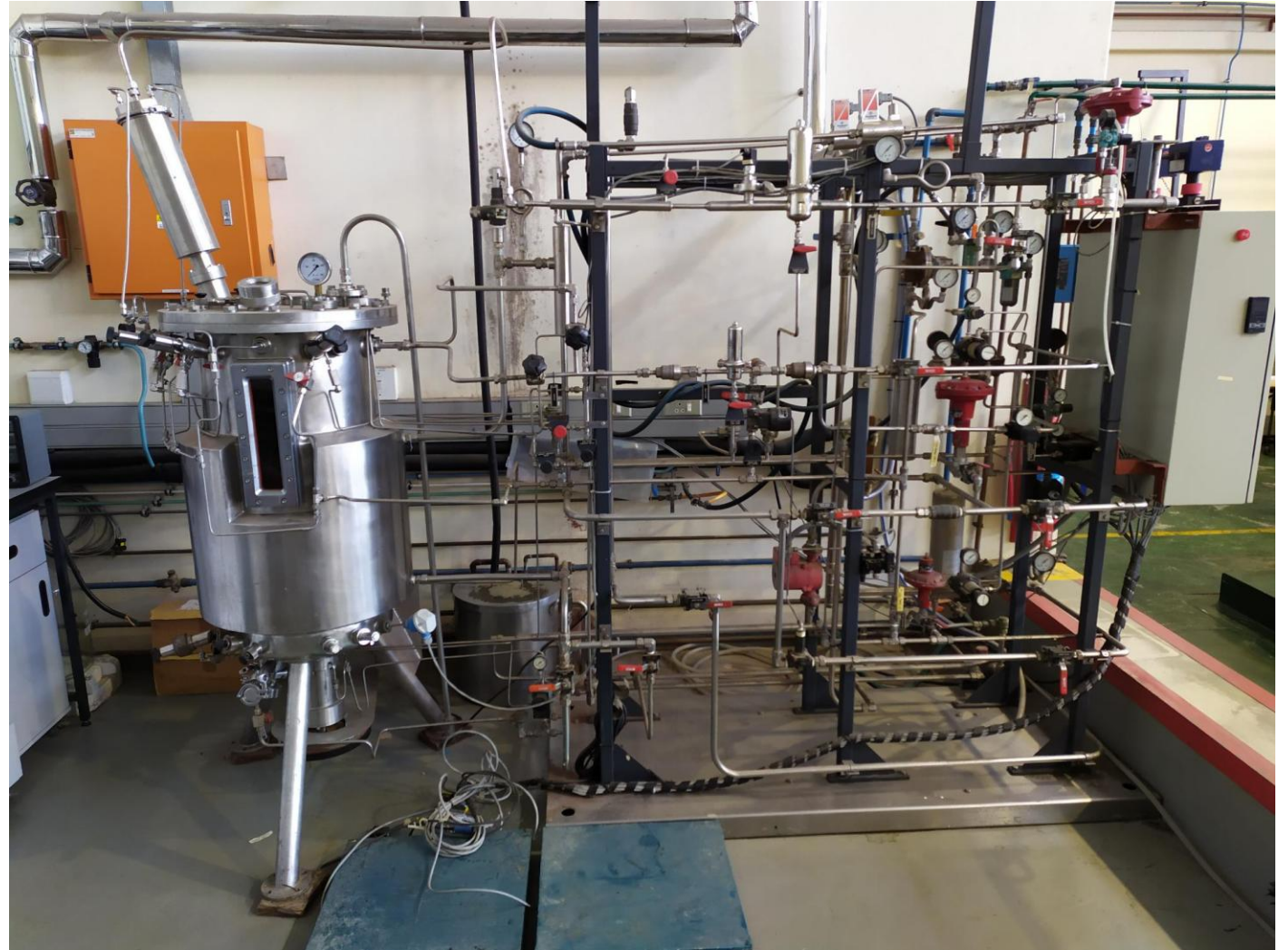
6. Co-production of bioethanol and combined heat and power



Steam Explosion Preparation of Lignocelluloses for Bioconversions and Biomaterial



Pilot-scale Bioprocess Development



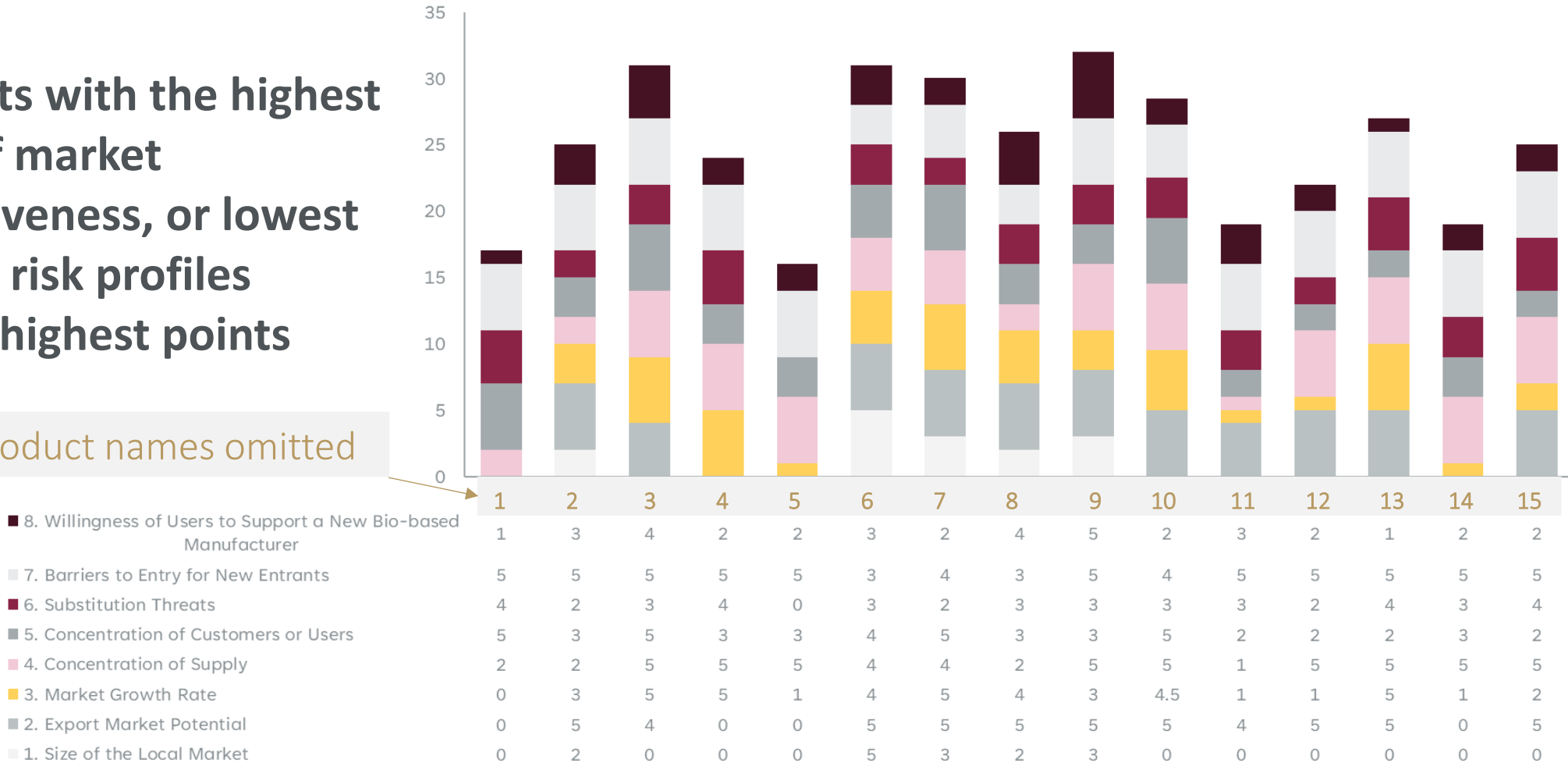
TECHNO-ECONOMICS AND SUSTAINABILITY

Benchmarking of alternative products

Preliminary market research

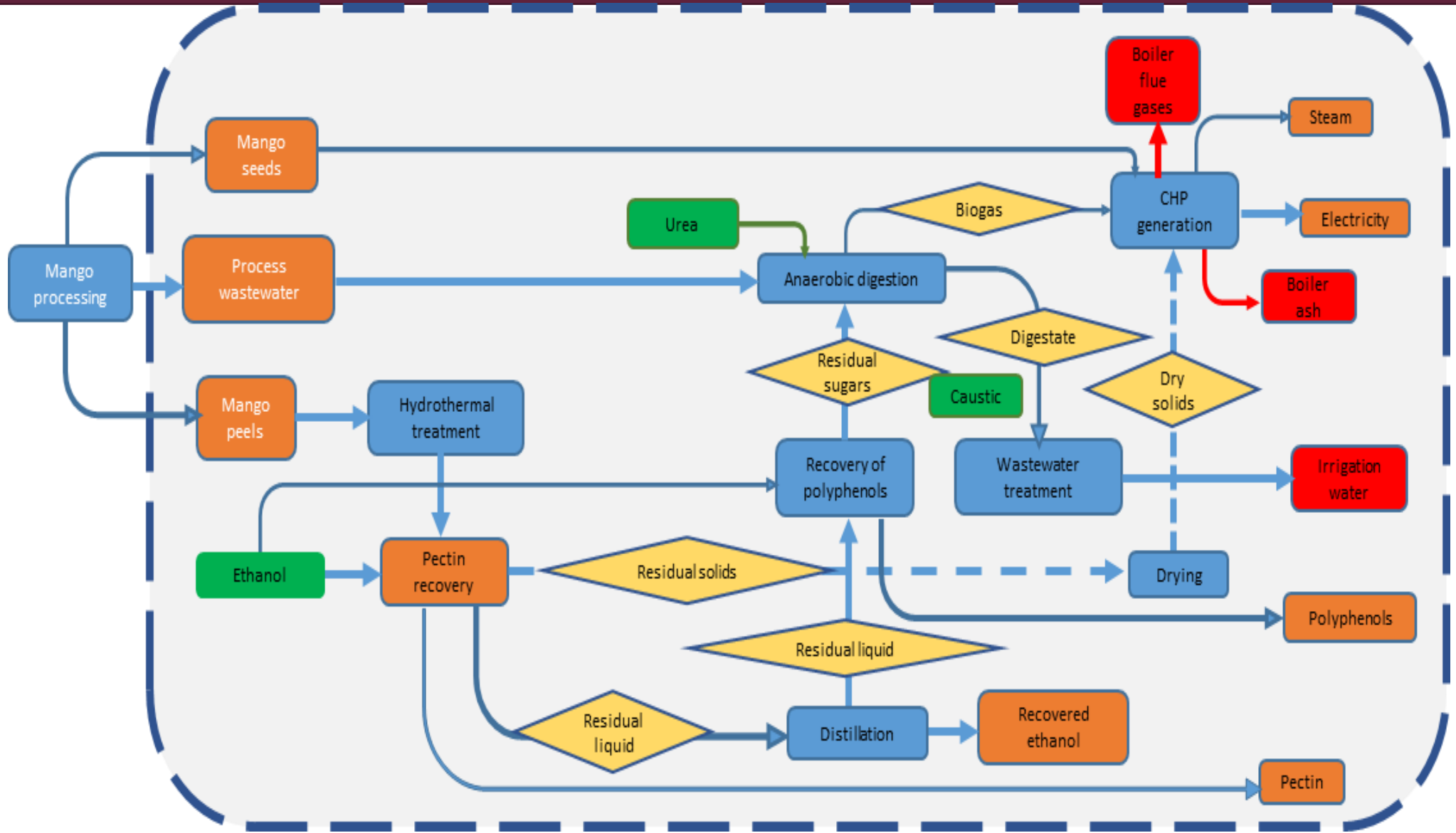
Products with the highest level of market attractiveness, or lowest market risk profiles scored highest points

Product names omitted

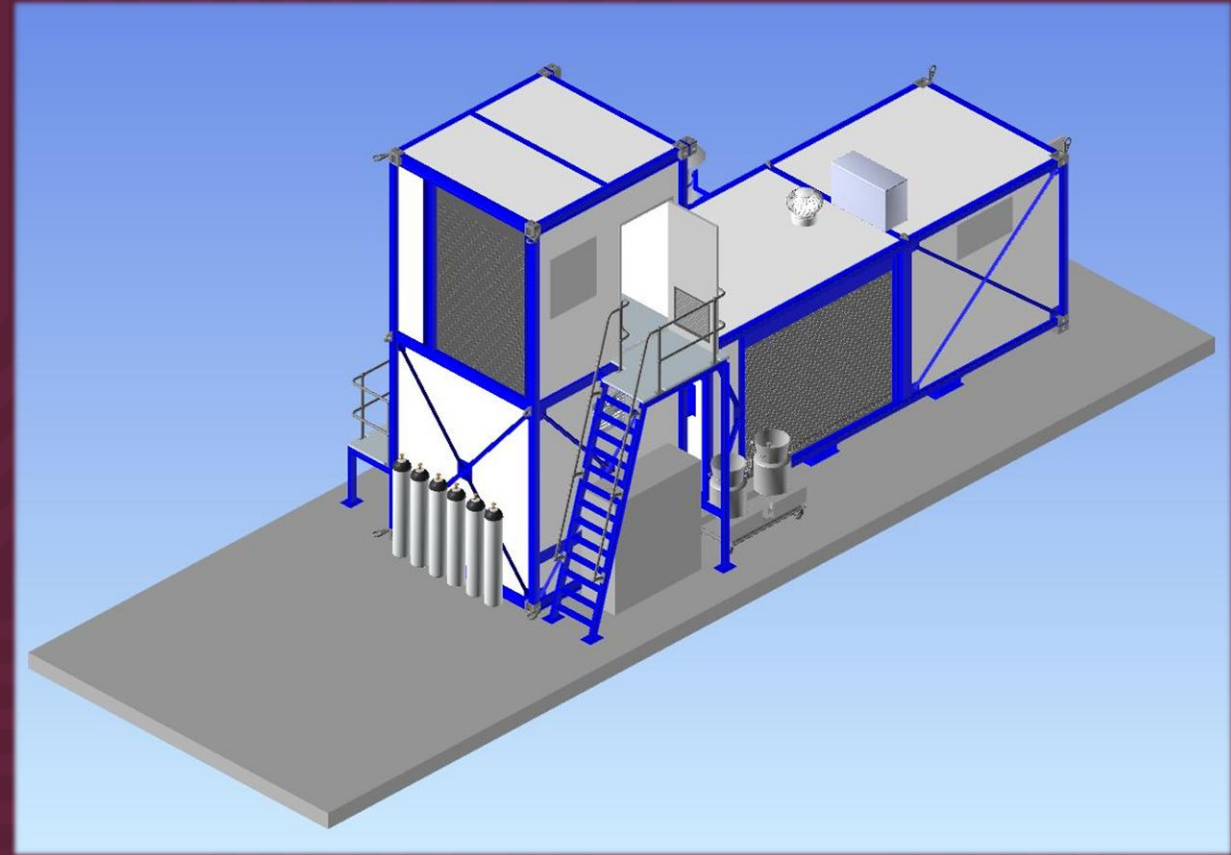
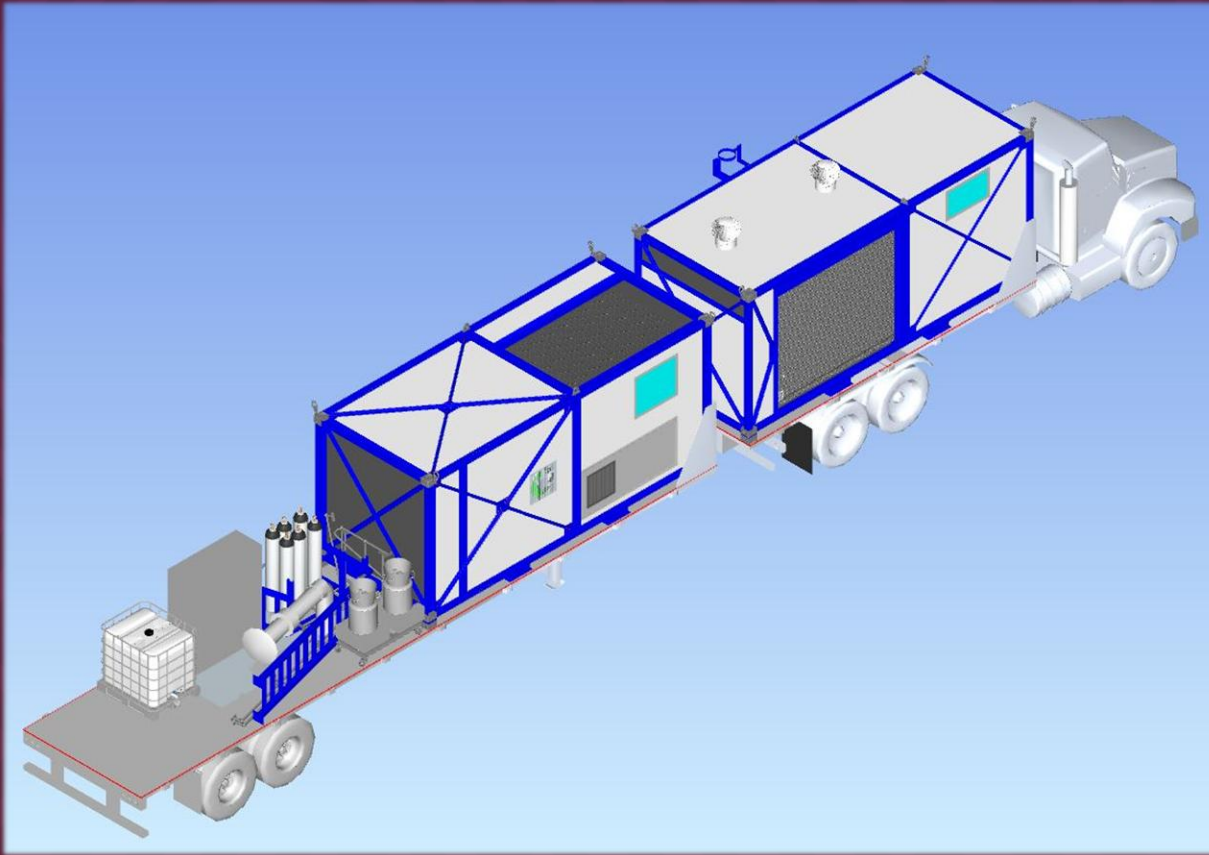


Techno-economic and sustainability studies

Sequential recovery of pectin and polyphenols coupled with production of biogas CHP (PPCHP)



Industrial Demonstration of Novel Bioprocessing Technologies



Improvements to Anaerobic Digestion of Organic and Biowastes



Biomethane potential assessment



Scale-up to semi-continuous 50 L digesters



Biogas -> Biomethane



Digestate -> fertiliser



MICROORGANISMS

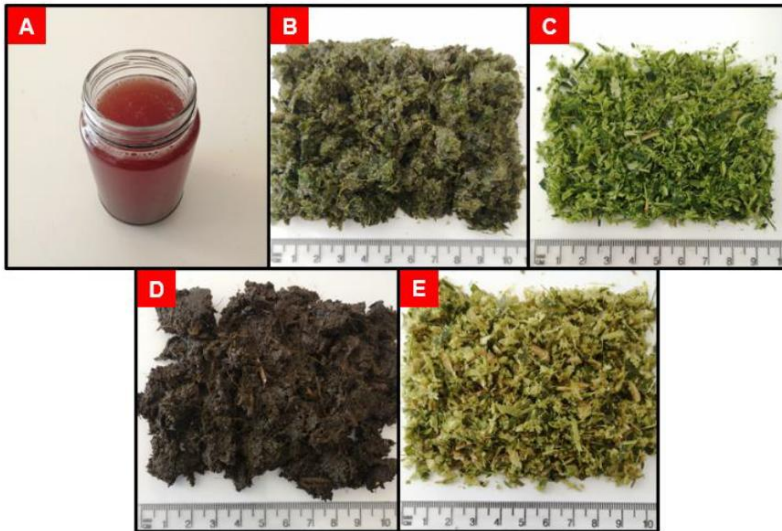
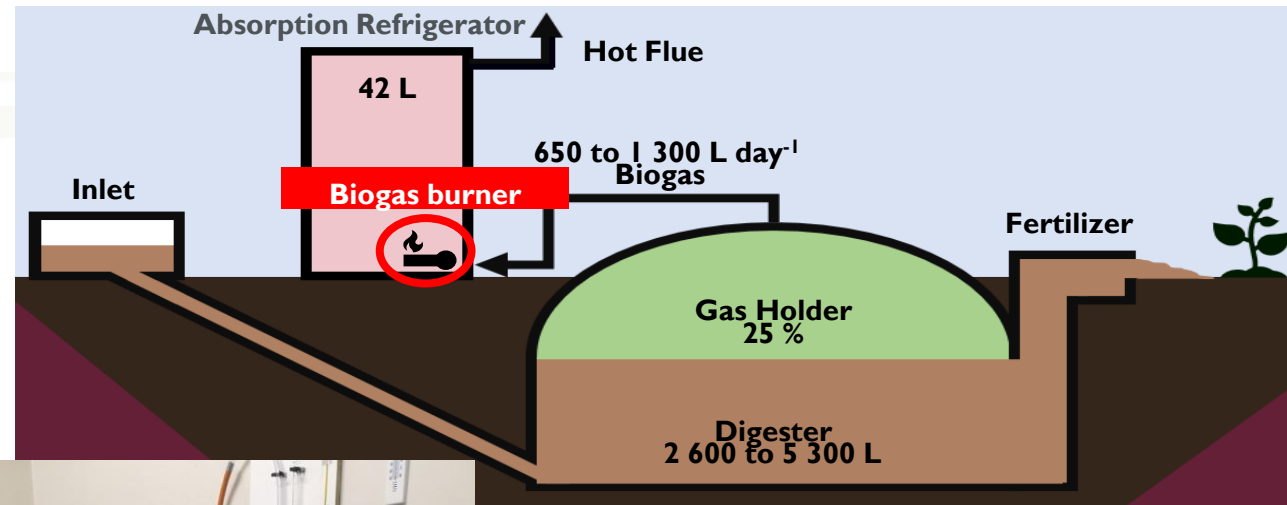


Bioaugmentation treatment using specific microbes

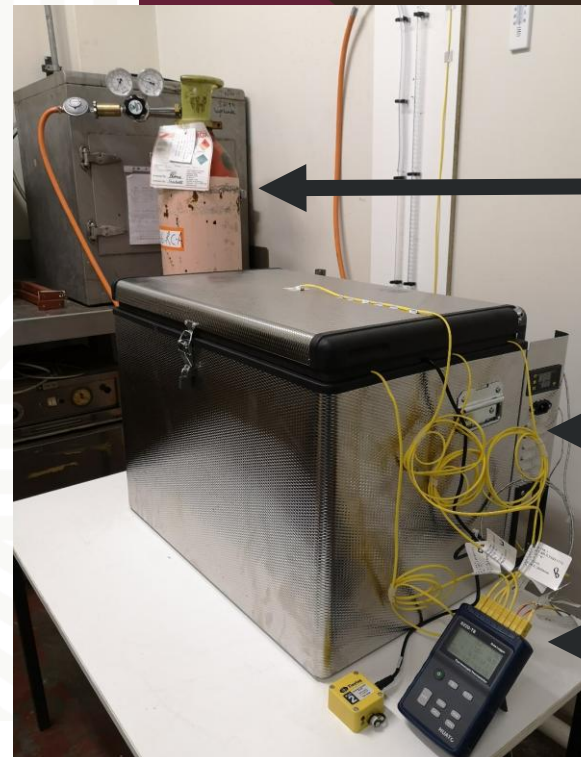
Biogas-fuelled absorption refrigeration to curb post-harvest losses

Completed Objectives

- Modified refrigerator running on biogas
- BMP selected feedstocks
- Fridge performance
- Thermodynamic modelling



Fresh shredded substrates for BMP analysis before ensilage and anaerobic digestion. A: Fish effluent; B: Water hyacinth; C: Common reed; D: Cow manure and E: Maize stover



Synthetic biogas
59% CH₄ & 41% CO₂

42 L absorption refrigerator

Temperature data loggers

Seaweeds: another biomass - processing and utilisation



Processing

Alginate (hydrocolloid)

- Gelling agent
- Slow-release matrix in food/feed/agriculture

Fuoidan (sulfated polysaccharide)

- Anti-cancer and anti-diabetic properties
- Nutritional supplement

Other components

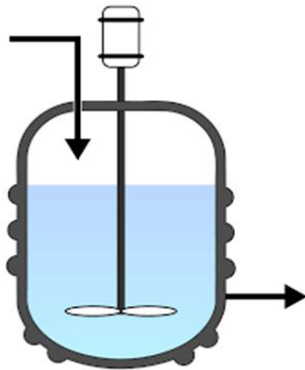
- Polyphenols as antioxidants
- Other polysaccharides
- Plant biostimulants

Utilisation

- Feed supplement for methane suppression in ruminants
- Substrate for bio-energy production

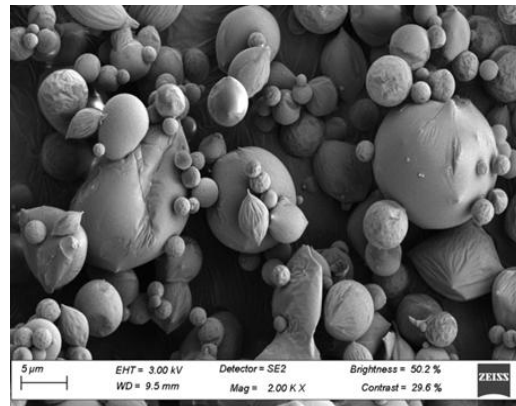
Processing of alternative proteins

Extraction and modification



- Alkaline and enzyme-assisted extraction
- Determination of optimal conditions to maximize yield

Downstream processing and drying



- Isoelectric precipitation, ultrafiltration, bleaching
- Spray drying

Evaluation of properties



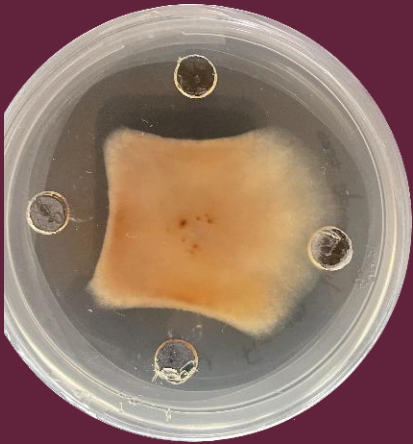
- Functional and shelf-life properties
- Nutritional characteristics

Wide range of proteins investigated, including black soldier fly protein, and by-product proteins from brewer's spent grains, fish processing by-products and typical oil seed residues (oilcakes)

Speciality bioproducts - getting the organisms to make value

Biosurfactants

Antifungal



Metal recovery



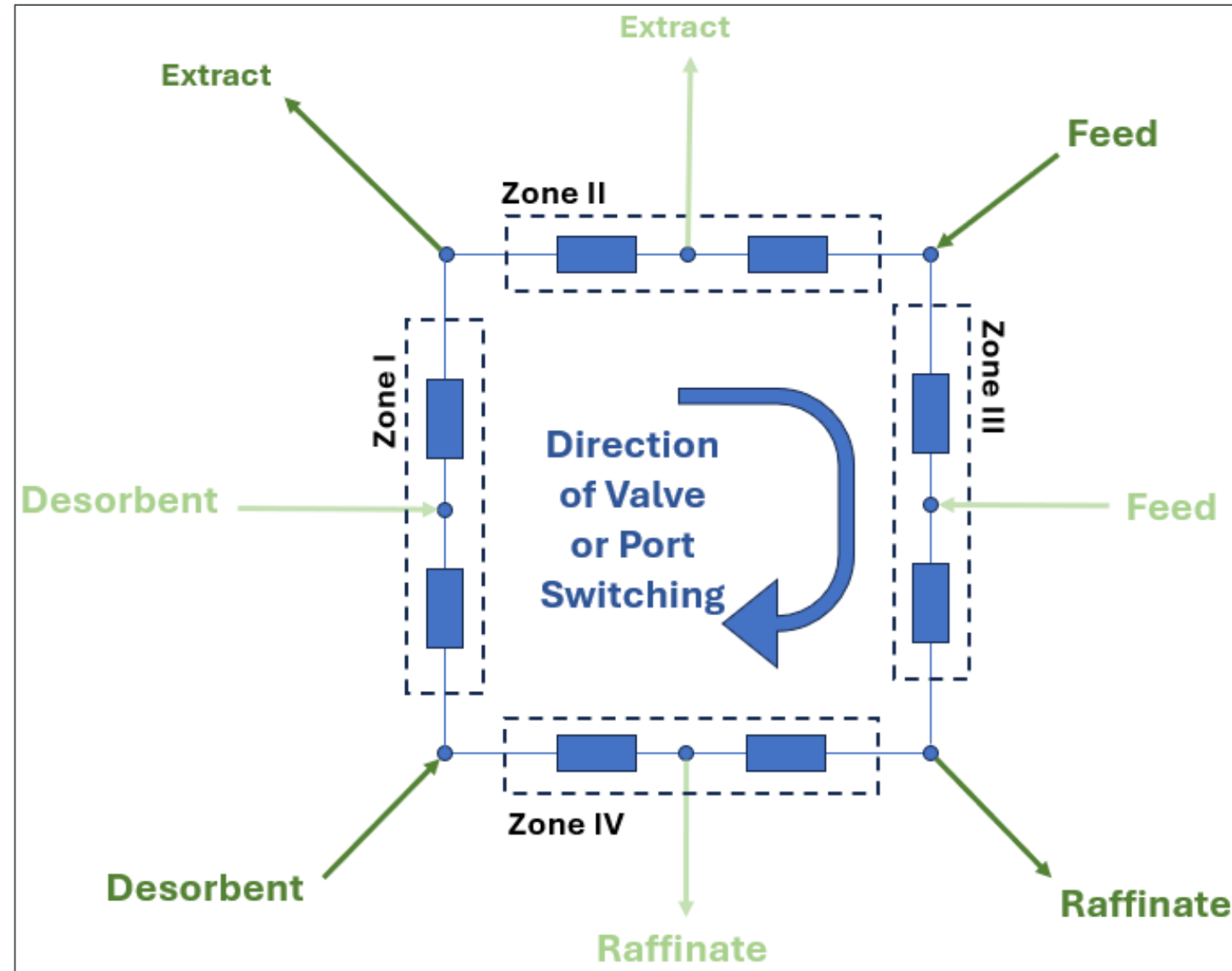
Skin care



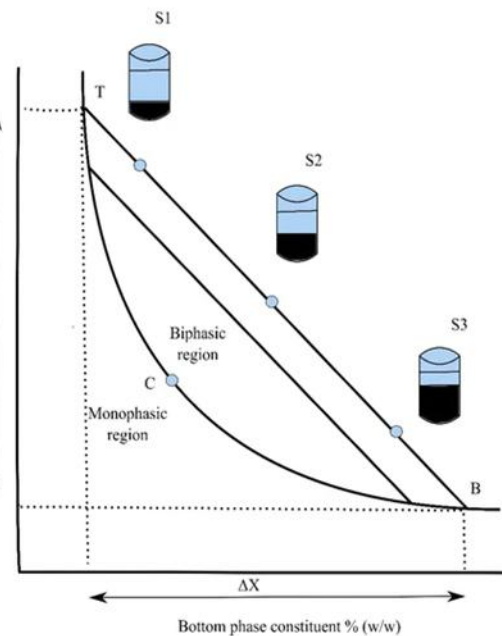
The science of separation: eg Simulated Moving Bed Chromatography

Applications:

- Metal ions
- Sugars (glucose, fructose)
- Oligosaccharides
- Anything that can be separated by chromatography



The science of separation: eg ATPS for selective biomolecule recovery



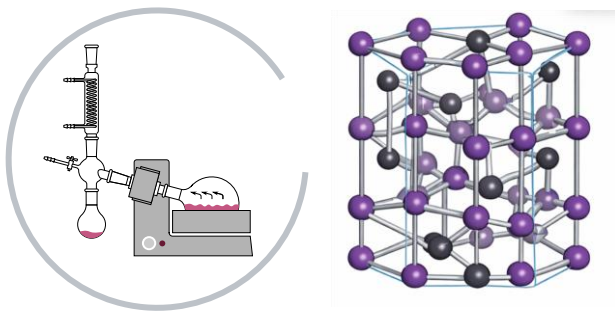
- Based on incompatibility of two aqueous solutions
- Separates and purifies molecules using two immiscible aqueous solutions
- Two phases are incompatible forming distinct phases
- Gentle environment (~80% water)

Photocatalysis: Using light to drive sustainable compounds

Catalyst Synthesis

Catalyst types:

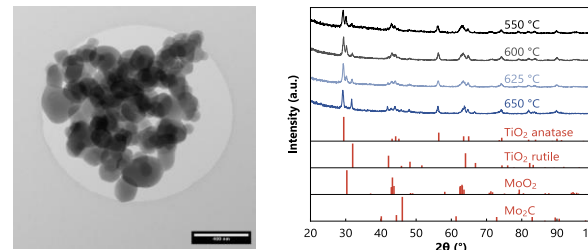
- Metal-supported and metal-oxide catalysts
- Mixed-phase and heterojunction catalysts
- Metal nanoparticles tuning



Catalyst Characterisation Analysis

Analyses using various standard and advanced characterisation techniques for:

- Structural and phase characterisation (XRD, in-situ XRD, Raman)
- Morphology (SEM, TEM)
- Surface and chemical species identification (XPS, XAS)
- Optical properties (UV-VIS, PL, FS)



Catalyst Testing

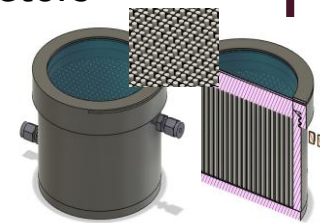
Photocatalytic testing for:

- **Hydrogen production** via water splitting and bioethanol reforming
- **Wastewater treatment**
- **Air quality improvement**

Reactor design

Design, commission and testing of photoreactors, including:

- Annular slurry reactors
- Optical fibre and,
- Monolith reactors



Extractive Metallurgy

Urban mining



Metal waste and scrap exports valued at more than R 5 billion

Recovery of base, precious, hi-technology and critical metals from electronic waste is critical from an economic and environmental management perspective

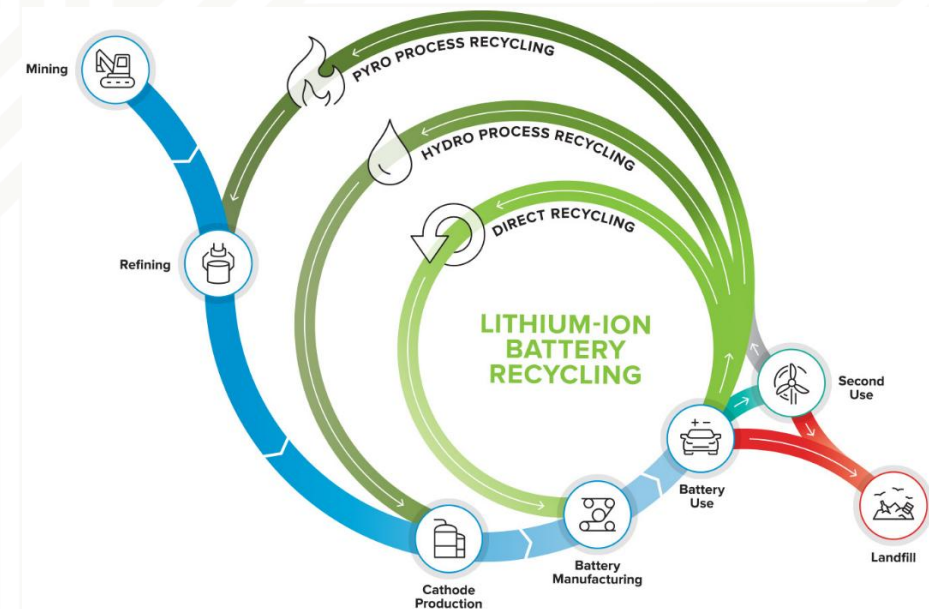
Develop hydrometallurgical processes for metal recovery:

- Printed circuit boards (copper & gold)
- Fluorescent lamps (rare earth elements)
- Lithium-ion batteries (lithium, cobalt & nickel)
- Automotive catalysts (precious metals)



Example: lithium ion batteries (LIBs)

- Used in cell-phones, laptops, hybrid electric vehicles
- Significant use of “critical metals” in LIBs, e.g. Co & Li
- 20% of Co from DRC, half of that artisinally-mined (child labour)



Extractive Metallurgy

Mine waste valorisation



Addressing the negative legacies left by mining in South Africa

- Mine dump currently cover up to 6000 Ha of land
- Dust and water pollution along with land utilisation
- Dumps carry unclaimed precious metals of significant value



Recovering value from waste

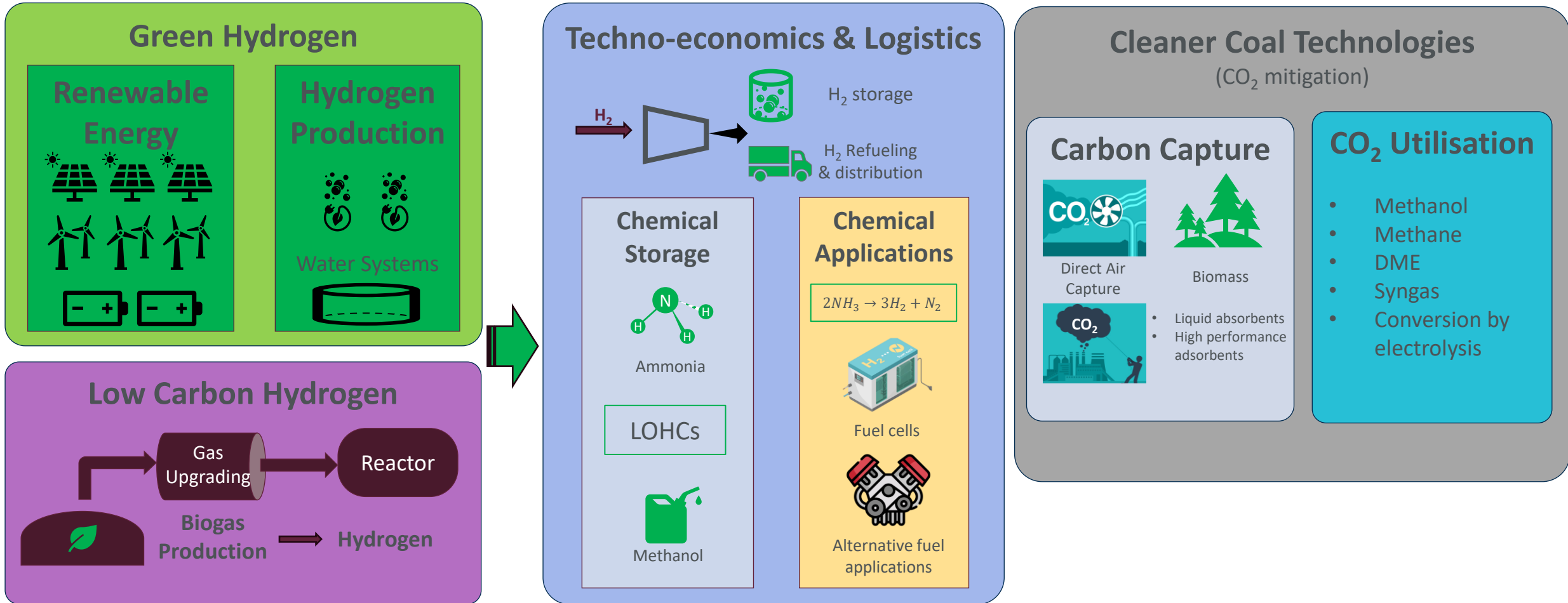
- Development of suitable pre-treatment methods for unlocking minerals in tailings
- Development of novel (Green Chemistry lixiviants) for extracting gold (cyanide replacement)



Co-ordinated capability to address gap between evolving carbon technologies and their implementation in industry

- Carbon technologies for a cleaner carbon economy: Improved carbon processes, cleaner combustion technologies and sustainable use of carbon resources
- **Carbon capture**
 - CO₂ sequestration from industrial flue gasses: From fundamentals to pilot plant scale experiments and process simulation
 - Direct air capture of CO₂
- **Carbon utilization and conversion:** Long term strategies to use captured carbon and convert to products in a sustainable way
- **Techno-economic analysis and lifecycle assessment of processes:** Illustrates real value of technologies

Hydrogen and Carbon capture



Experimental → Modelling → techno-economics

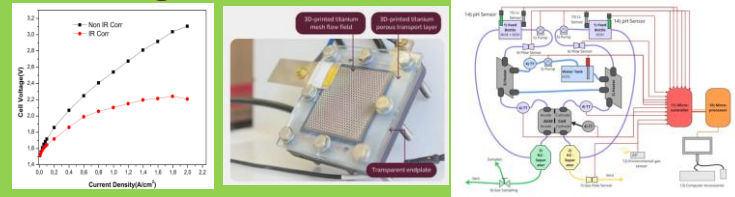
Hydrogen-related projects (experimental/modeling)

Green Hydrogen Production

- Proton exchange membrane
- Anion exchange membranes

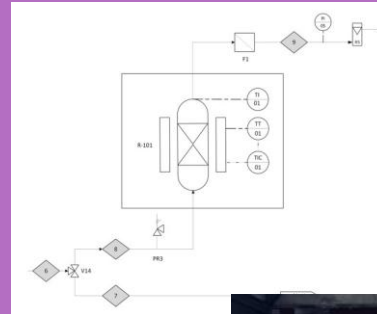


- Catalysis synthesis and testing
- Catalyst characterisation; materials manufacturing
- Single cell flow testing



Collaborators: UCT HySA Catalysis, UniZulu, Coventry University

Turquoise Hydrogen



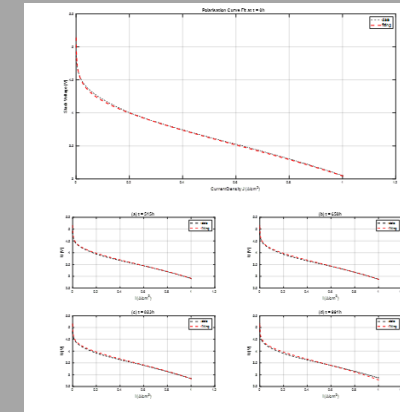
Biomethane

hydrogen

Collaborators: CSIR Future chemicals

Fuel Cell Degradation modeling

- Aging and stress tests
- Single cell → stack
- Predictive maintenance

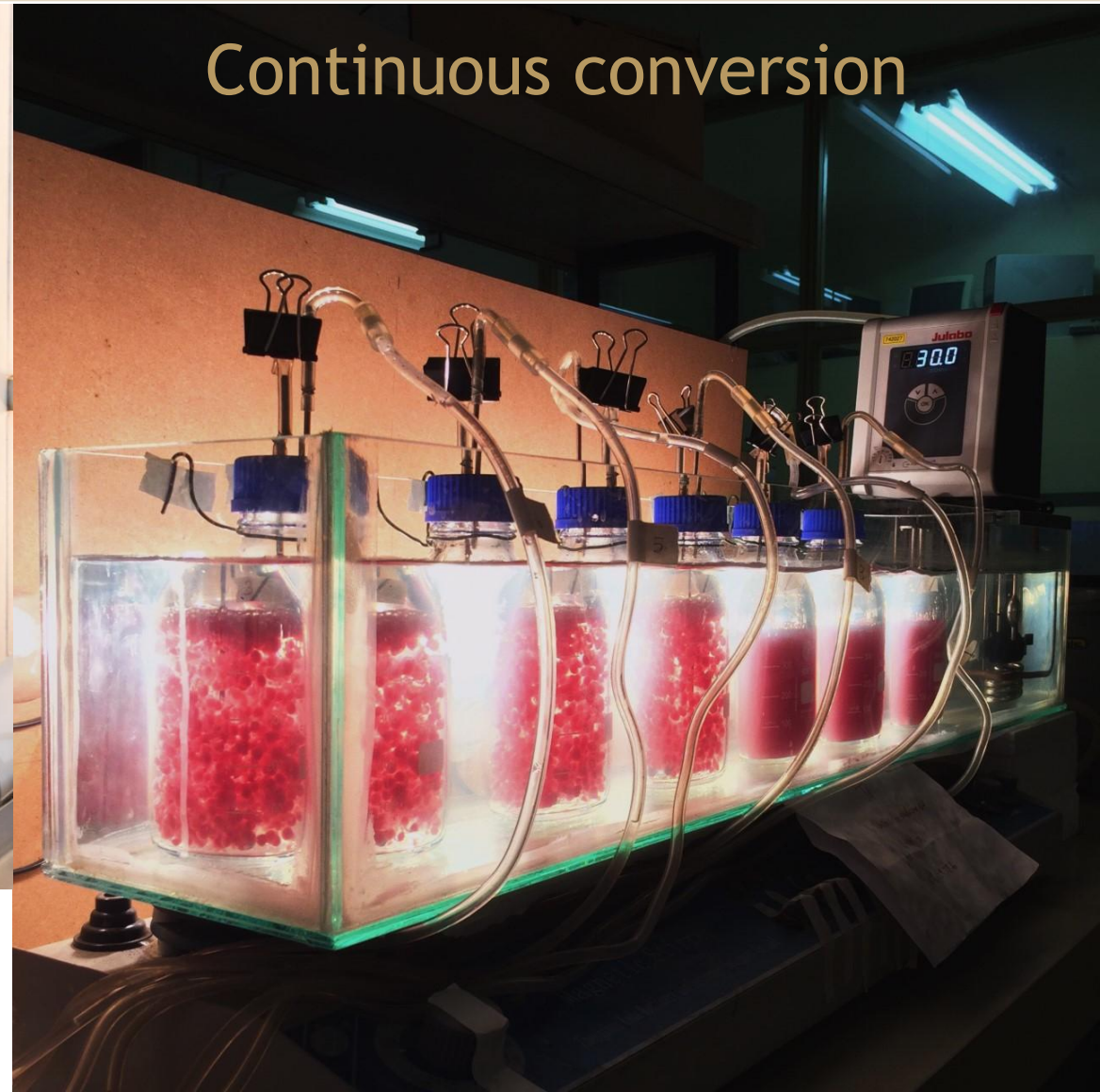


Mechanical
Thermal
Chemical
Degradation

Models to machine learning

Collaborators: School of Data Science, Coventry University, UWC HySA Systems

Biohydrogen via photofermentation



Continuous conversion

Reactor design



FOCUS AREAS

H₂GEN – Hydrogen Generation and Energy Network

The Hydrogen Generation and Energy Network (H₂GEN) at Stellenbosch University presents a platform for extending South Africa's reach in the global hydrogen economy. By leveraging the country's abundant renewable energy resources in alignment with the national green hydrogen roadmap, H₂GEN addresses critical knowledge gaps in hydrogen engineering through research across various engineering disciplines.



Thank you Enkosi Dankie

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Photo by Stefan Els