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EBRI
Energy & Bioproducts Research Institute

Sustainable and inclusive bioenergy for rice growing communities in the Philippines

Rebecca Fothergill, Craig Jamieson, Mirjam Röder

Energy and Bioproducts Research Institute Aston University, UK

Supergen Bioenergy | SUSTAINABLE BIOENERGY SYSTEMS FOR OUR LOW-CARBON FUTURE

Straw Innovations Ltd

UKRI Innovate UK

Rice straw in the Philippines

Developing a community-scale bioenergy systems

- Bioenergy from rice straw in the Philippines (Straw Innovations)
- Shifting from unsustainable straw disposal to improved agricultural practices and renewable energy production
- Develop community co-designed business models
- Enabling positive sustainability trade-offs from rice straw bioenergy

Rice straw in the Philippines

Philippines
~2.3 million hectare of paddy fields
~12.5 million tonnes of straw (wet) per year

Laguna (pilot project area)
~15k hectare of paddy fields
~83k tonnes of straw
Typical rice farm size ~1.5-2 ha

Barriers of rice straw utilisation:
- Logistics straw collection
- Rice straw fuel characteristics
- Policy support
- Lack of tested and proven business models

Co-designed technology integration

- 2 x 500 m3 dry digester facility
- Socio-economic assessment (perception of communities about rice straw use)
- Lifecycle assessment (environmental/ GHG impact)

Socio-economic assessment

Business models assessment

Current straw management practices

In-field burning of straw

OR

Straw incorporation

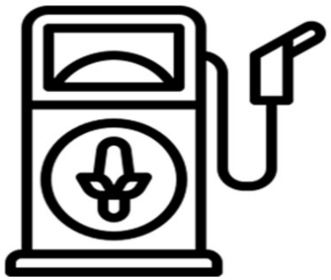
Rice straw biogas business models

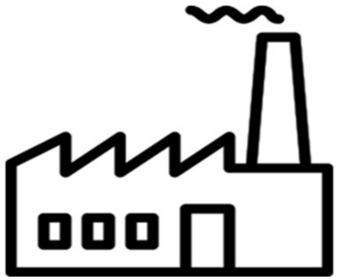
Biogas use at farm household

Biogas sold at fuel station

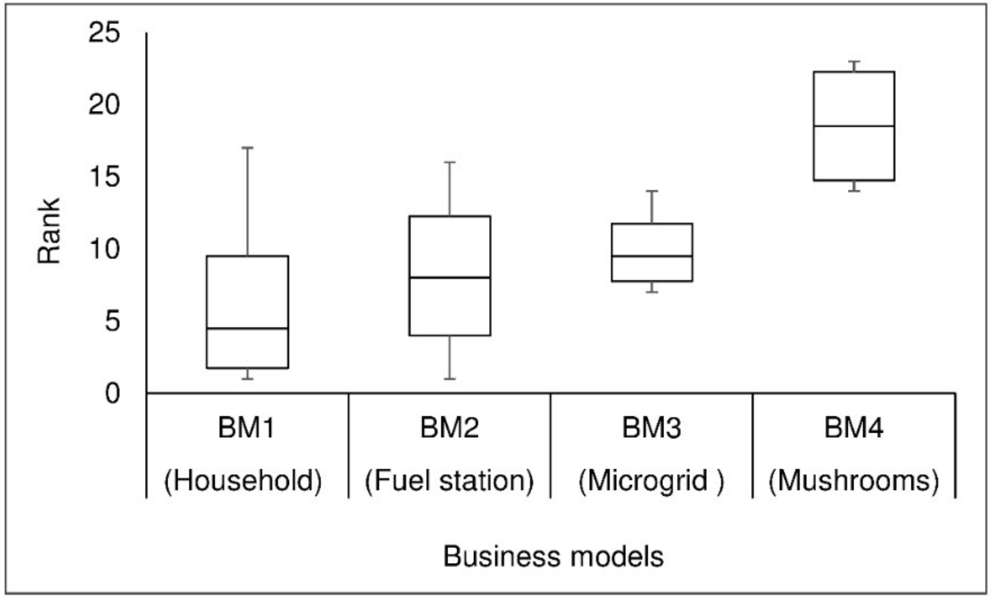
Biogas used in micro-grids

Biogas integrated with mushroom production





Farmers' preferences and acceptance



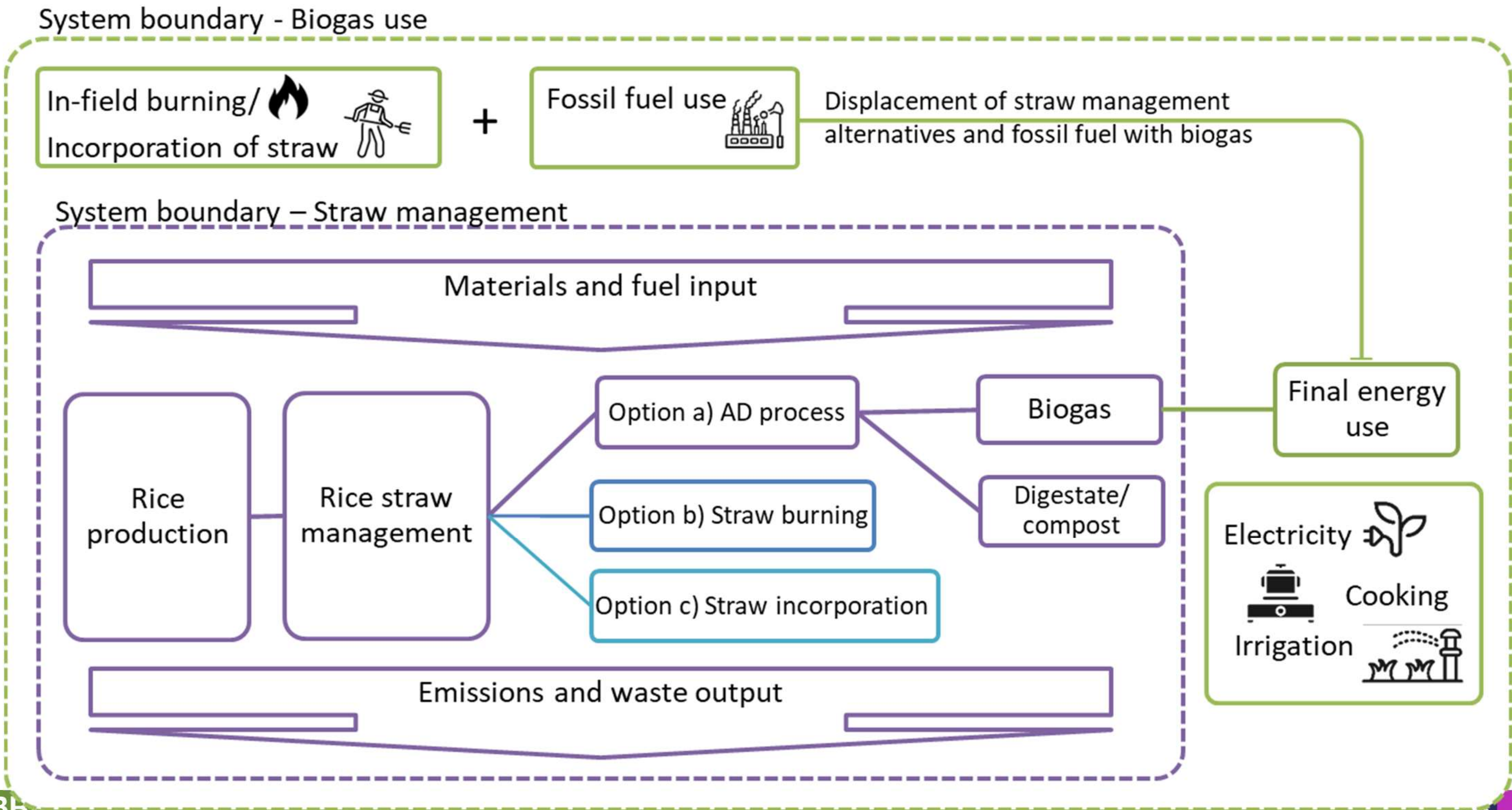
- Farmers don't want to be energy users only
- Farmers want to be part and benefit from the intervention

- **Understanding what drives stakeholders**

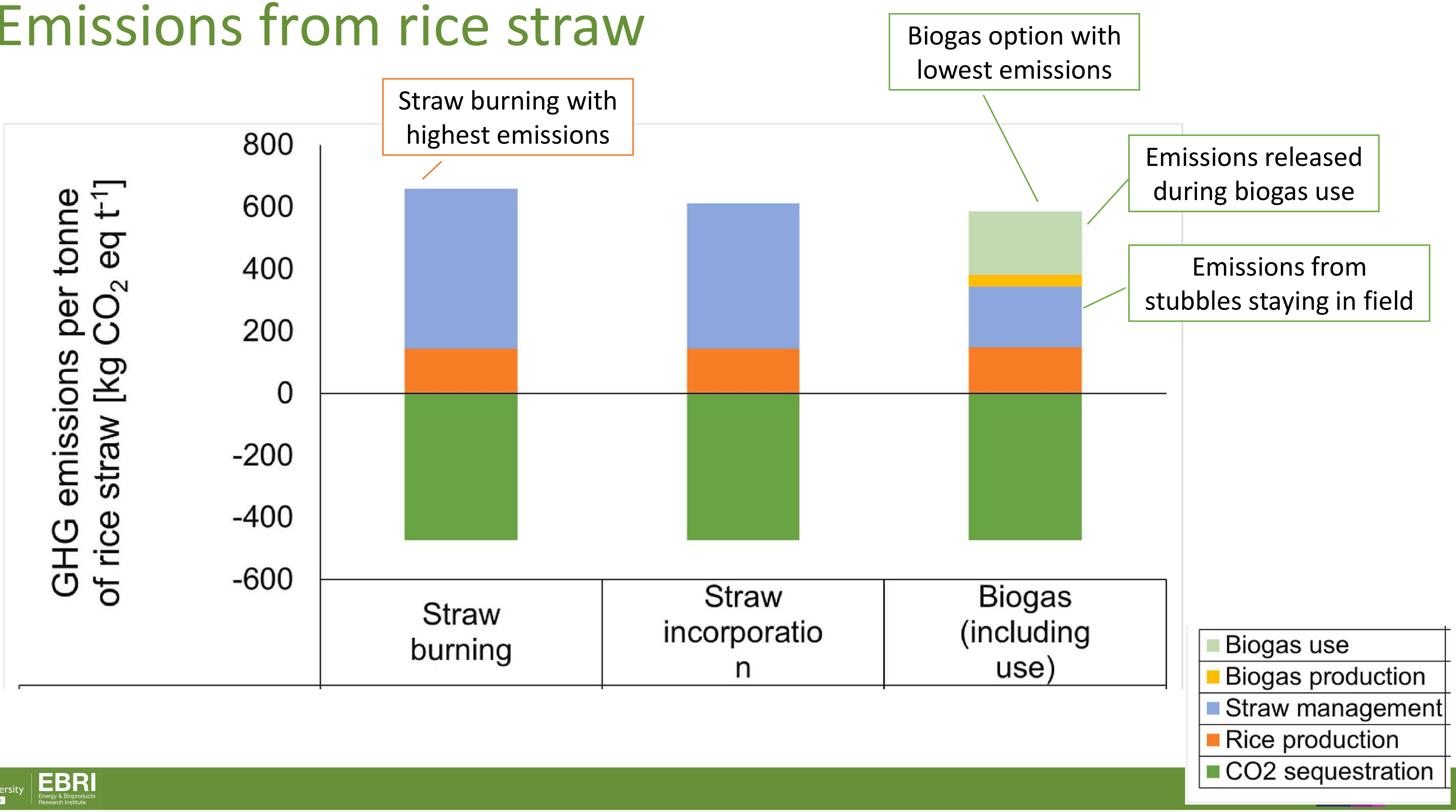
Stakeholders, drivers, perceptions

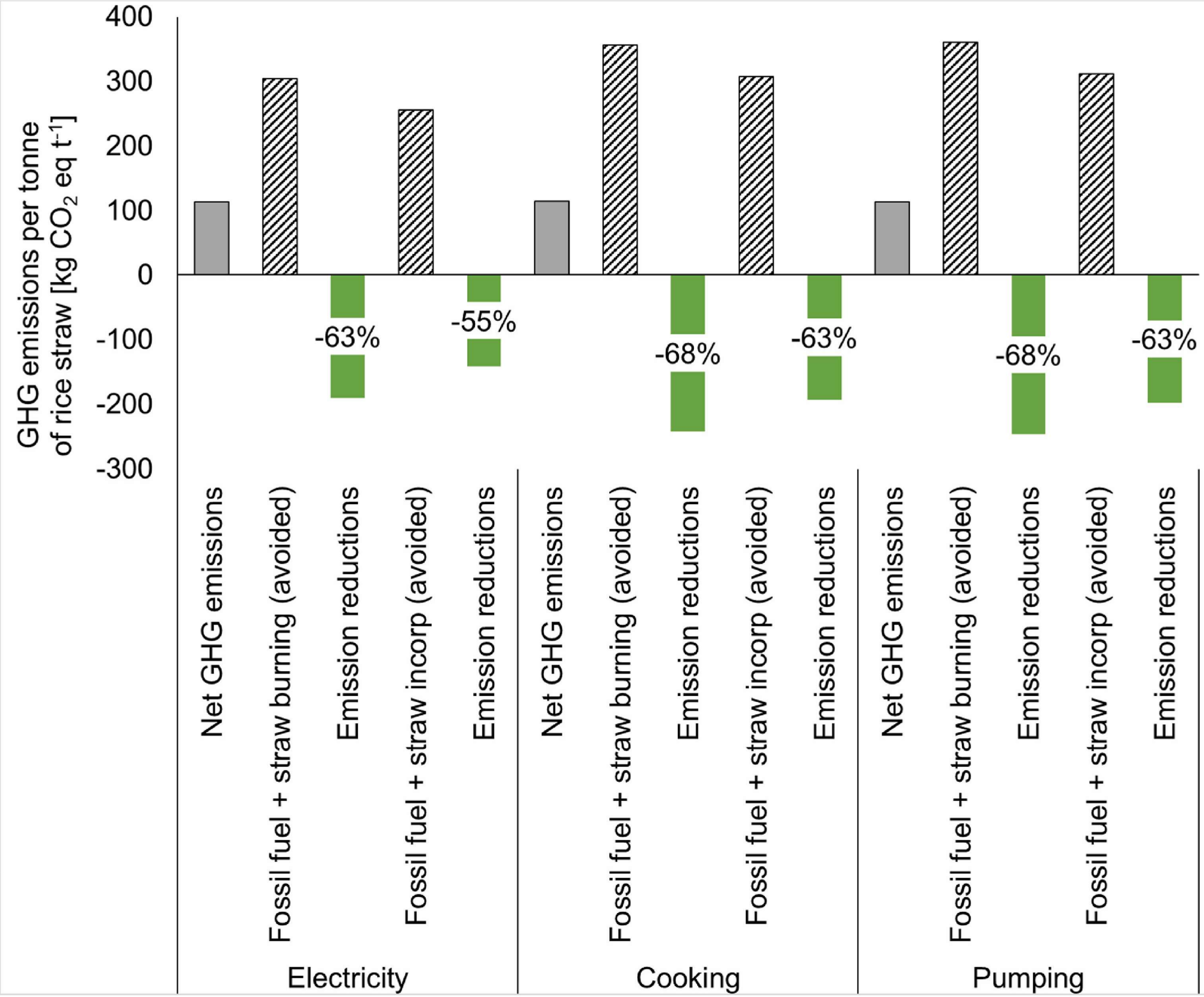
Lifecycle assessment

Rice straw biogas system



Emissions from rice straw





Electricity:

Lowest **net** emission

Lowest **relative** emissions savings

Cooking and irrigation pumping:

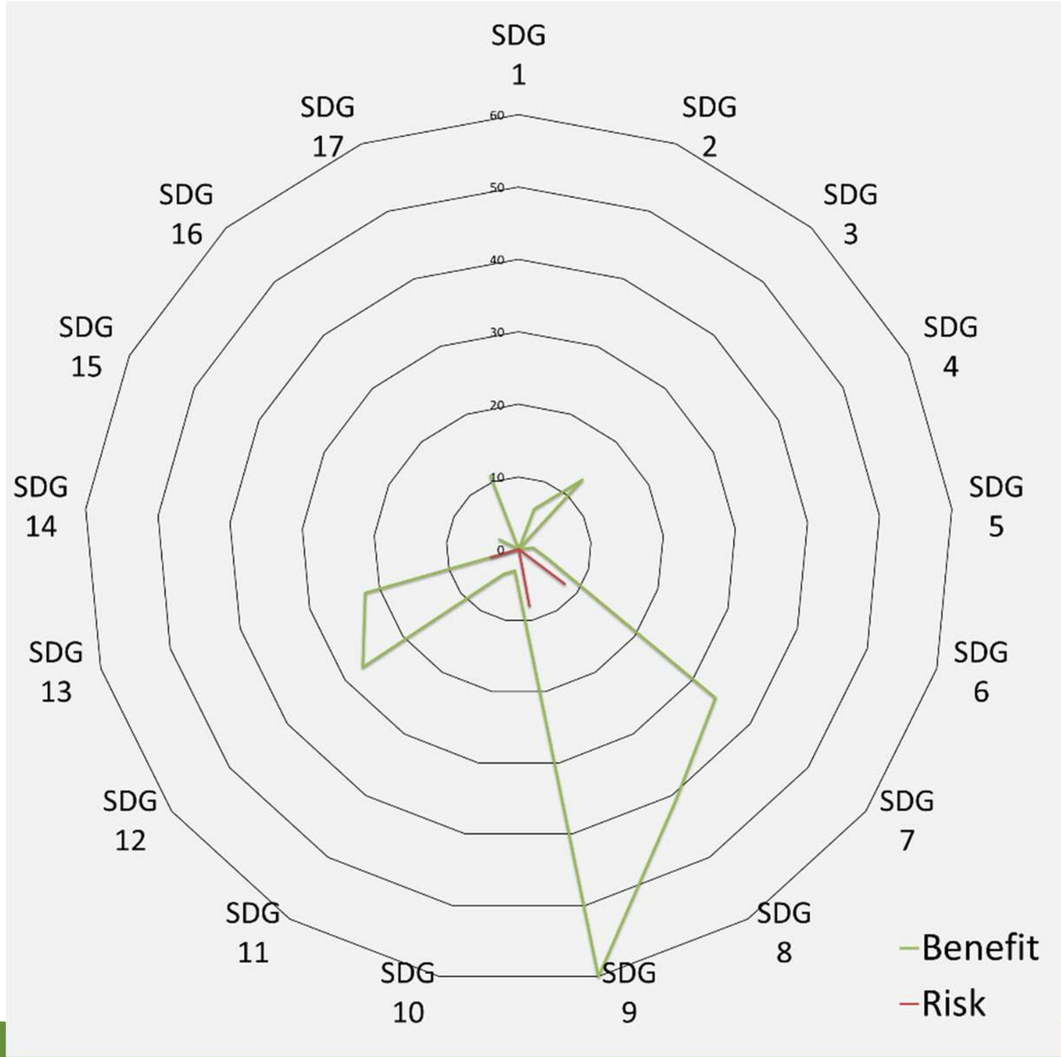
Highest **net** emission

Largest emission savings

Highest amount of avoided emissions

Sustainability mapping

Non-market values and co-benefits of rice straw bioenergy



Key message

- Utilising rice straw for energy offers various sustainability benefits
- Biogas from rice straw reduces emissions compared to current straw management (straw burning and straw incorporation) and fossil fuel use
- Community co-designed interventions offer socio-economic benefits and enable opportunities and empower people
- Benefits and opportunities will vary depending on context and perception of stakeholder group and business models
- Understanding governance frameworks is key as this will determine outcome- who makes decision and who is affected by them
- System interfaces are often complex, but offer opportunities to improve overall system performance and allow to go beyond individual sustainability indicators and maximise positive trade-offs

Contact details

Mirjam Röder
m.roeder@aston.ac.uk

Rebecca Fothergill
r.fothergill@aston.ac.uk

Energy and Bioproducts Research Institute (EBRI)
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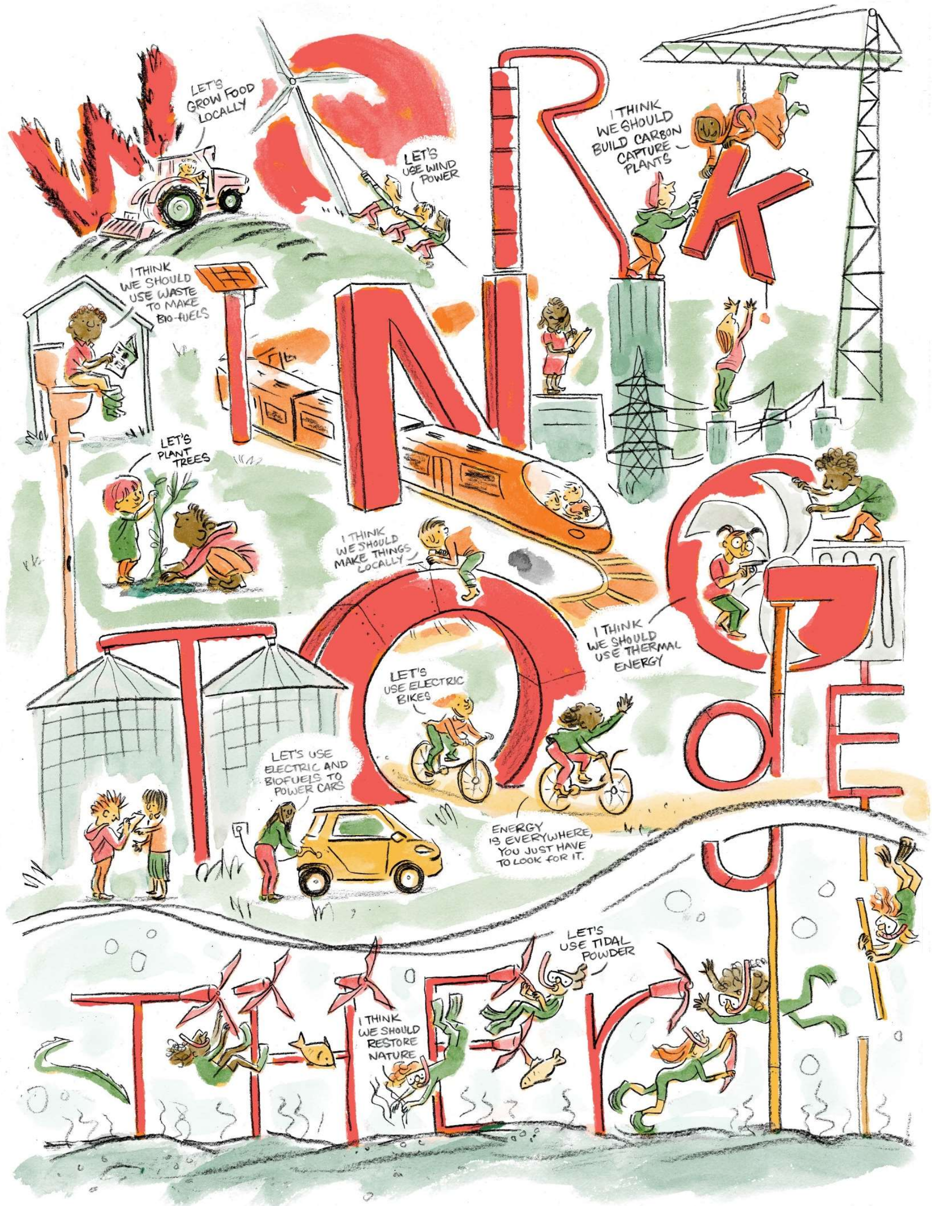


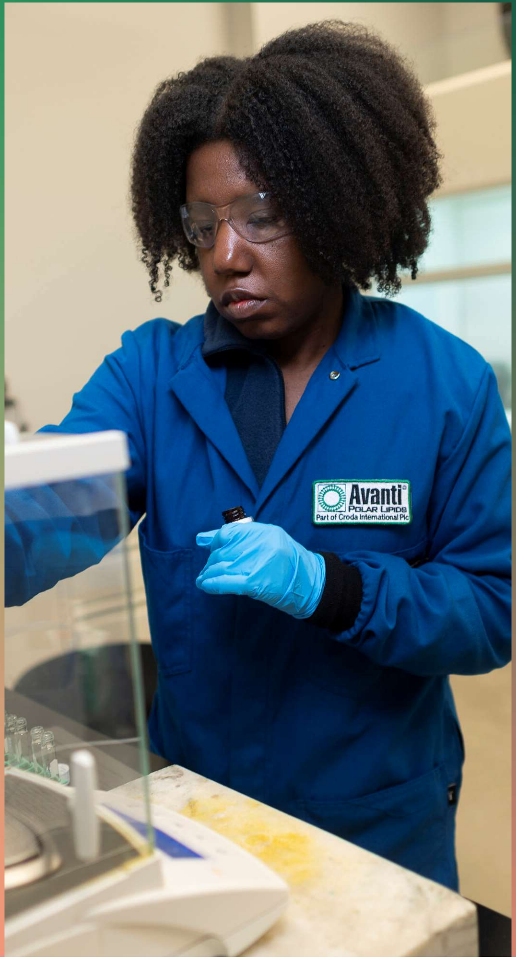
CRODA

Croda International Plc

Circular chemicals and the bioeconomy

BBNet Conference

11th April 2024



Introduction

Introduction

Sarah Davidson
Technology Development Lead

Croda Head office
Cowick, East Yorkshire, UK

Consumer Care and Life Sciences markets

Life Sciences

We reach customers worldwide with our ingredients to deliver health care solutions, protect crops and enhance seeds. From our vaccine technologies to microplastic-free seed coatings, we are using our smart science to improve lives everywhere.

- Croda Pharma
- Crop Protection
- Seed Enhancement

Consumer Care

Our smart science is helping our customers, large and small to create formulations with improved environmental profiles for thousands of personal and home care products while delivering clear benefits to consumers.

- Beauty Actives
- Beauty Care
- Home Care
- F&F

Supported by **Industrial Specialties**

Sustainability strategy

Our 2030 Commitment

We are committed to being the worlds most sustainable supplier of innovative ingredients.

We will create, make and sell solutions to tackle some of the biggest challenges the world is facing. The United Nations Sustainable Development Goals (SDGs) are the foundation of our approach.

Our priority SDGs

What does circulatory mean for chemicals?

Design
using renewable feedstocks, with end of life in mind e.g., (bio)degradability

Manufacture
maximising atom, resource & energy efficiency

Use
including consumption of chemical products

End of life
where recycling and reuse put into practise

Circularity: core to Our Commitment

Environmental Stewardship

We will protect the natural environment through the responsible management of our water consumption and waste production

Renewable feedstocks

We will accelerate the transition to biobased products, moving away from fossil/petrochemical feedstocks.

Product Stewardship

We will take a leadership role... Helping the markets in which we operate move towards more circular economies and reducing …exposure to chemical hazards.

But it gets complicated!

Consider core Croda's core product applications…

Pharmaceuticals

…these products end up in medicines, vaccines and ointments

Agrochemicals

…these products end up in the ground, or our natural environment

Consumer products

…these products are usually washed down the drain, ending up in water treatment

So how do we manage their end-of-life impact?

Circular carbon & the bioeconomy

From biomass

From CO_2

From recycled material

Biobased swaps for large volume raw materials

(Mono-)propylene glycol (MPG) is a diluent used by Croda in multiple products across multiple sites. 2023 was the first year we sourced 100% bio-based MPG for use at our manufacturing site in Spain. The move from petrochemical sourced MPG resulted in….

A **33% reduction** in the **carbon footprint** of this raw material as it reaches our gate

A reduction in our **scope 3 purchased good and services** emissions of more than **750 tonnes CO_2e** associated with purchasing this material at this site

The emission **improvements** associated with bio-MPG will be reflected in our **customers product carbon footprints** and **customers' emissions**

In 2024 we will expand our purchasing of this raw material for use at other Croda sites.

From biomass

Maria, Christina & Adelaida (part of the Croda Mevisa team)

Innovation using biobased ingredients with degradability built in

From biomass

UKRI Engineering and Physical Sciences Research Council

EPSRC Prosperity Partnership

Generating knowledge, future technology and developing people

Croda, UoY and UoN team

Polymers in Liquid Formulations

$125bn market value, enough to fill Wembley stadium 32x

Structure

Raw Material Choices, Net Zero Manufacture

Biodegradability

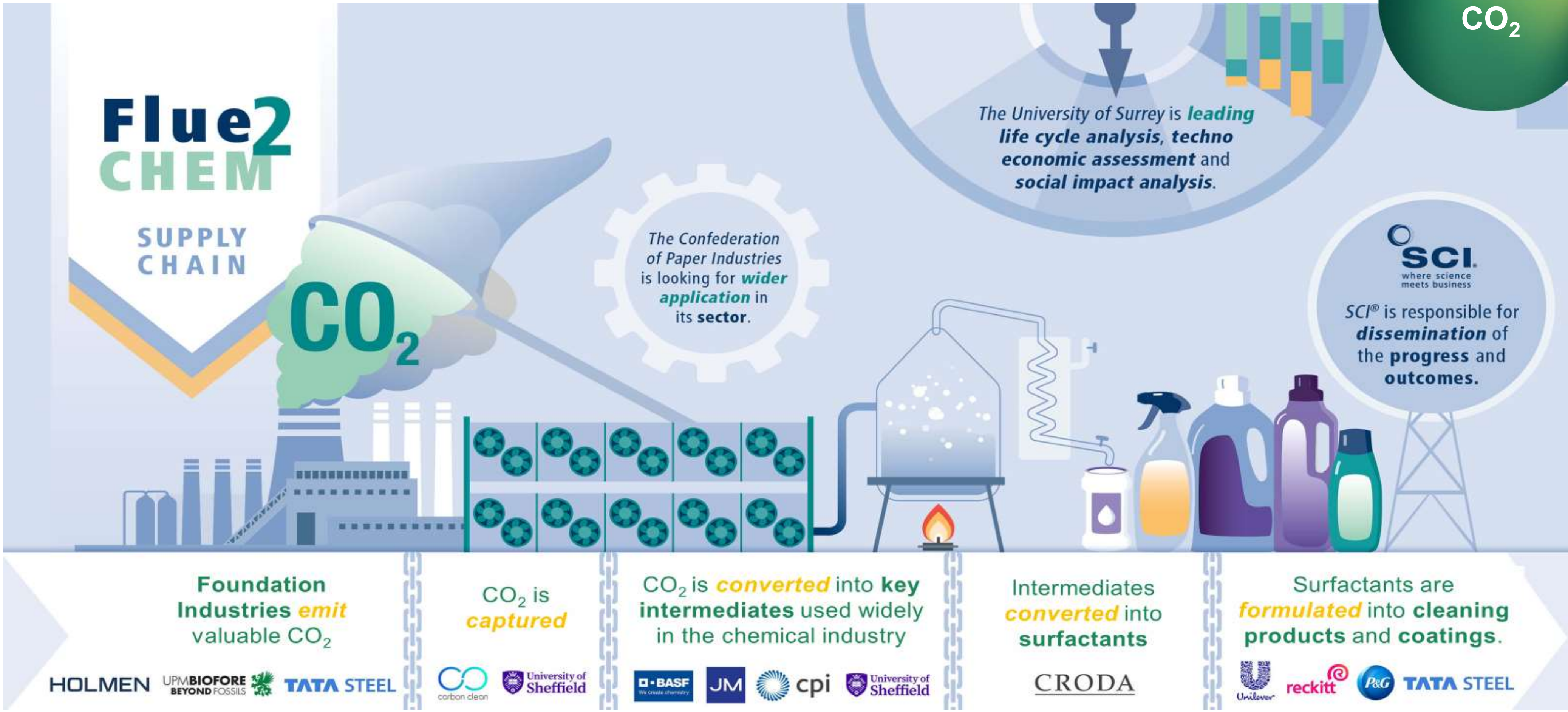
Stability vs end-of-life fate

Performance

Life Sciences & Consumer Care

Cross industry collaboration for valorisation of waste CO_2

From CO_2



Contact Information

Sarah Davidson

Technology Development Lead

On LinkedIn: https://www.linkedin.com/in/sarah-davidson-0a71b1167/

Via Email: sarah.Davidson@croda.com

CRODA

COPERNICUS INSTITUTE OF SUSTAINABLE DEVELOPMENT

Upstream sustainability of biomass feedstock

Key methodological challenges and opportunities

BBNet Conference
Sheffield, April 11th 2024

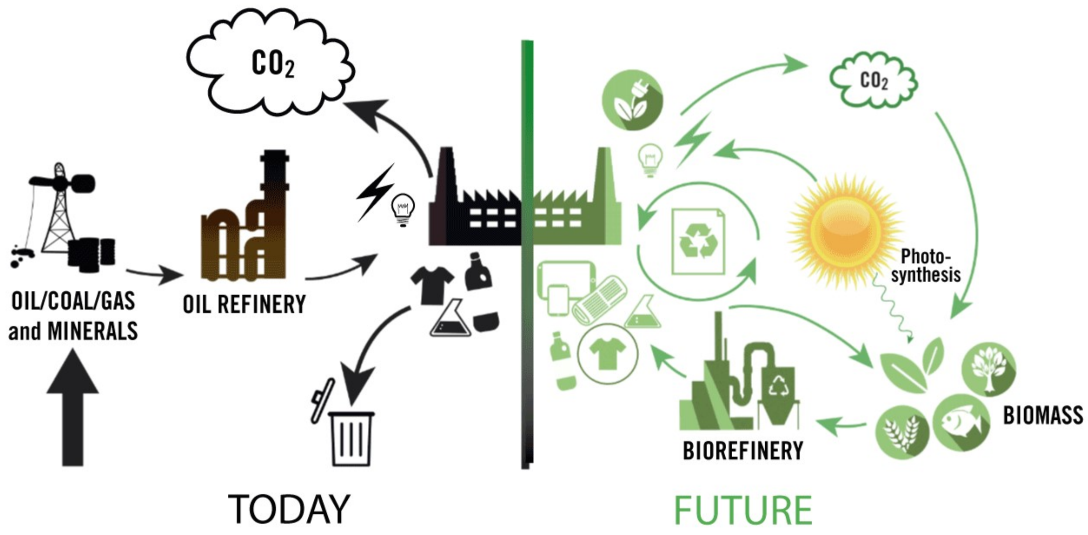
Anna Duden
Assistant Professor

Copernicus Institute of Sustainable Development - Utrecht University

Bio-economy

Sustainable economic system: biomass production/biorefining goods & services

- reduced GHG emissions
- increased rural development
- reduced dependency on energy imports
- can be reused/recycled in a circular economy model → < pollution/disposal problems



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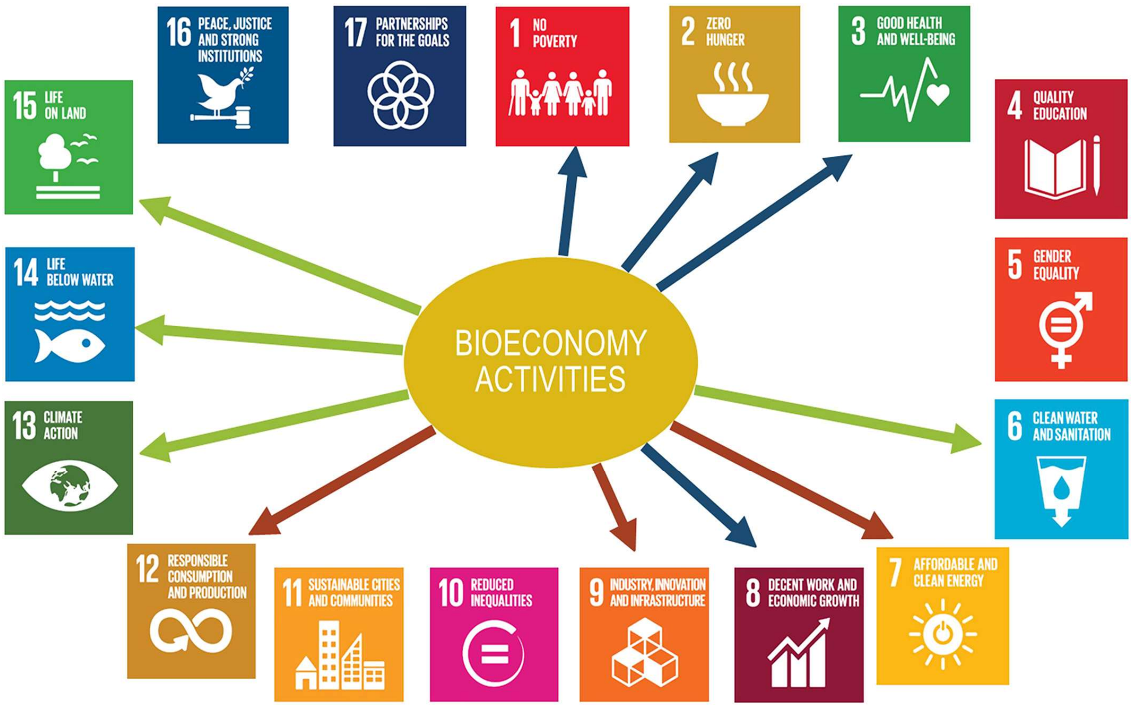
Bio-economy and SDGs

Transition towards bio-economy can reduce GHG emissions, but indirectly links to many other sustainable development goals



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Heimann, 2018

Bio-economy: sustainable biomass

Transition towards bio-economy can reduce GHG emissions, but links to many other sustainable development goals

Realizing the transition towards the bio-economy necessitates increased sourcing of biomass feedstock; for both energy and products

→ Global biomass demand expected to double between 2005 and 2050[1]

→ Increased pressure on land and water resources in sourcing region

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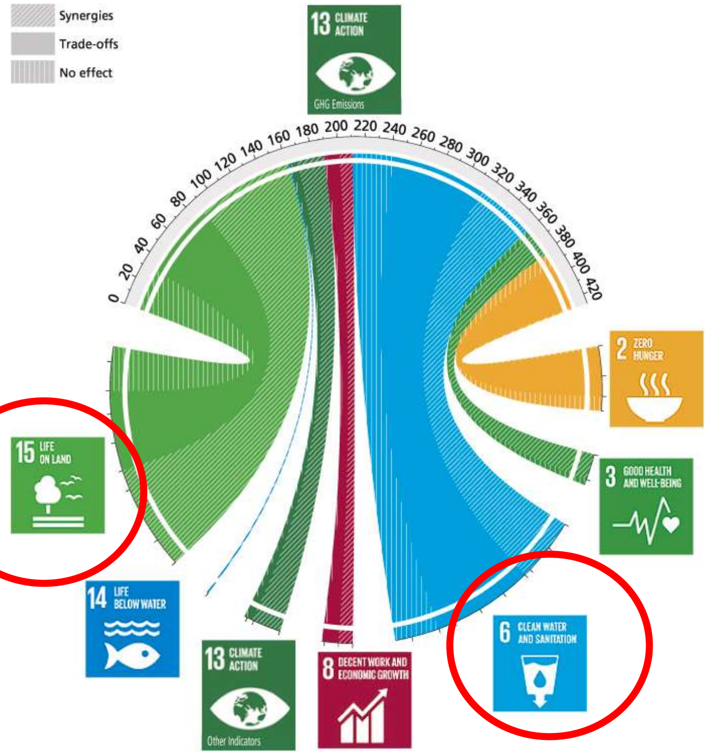
Mauser et al., 2015

Bio-economy and SDGs

Review: land used for dedicated energy crops - effects on climate change mitigation on one hand and other SDGs on the other

SDGS show synergies and trade-offs, especially for SDGs 6 and 15

Biodiversity and life on land



Availability and quality of water

Vera ***et al.,*** 2022

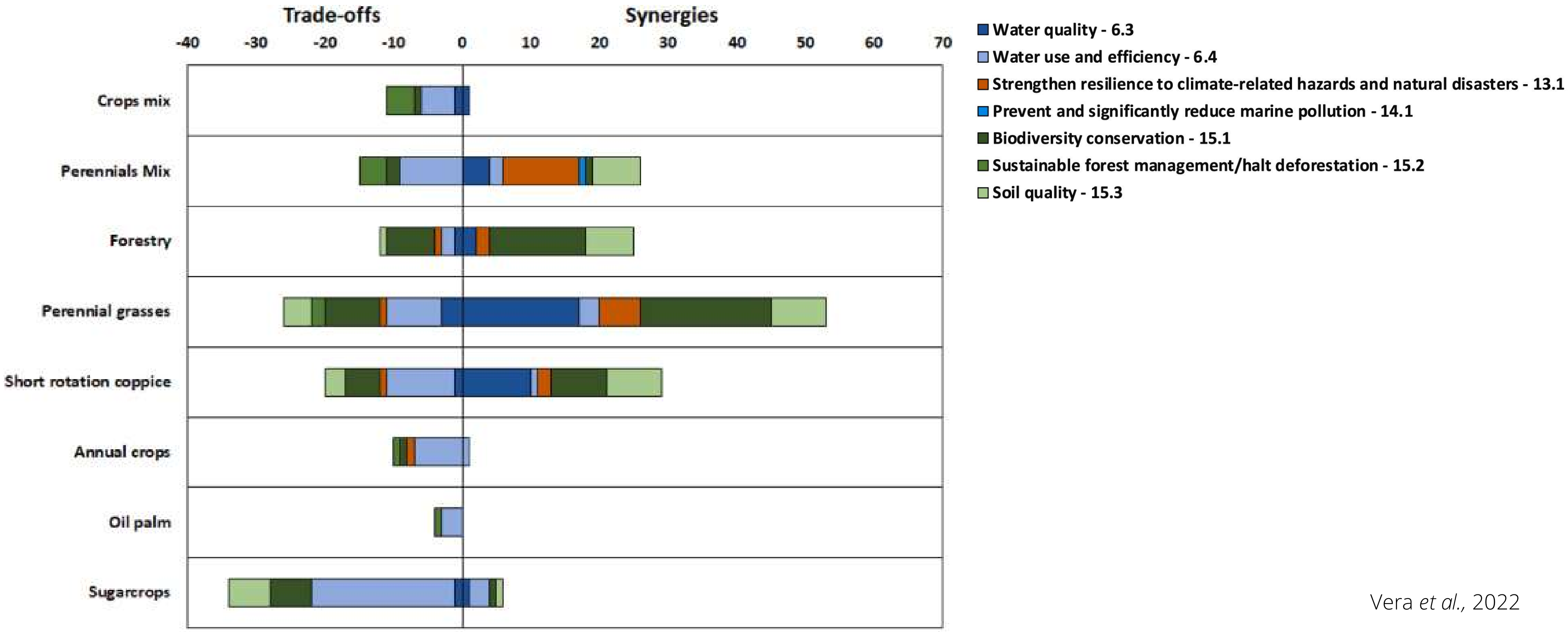
Utrecht University

Synergies and trade-offs

Trade-offs and synergies: differ per feedstock and land-use type

→ Perennial crops: more synergies

→ Oil palm/sugar crops/annual crops: more trade-offs



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Vera *et al.*, 2022

Sustainable biomass feedstocks

- The bio-economy necessitates increased sourcing of biomass, which can result in both positive and negative sustainability impacts.

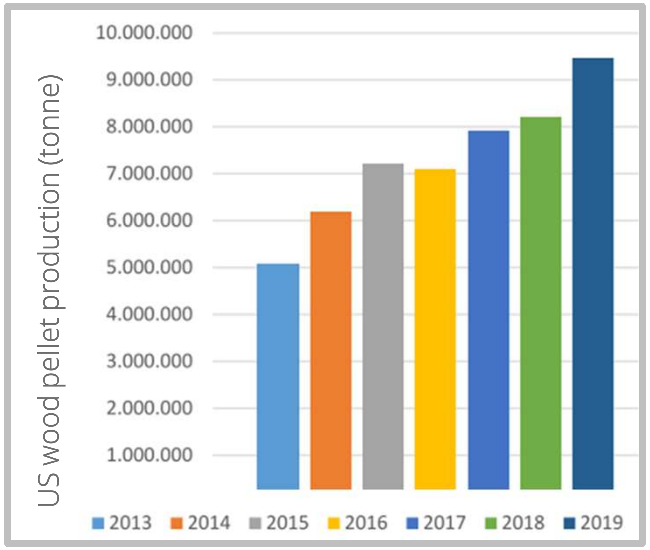
- Impacts of increased biomass demand occur in the sourcing landscape and are context specific and therefore spatially variable.

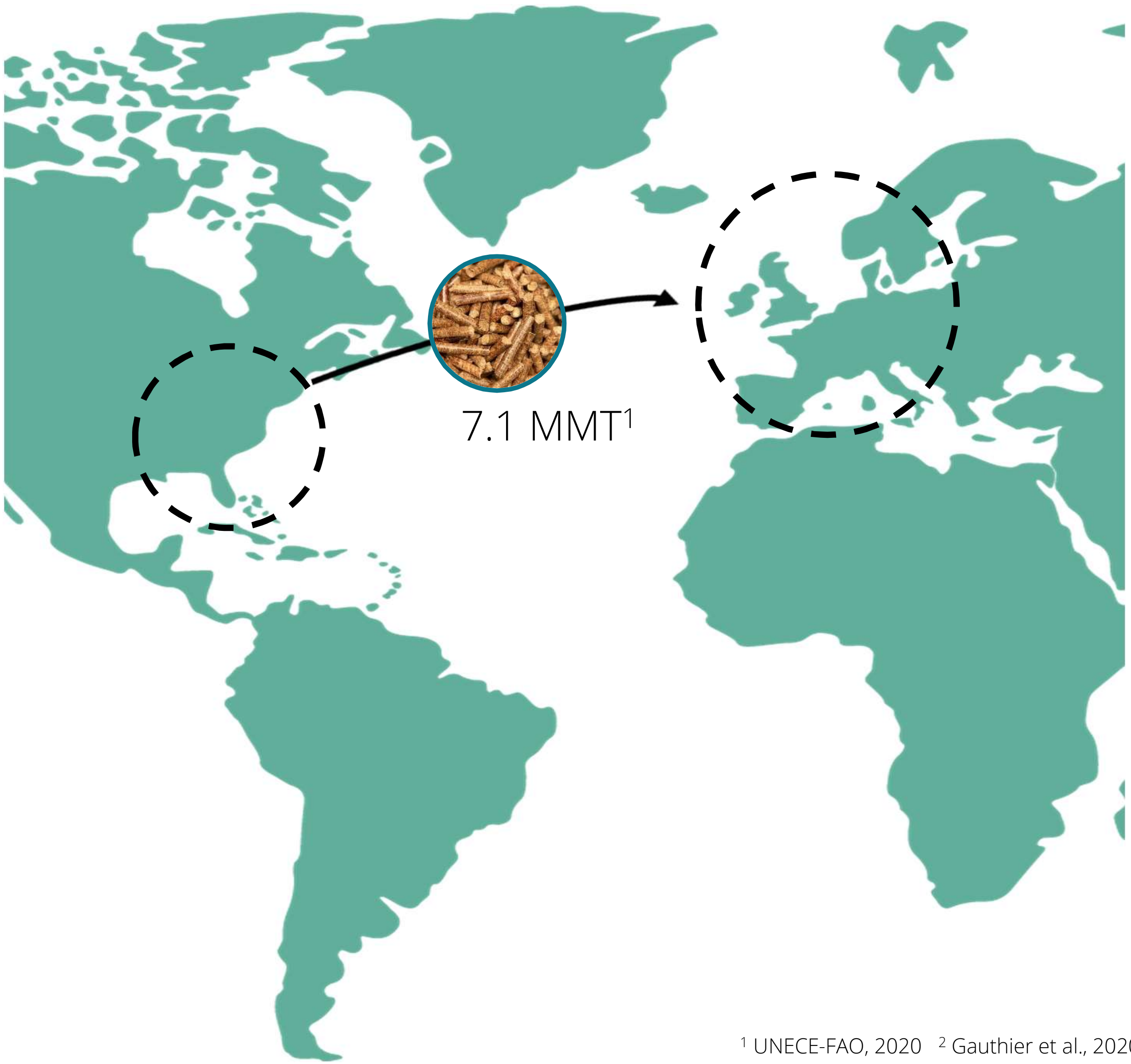
How can we quantify the ex-ante impacts of increased biomass demand?

→ Case study: impacts of increased European demand for wood pellets from the Southeastern US

Wood pellet demand

- ❖ Industrial pellets: co-firing in coal power plants
- ❖ Europe main consumer – imports largely from US[1]
- ❖ Increased demand – almost doubled 2013-2019[2]





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[1] UNECE-FAO, 2020 [2] Gauthier et al., 2020

Wood pellet production - Southeastern US

- Southeastern region US: 98% of exported wood pellets US [1]
- High forest cover: 740.000 km^2 of timberland [2]
- About 25% of timberland area is pine plantation [2]
- Part of the region biodiversity hotspot[3], largest carbon sink in the US[4]

→ Concerns about sustainability of increased wood pellet production

[1] Wang et al., 2015, [2] FIA, 2017,[3] Noss et al., 2015, [4] Chen et al., 2006

Wood pellets: problem or solution?

Different outcomes scientific studies: different scope and methods
→ Market effects & indirect land-use effects[1,2], potential forest expansion[3] often not included in scope of analyses

Interconnectedness of wood markets and land uses in SE US
Spatial variation feedstock, land-use change, carbon stocks, biodiversity
→ Integrated spatial assessment, including indirect effects of market and land-use change

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[1] Buchholz et al., 2016 [2] Wang, 2015 [3] Kim et al., 2018

Environmental impacts of wood pellet sourcing

Aim: quantify potential future impact of increased wood pellet demand on carbon stocks and biodiversity in the Southeastern US

Approach:

❖ Scenarios between 2010 and 2030

❖ Spatially explicit combined modeling

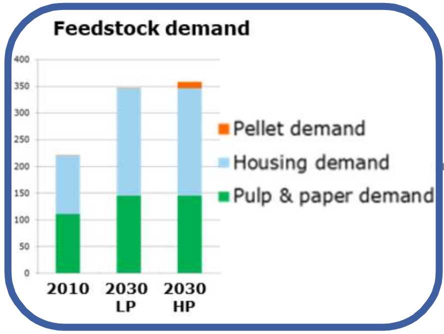
→ Include market effects

→ Include indirect land-use change

❖ Impact on carbon in biomass and soil & biodiversity

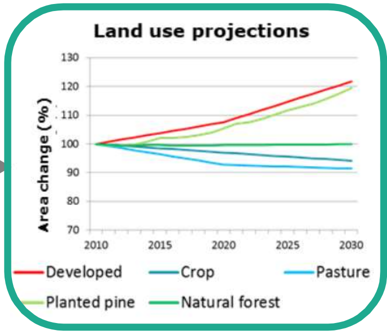
Approach: combined modelling study

Wood pellet demand scenarios



1

Timberland projections

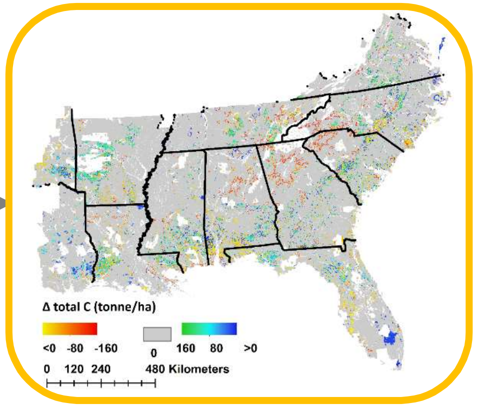


2

Land-use change

3

Carbon storage change



1. Wood pellet demand → forest area
Economic model: SRTS (NC State University)

2. Forest area & other LU demand → LUC
LUC model: PLUC (UU)

3. LUC → Δ carbon storage
Spatial calculation: IPCC equations in Arcpy

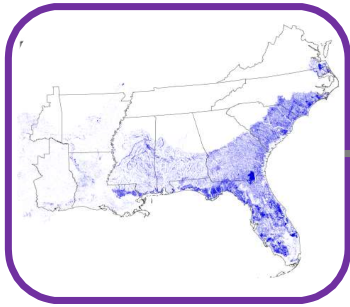
4. LUC → Δ species richness index
Neighbourhood analysis in Python

Land use	Climate zone	C in AGB (tonnes ha^{-1})
Forest	All	32.5 – 52.4
		23.9 – 65.7
		31.2 – 64.9
		14.4 – 77.0
		33.3 – 71.8
Cropland	All	4.7[1]
	Temperate moist	63
	Tropical moist	21
Grassland	Warm Temperate – Wet	1.3[1]
	Tropical - Moist & Wet	2.9[1]
Urban	All	0

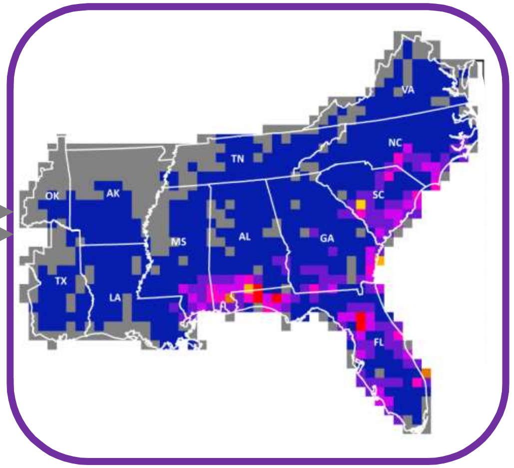
Carbon stock data

Potential species richness change

4



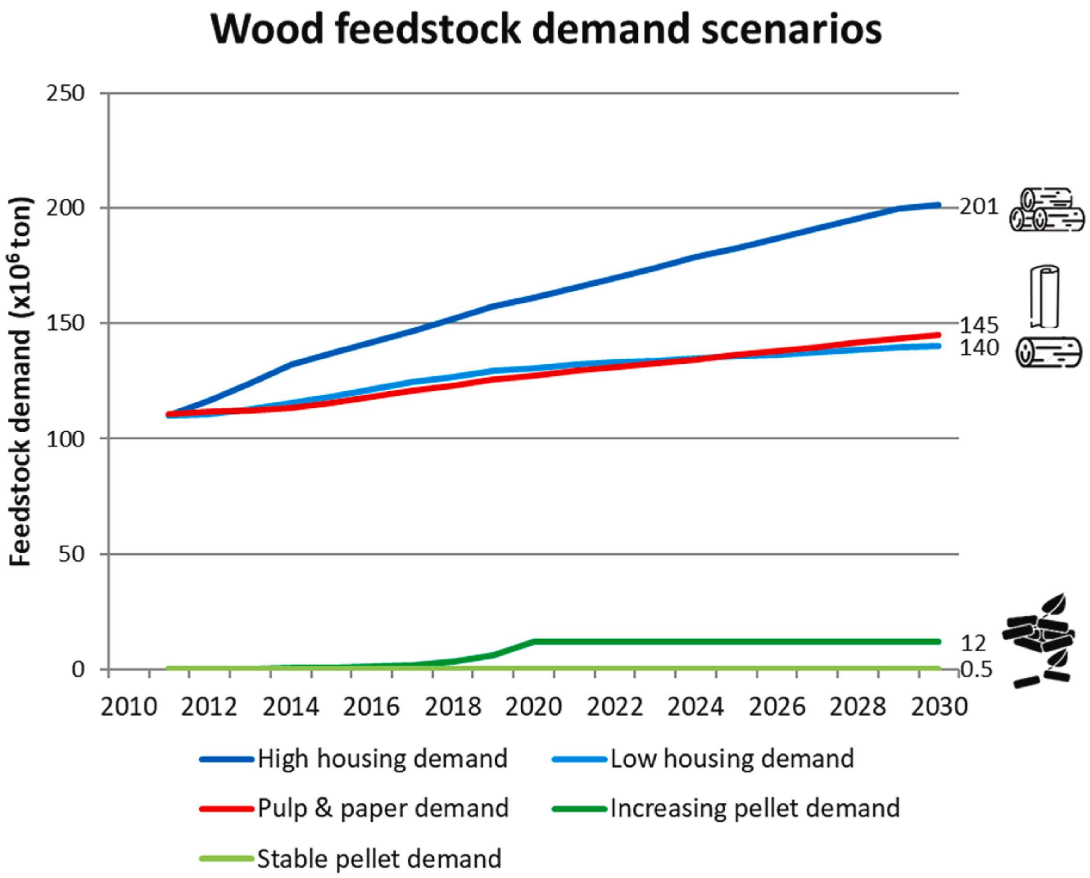
Potential species habitat



Carbon stock impacts: southeastern US

Increased demand for wood pellets & other wood products SE US

- low: 0.5 Mt
- high: 12 Mt



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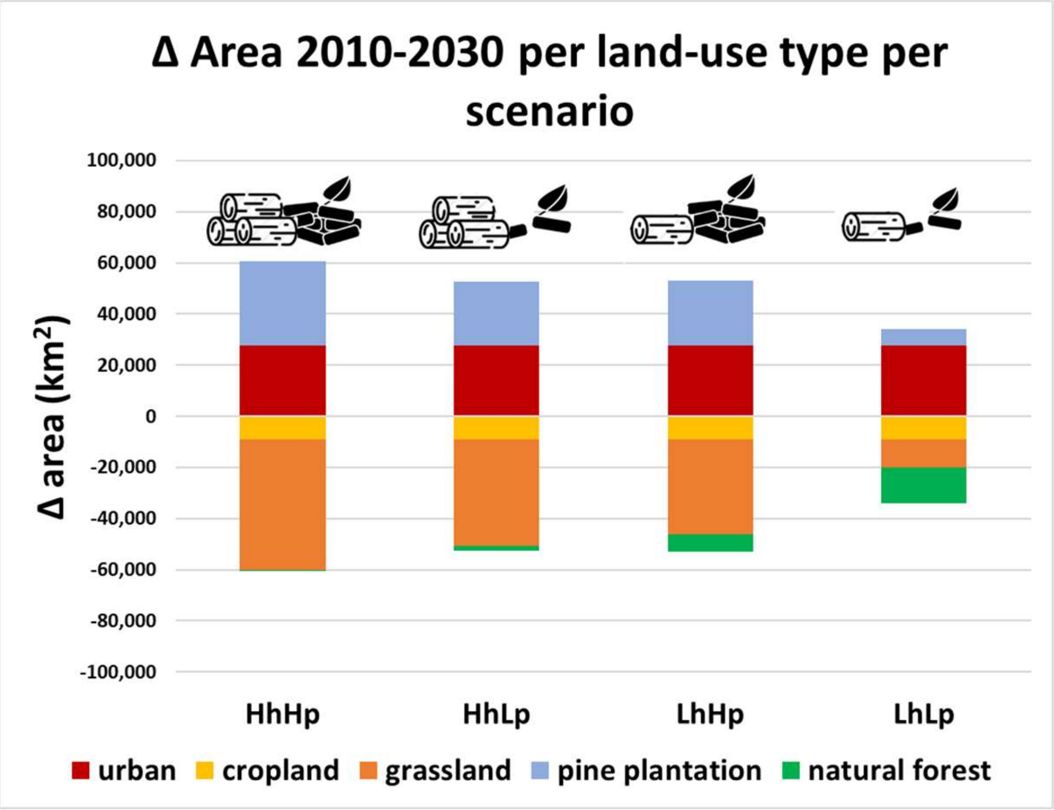
Duden et al., 2023

SRTS & PLUC

Increased wood pellet demand → increased forest rent

Changes in land use between 2010 and 2030 in the different scenarios

- More pine plantation in the high pellet demand scenarios
- More loss of natural forest in the low housing demand scenarios
- Urbanization in all scenarios



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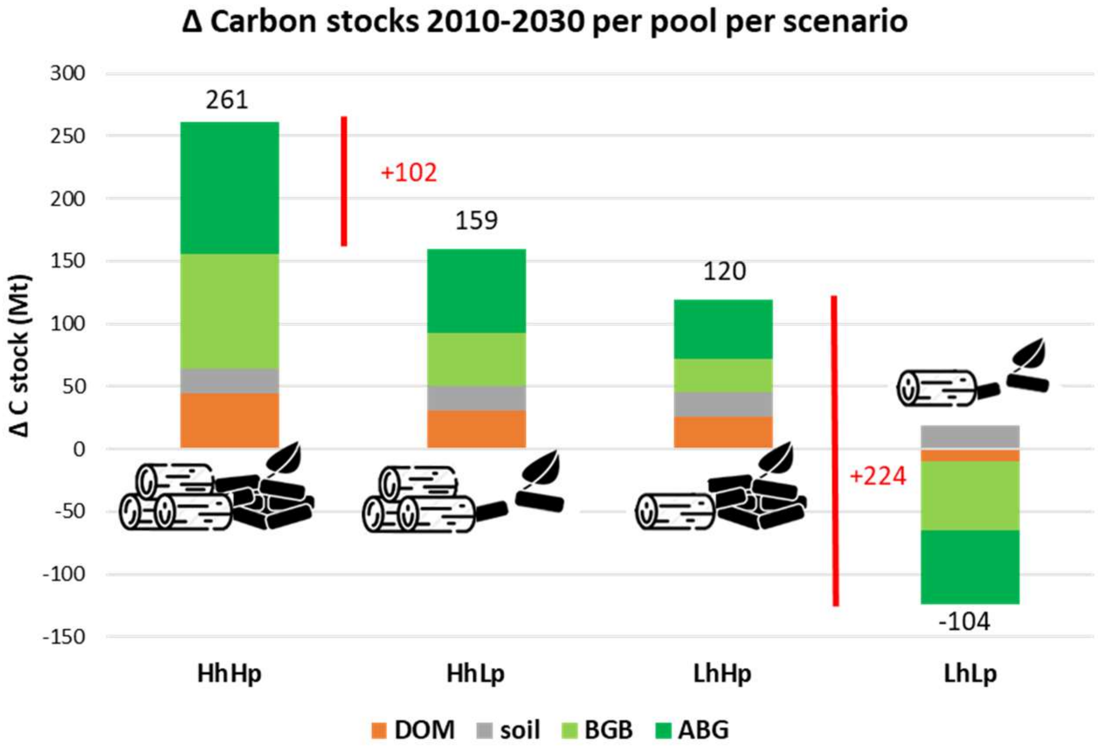
Carbon stock impacts

Increased demand for biomass can result in more carbon stored in biomass in the sourcing region….



Duden *et al.*, 2023

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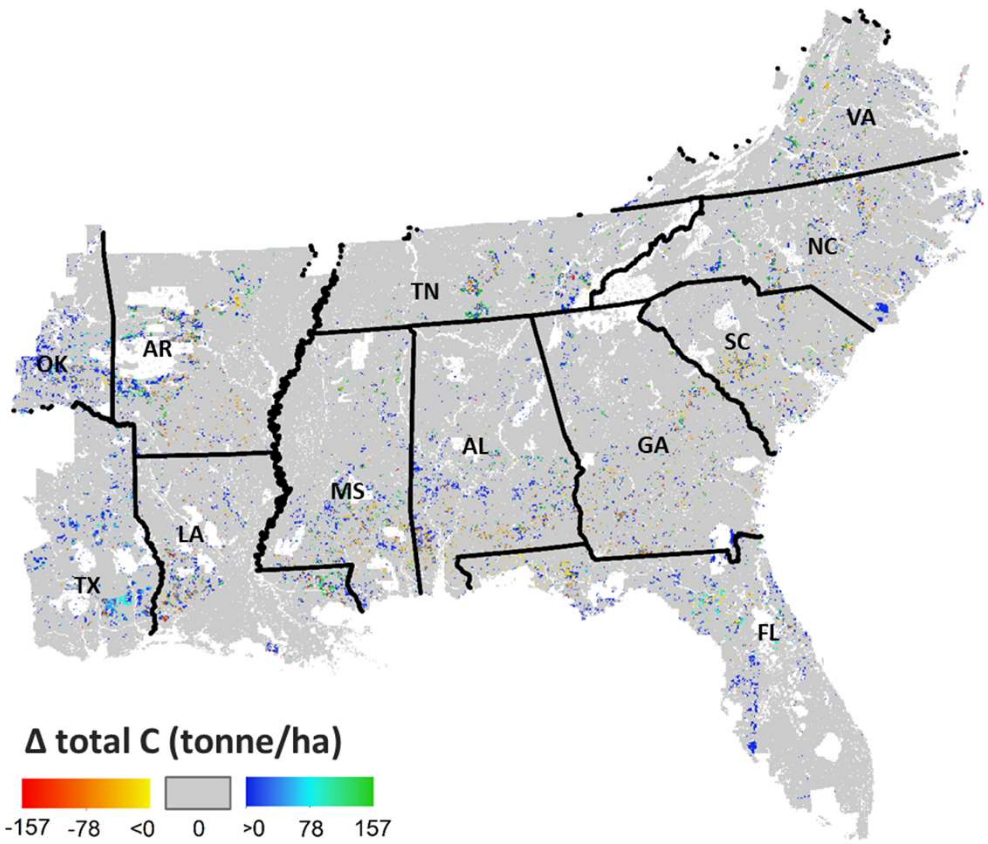
Carbon stock impacts

… but these carbon stock changes show a lot of spatial variation



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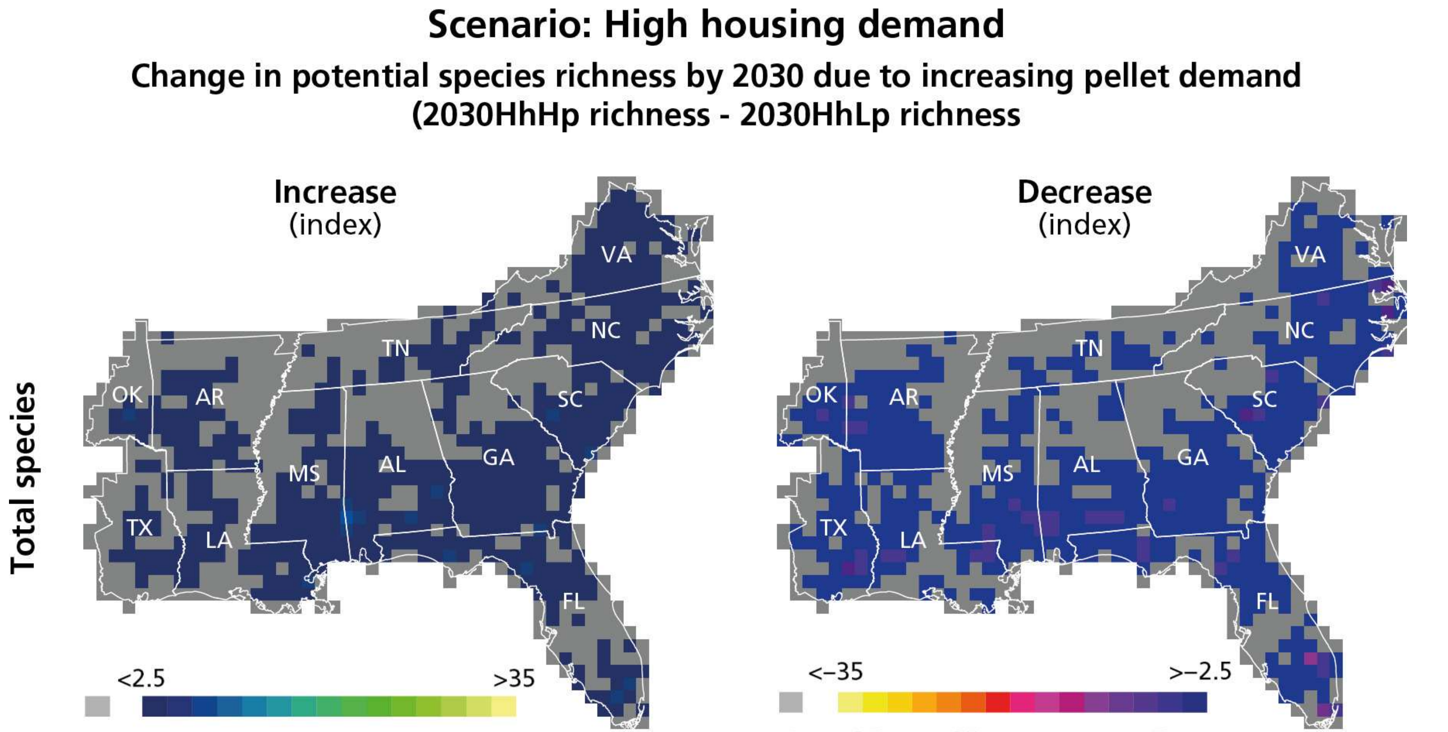
Dude *et al.*,n, 2023

Biodiversity impacts

… and biodiversity shows both positive and negative impacts



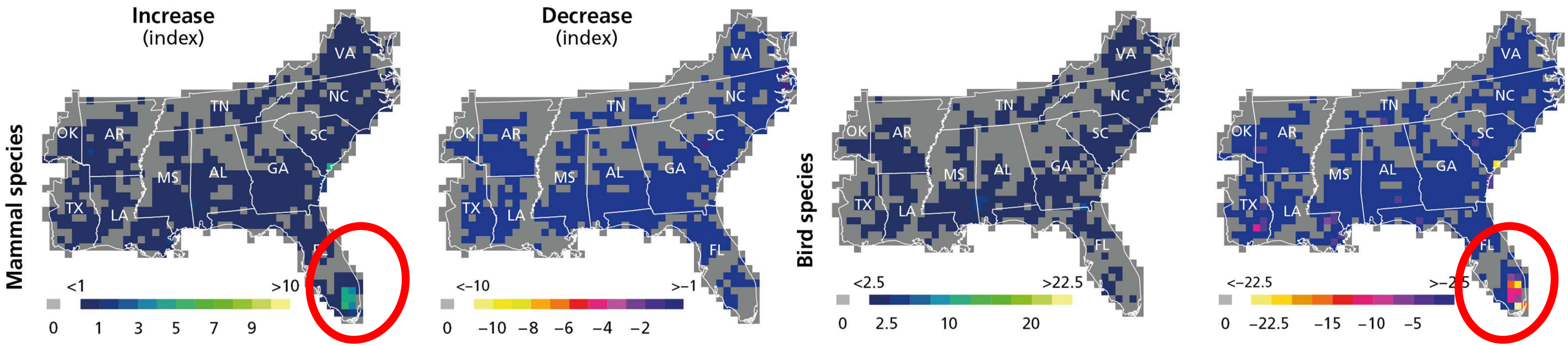
Duden, 2018

Biodiversity impacts

… biodiversity impacts depend on the indicator used: trade-offs within SDG

Scenario: High housing demand

Change in potential species richness by 2030 due to increasing pellet demand (2030HhHp richness - 2030HhLp richness



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Duden, 2018

Future challenges

Summary of findings:

- We can quantify and project sustainability impacts of increased biomass demand in a spatially explicit manner
  - developed and applied multiple approaches
  - ex-ante and spatially explicit assessment
  - including indirect land-use changes
- Trade-offs between and even within impact categories (SDGs) exist

Next steps: Integrate sourcing region and value chain impacts

→ Assess value chain impacts (including negative emissions) for BECCS

→ Introduce spatially explicit impact assessments in LCA for biobased products

Future challenges: BECCS value chain

Environmental impact assessment across BECCS value chain

- ❖ Assessment of social, environmental (soil, water, carbon, biodiversity) impacts of feedstock sourcing and carbon impacts along the value chain
- ❖ 2 junior researchers, 1 visiting PhD and 3 master students
- ❖ Collaboration with Solidaridad









Future challenges: Dynamic LCA

EU Horizon project ESCIB

- Lead a work package on the integration of spatially explicit land-use modeling and impact assessment into LCA methodology
- 2 PhDs
- Collaboration UU, Ghent University, WIP Munich, TUM, DAI, VTT
- 6 Industry partners; chemicals, textiles, building materials, packaging





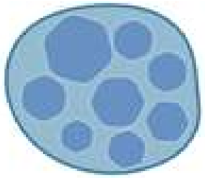


Thank you for your attention!

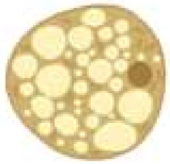
Utrecht University

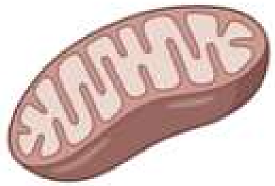
Sharing science, *shaping tomorrow*

- Questions?
- Contact: a.s.duden@uu.nl



Synthetic Organelles





From lignocellulosic waste to chemical wealth

Mauro Adriel Rinaldi PhD SFHEA MRSB

3rd BBNet Conference

11 April 2024

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Toxicity limits titres

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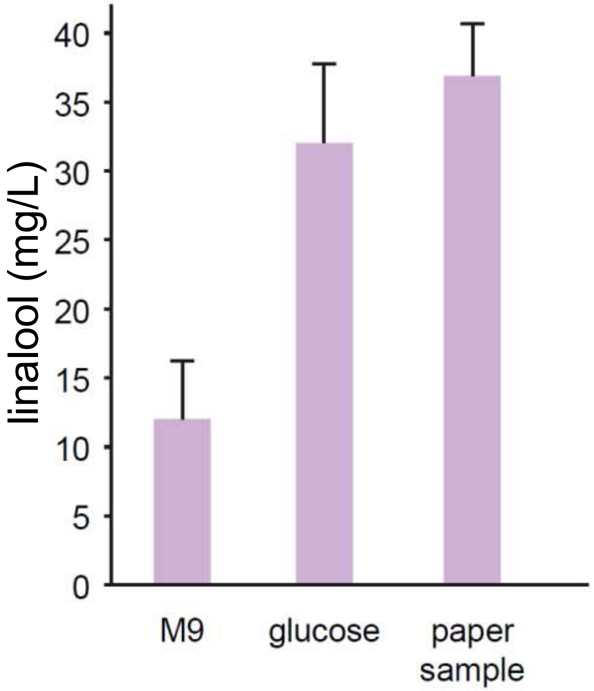
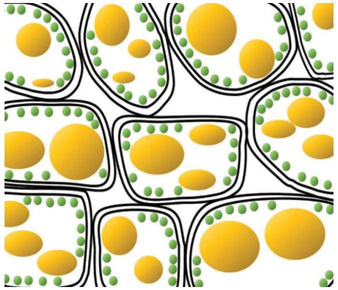


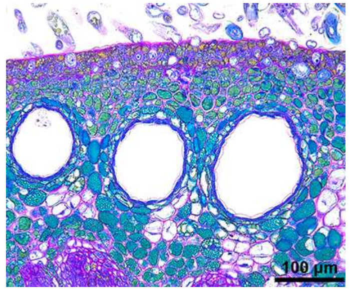
Rinaldi *et al.* 2022 Front Bioeng Biotech

Terpenoid	Highest reported titre (g/L culture)
Hemiterpenoids	
Isoprene	60
Isoprenol	10.8
Monoterpenoids	
Limonene	3.65*
Sabinene	2.65
Geraniol	2.124
Linalool	1.523
a-Pinene	0.97
1,8-Cineole	0.653
Sesquiterpenoids	
Amorphadiene	30
Viridiflorol	25.7
b-Farnesene	10 .67
(-)-a-Bisabolol	9.1
Diterpenoids	
Sclareol	1.46
Taxadiene	1.02
Triterpenoids	
Squalene	0.612
Tetraterpenoids	
Lycopene	448 mg/g DCW
b-Carotene	3.6
Astaxanthin	1.18
Zeaxanthin	0.722

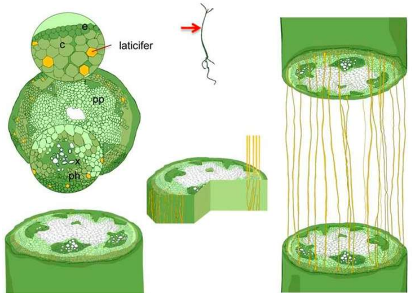
Rinaldi *et al.* 2022 Nat Prod Rev



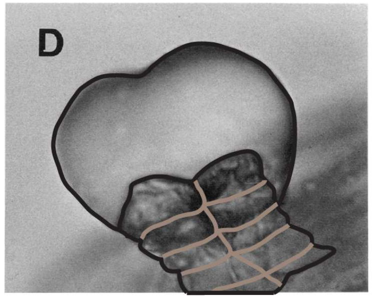
Liverwort oil bodies



Secretory ducts and cavities



Laticifers



Glandular secretory trichomes

Lange 2015 Annu Rev Plant Biol,
De Barros et al., 2017 Acta Bot Bras,
Castelblanque *et al.*, 2016 Plant Phys,
Ferreira and Janick 1995 Int J Plant Sci

Synthetic organelles for high-value chemical biomanufacturing

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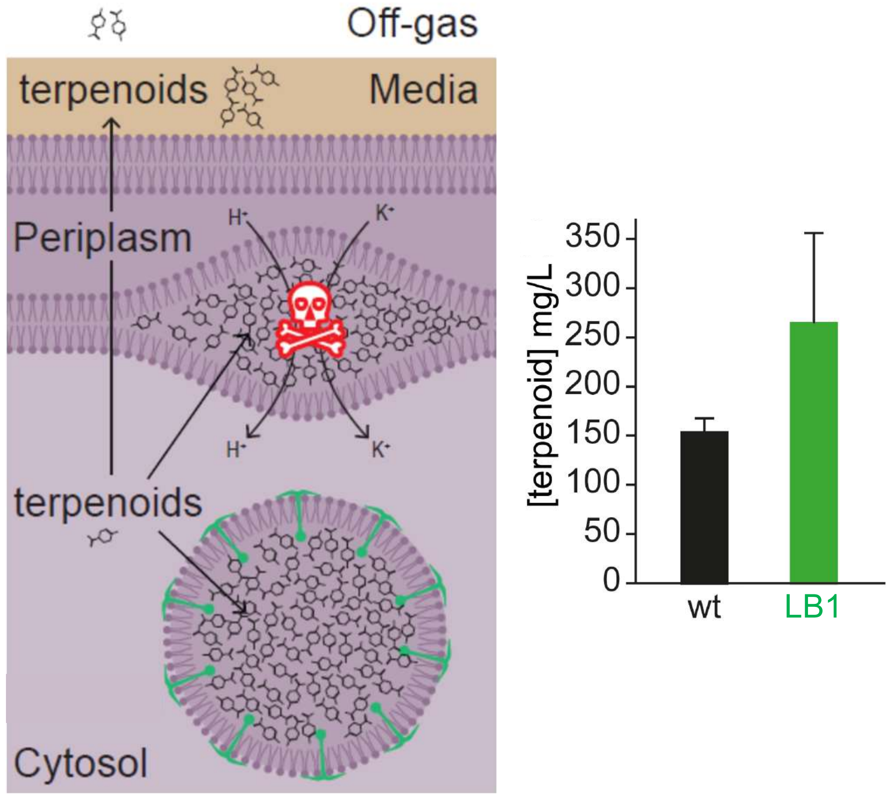

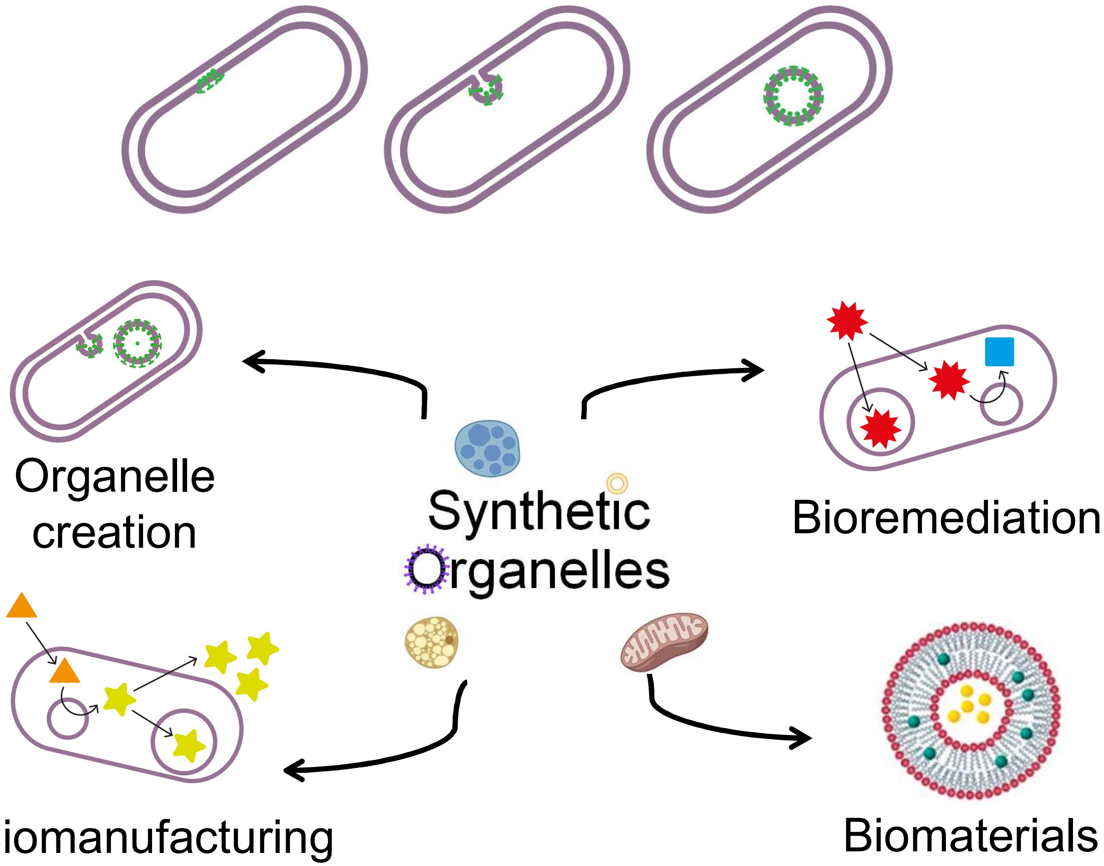

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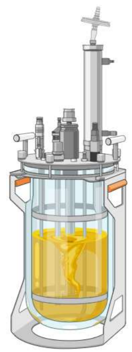


Thank you, BBNet!

→ PhD position

Poster 23

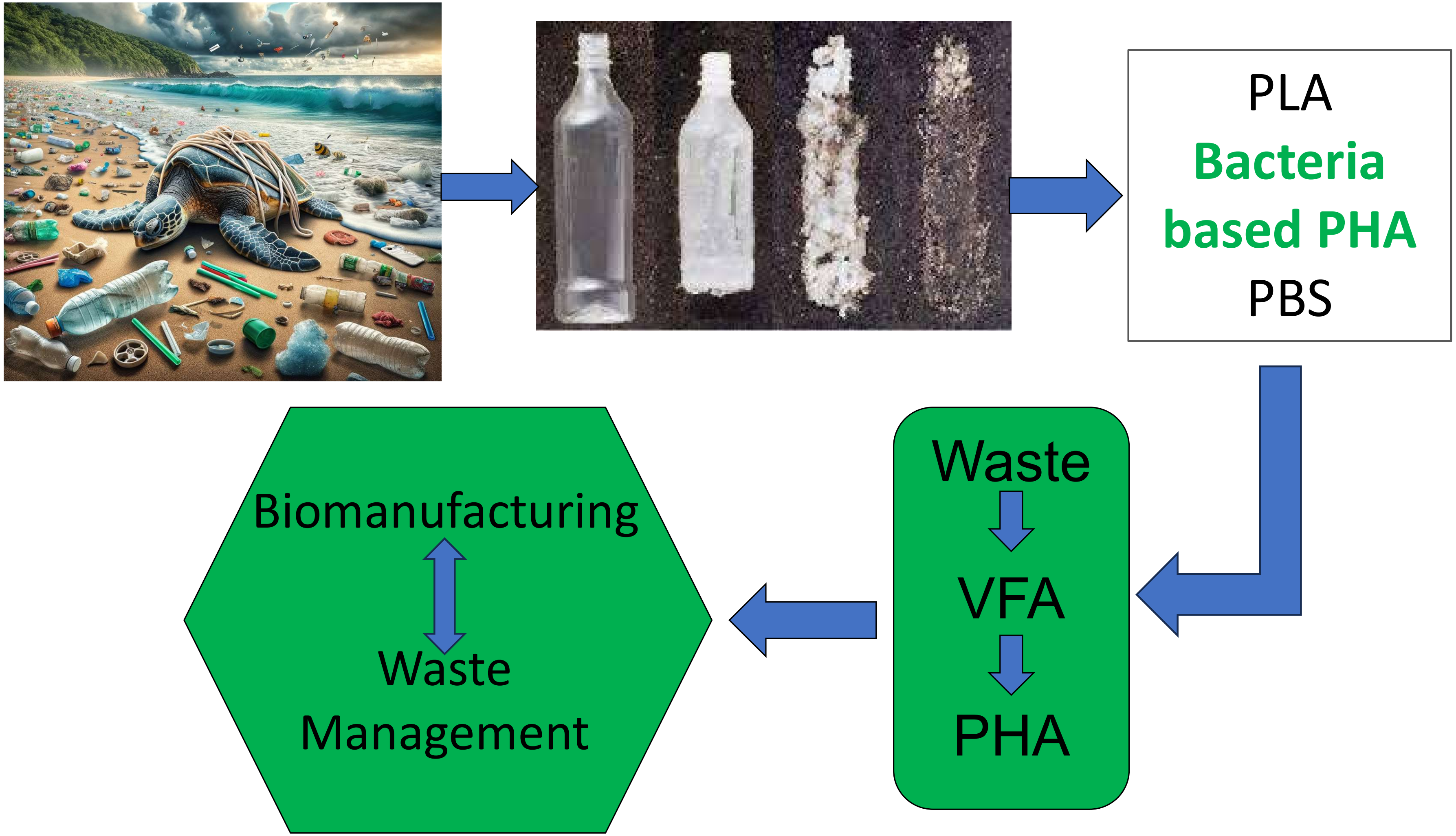
Conversion of organic waste into biodegradable plastics: a dual and synergistic solution in a circular economy

Yongqiang Liu

University of Southampton

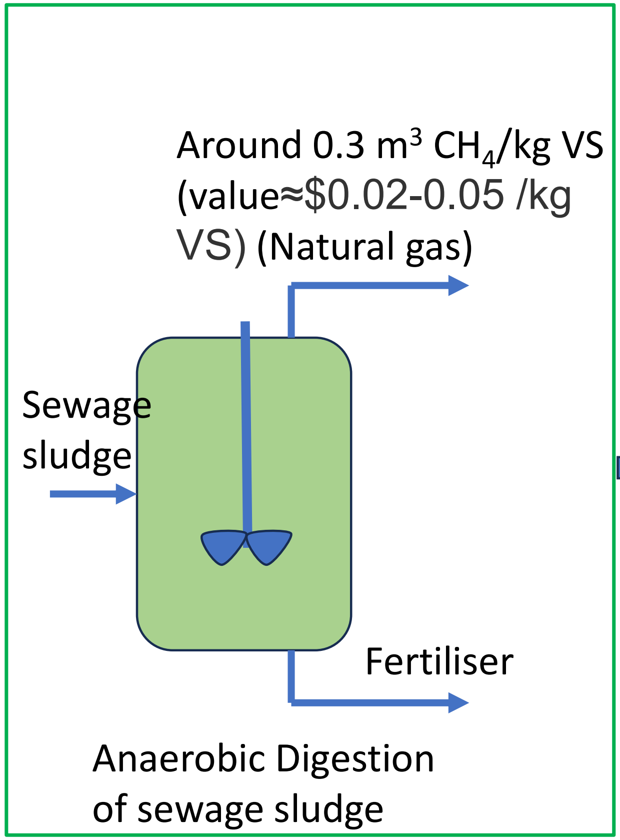
11/04/2024

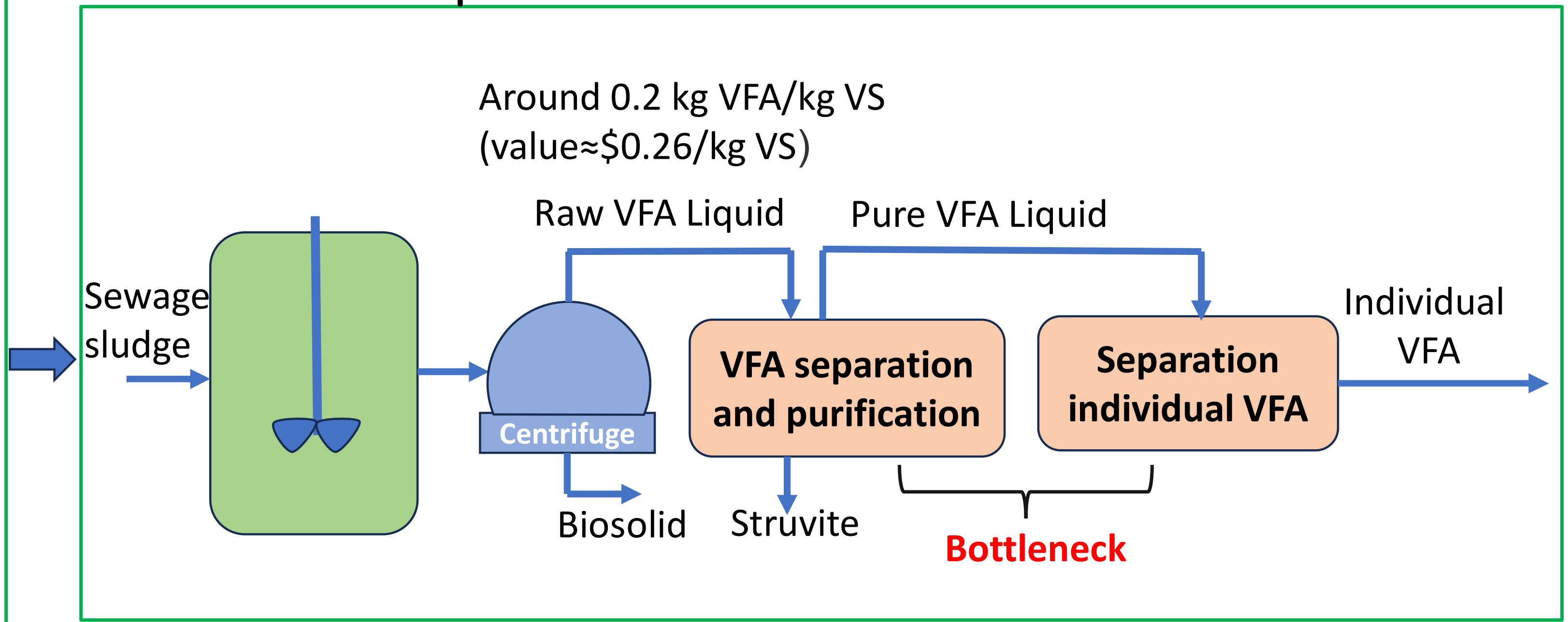
Plastic pollution and potential solution



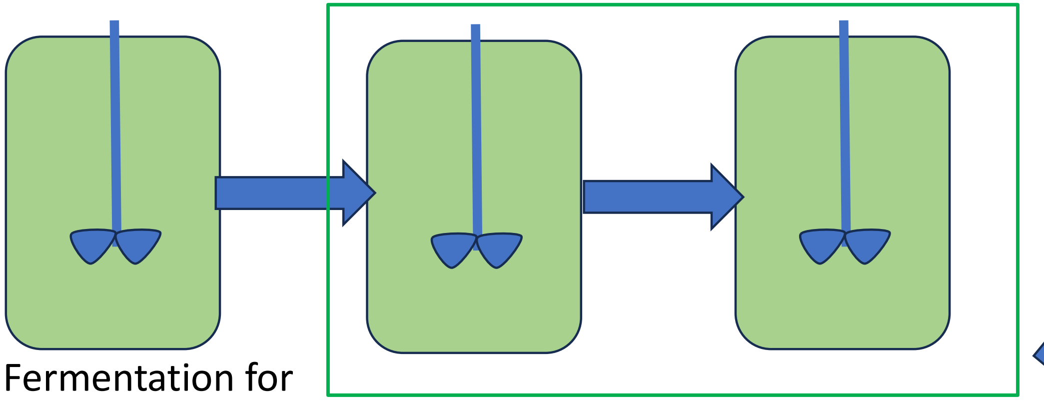
Shifting anaerobic digestion to anaerobic fermentation for VFA production

- More value-added products
- More flexible products
- Can be transported and used somewhere else





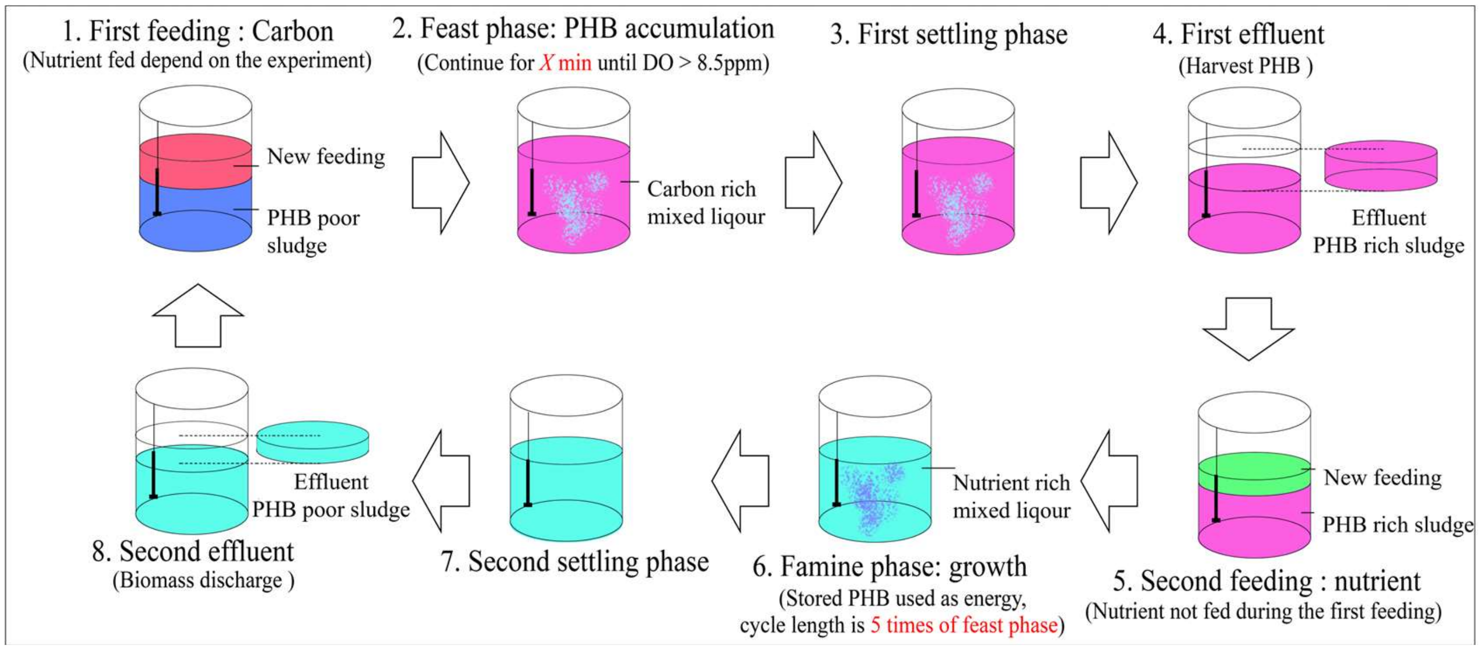
3-stage PHB production



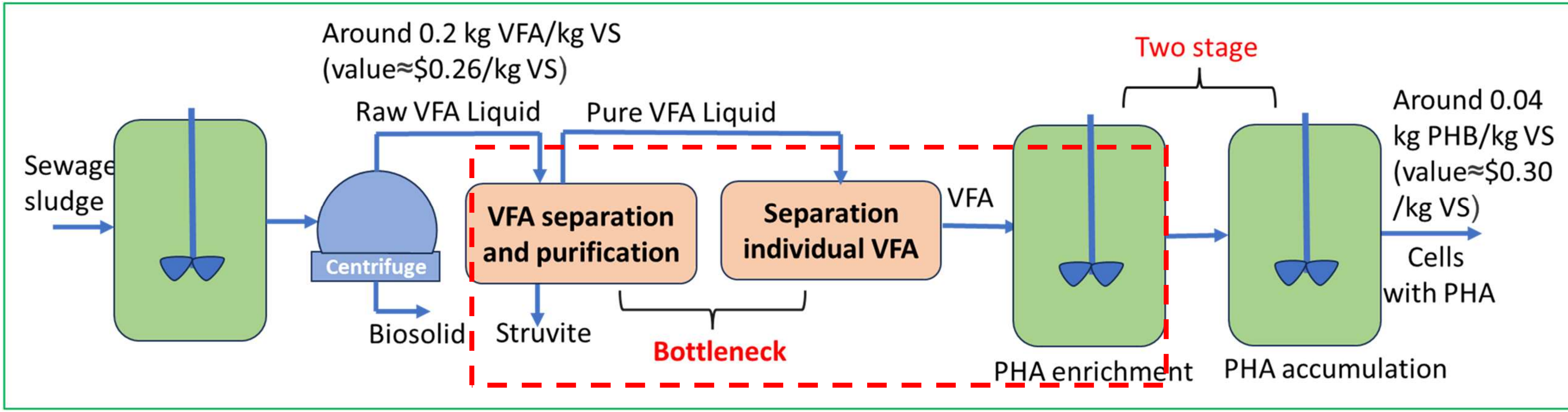
Sing-stage by combining enrichment and PHA accumulation in one reactor?

Nutrient decoupling in feast and famine phases in one SBR reactor

Cycle of a sequencing batch reactor employing nutrient decoupling strategies in Feast/Famine phases for single stage PHAs production

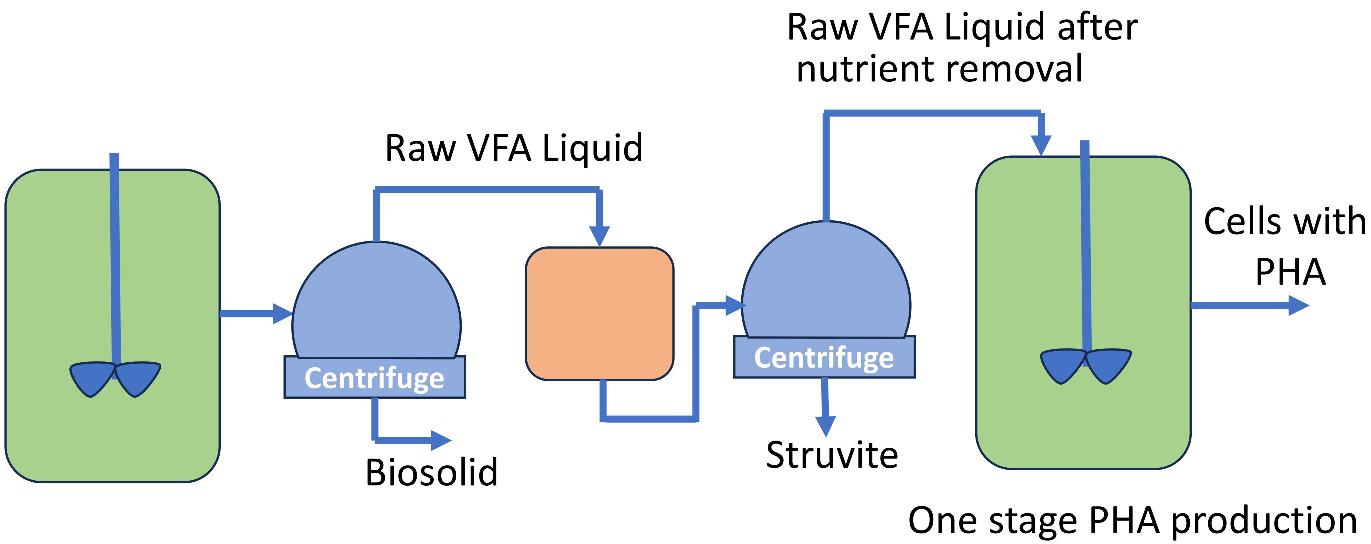


The utilisation of refined VFA solution for PHA production in conventional two-stage reactors



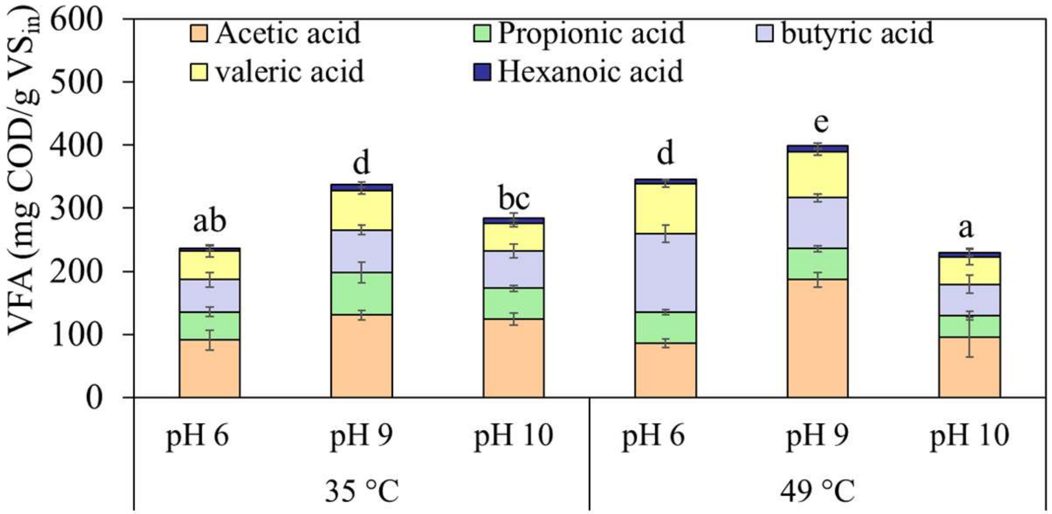
No much additional monetary value is added with the current technology if operational costs for VFA separation and purification and PHA enrichment are considered

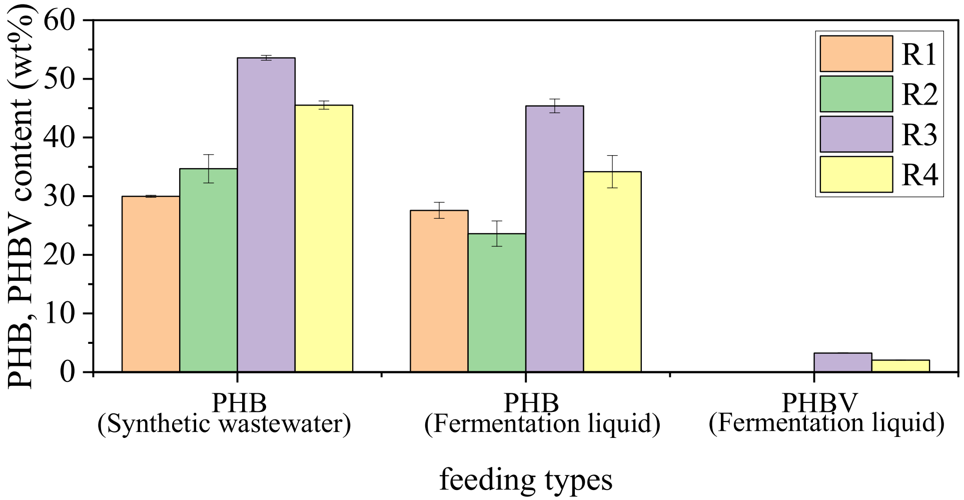
The utilisation of unrefined VFA solution for PHA production in a single reactor



- Simplified process, resulting less capital and operational costs
- Eliminate the need for VFA refinement

Anaerobic fermentation of sewage sludge and single-stage PHB production





- Thermophilic fermentation has higher selectivity for acetate or butyrate production
- PHB content with unrefined VFA solution from sewage sludge is 45%, around 10% lower than pure acetate
- The combination of fermentation and single-stage PHB production is feasible
- Life cycle environmental and economic assessment should be conducted to confirm the optimal technological route for the integrated waste management and PHA production in a biocircular economy

Conclusions:

- Thermophilic fermentation without pH control results in higher selectivity for butyrate
- PHB content is above 45% of dry biomass in a single-stage PHB production
- PHB production using a real unrefined VFA solution is slightly lower than when using pure acetate
- Feasibility of PHB production in one-stage reactor using a real raw VFA solution is validated
- Life cycle environmental and economic assessment should be conducted to confirm the optimal technological route for the integrated waste management and PHA production in a biocircular economy

HAROW and REvAR: Fuel gases from organic-rich wastewaters

Dr Malcolm Glendenning,
Dr Claudio Amorese, Brad Forrest, Rachel Jefferson, Jake Milstead (ICMEA-UK)

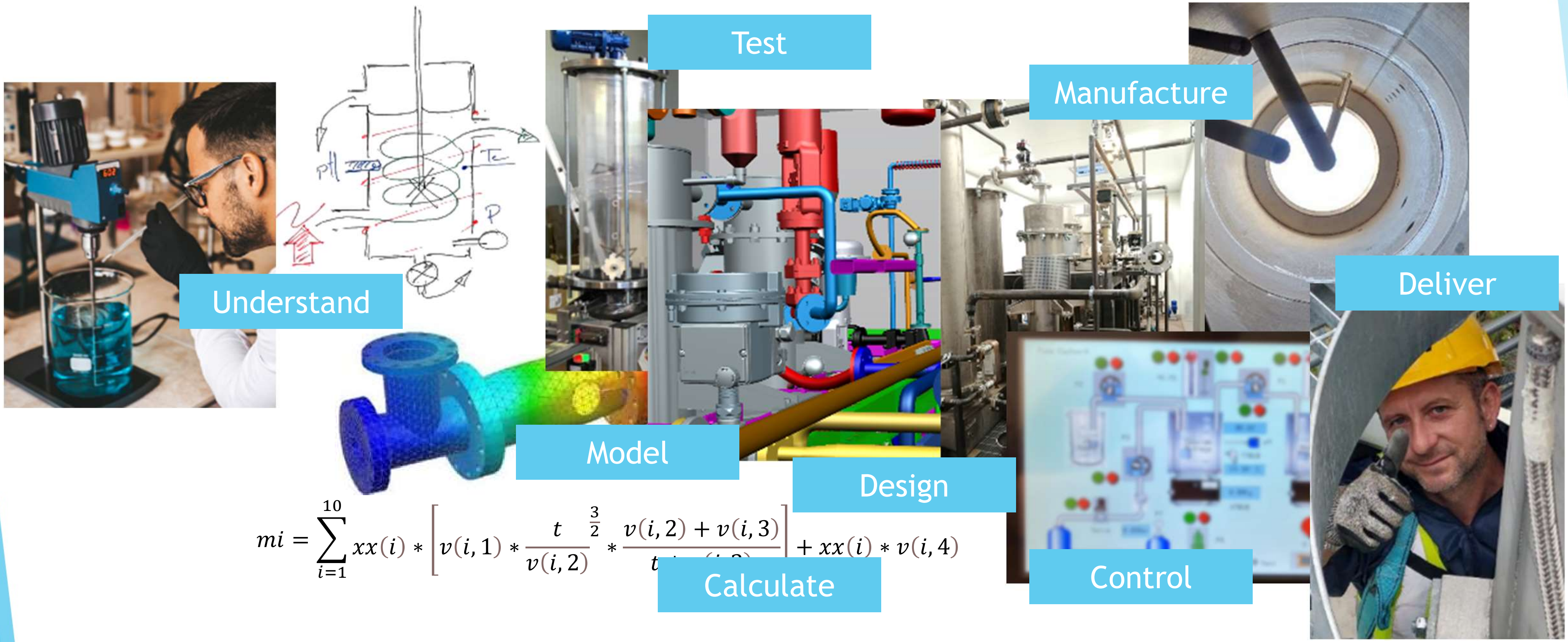
Working in partnership with:

Dr Jude Onwudili, Alberto Almena, Onyi Okoligwe and Mirjam Röder (Aston University),

Dr Ifeoluwa Akande (Costain Group),

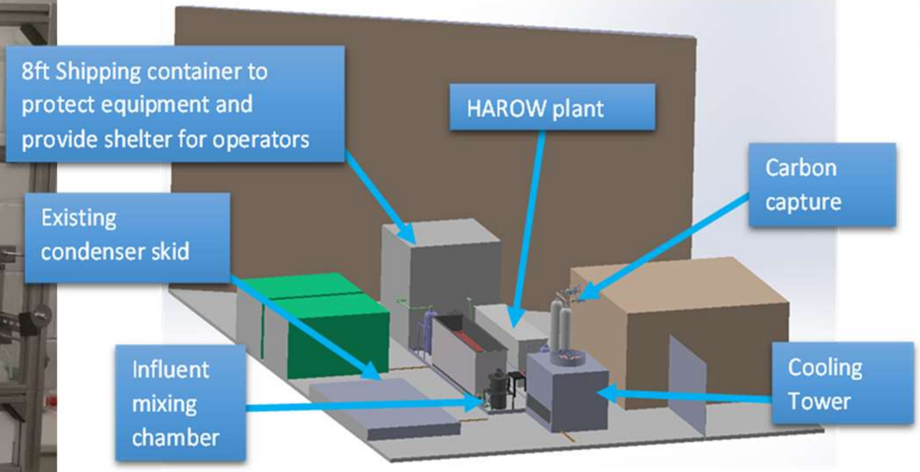
Dr Sergio Blanco-Rosete (Olleco),

From concept to reality…



HAROW - Hydrogen via Aqueous-phase Reforming Of Wastewater

- Feedstock: waste glycerol in water from biodiesel production (Olleco Plc, UK)
- Produced hydrogen via methane

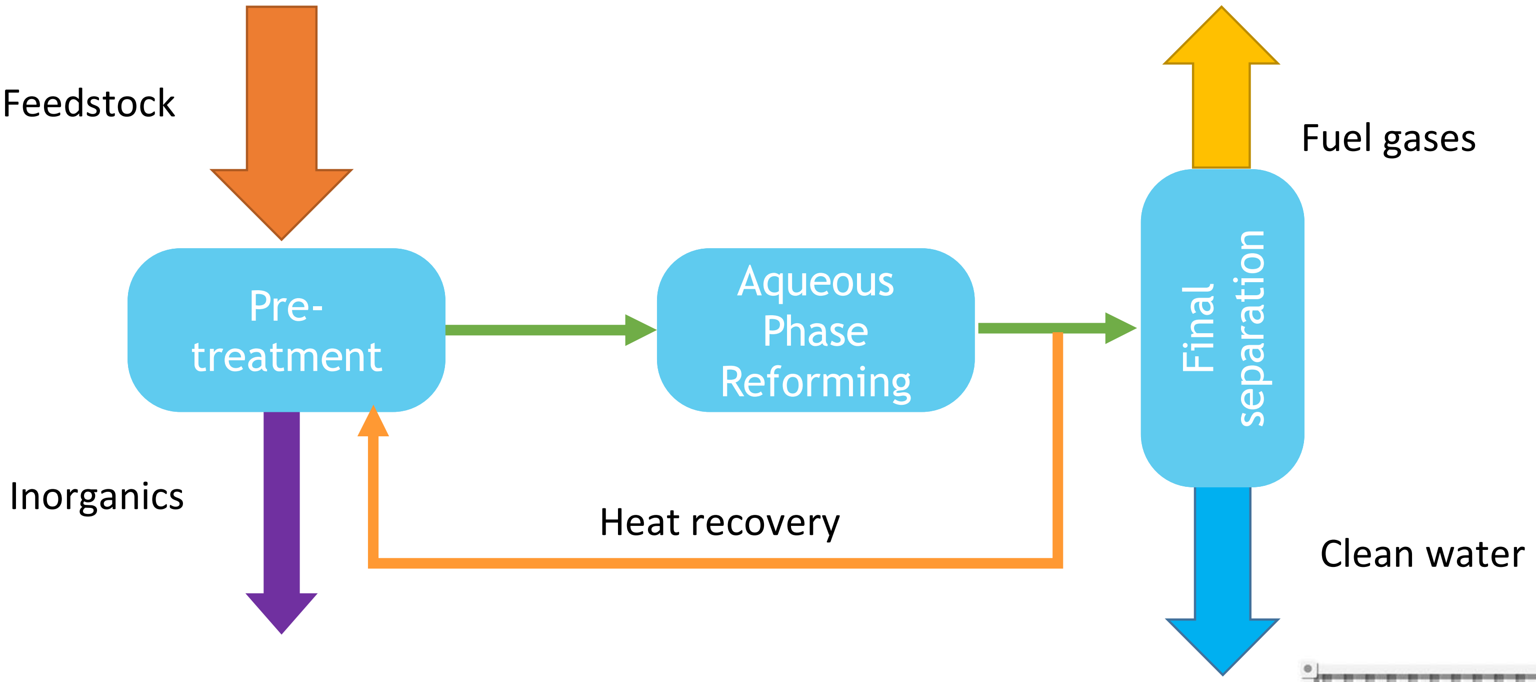


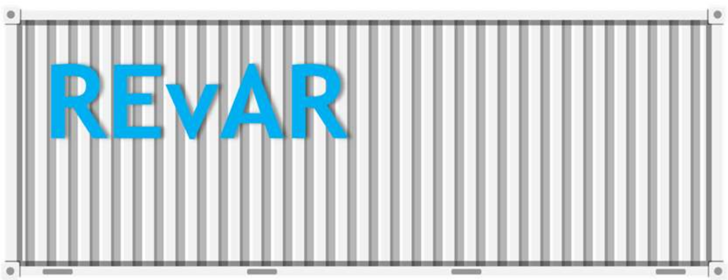
Funded by BEIS H2BECSS program

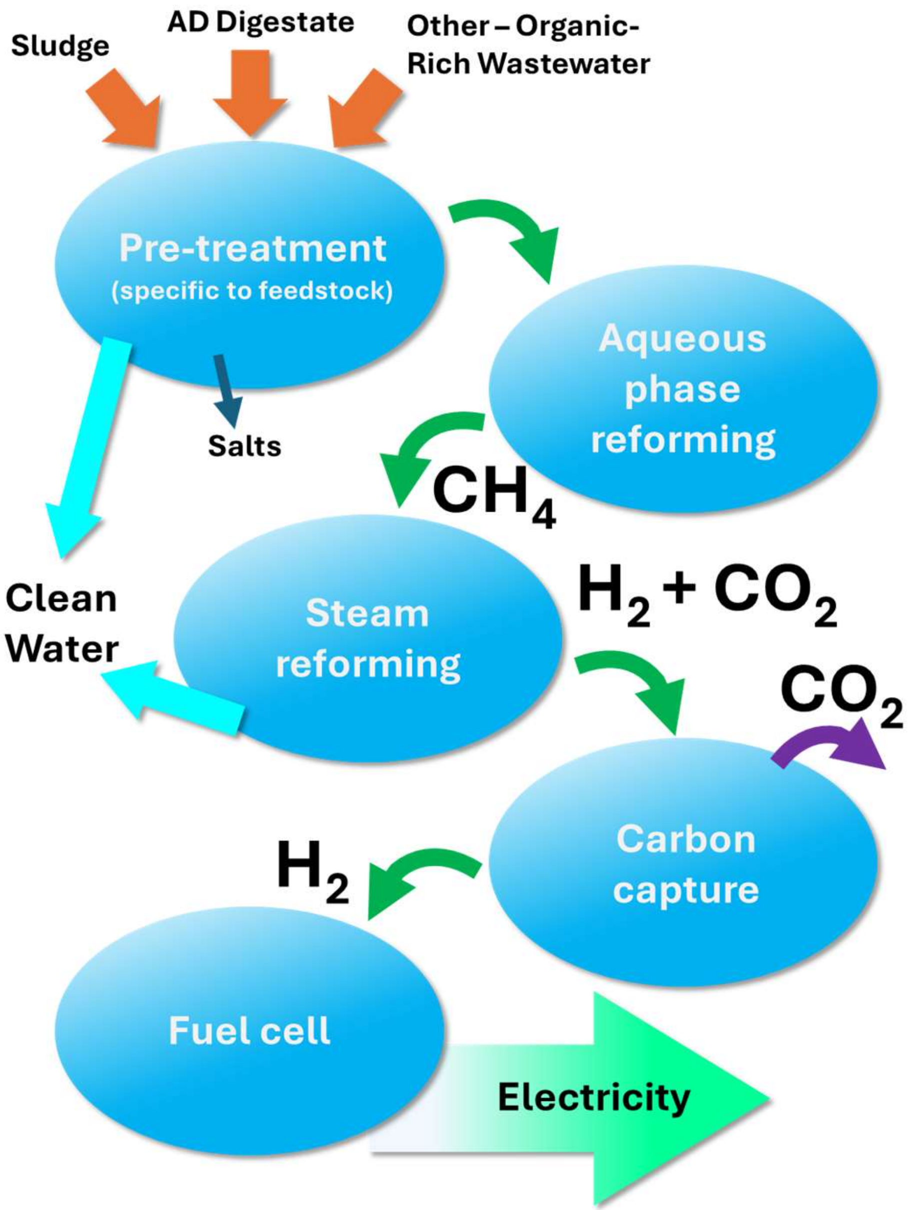
REvAR - Renewable Energy via Aqueous-phase Reforming

- Feedstock: sewage sludge, dewatered sludge or digestate from AD

REvAR - Renewable Energy via Aqueous-phase Reforming







- H_2 or CH_4 from organic rich wastewater
- Could be added to any bio-refinery process

Dr Malcolm Glendenning

ICMEA-UK

m.glendenning@icmea.co.uk

+44(0)7380 276048