Flower waste biorefinery for a scalable production of terpene-based chemicals



Dr Parimala Shivaprasad, FHEA, AffIChemE
Assistant Professor
Department of Chemical and Environmental Engineering
University of Nottingham
BIST (formerly DSIT) Fellow at Government Office for Science

Parimala.Shivaprasad@nottingham.ac.uk

Challenge

The UK imported
£1.23bn
of fragrance ingredients in 2020 from EU and non-EU countries (Statista)

Bridge Farm (UK) produce 5m waste flowering plants and cut flowers annually



THE FUTURE OF MANUFACTURING:
A NEW ERA OF OPPORTUNITY AND CHALLENGE FOR THE UK

2013–2025: Efficiency & resilience

- Minimized material inputs
- Waste management
- Increased energy efficiency
- Reduced water usage
- Improved efficiency in land use
- UK leadership in areas including low-carbon technology

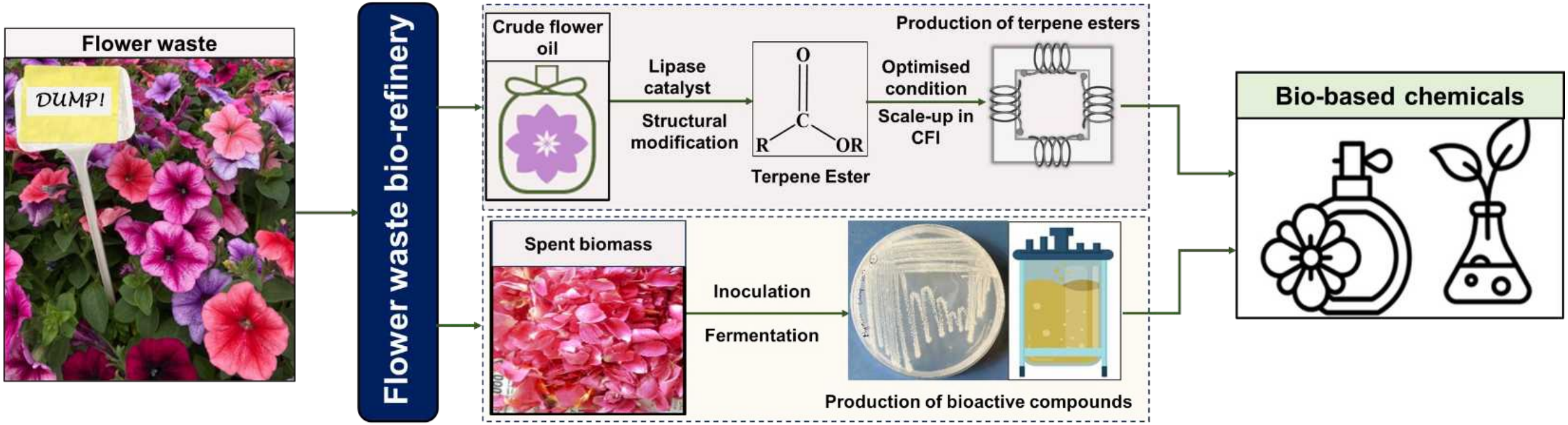
2025–2050: Experimentation with new systems

- New forms of value associated with products including sustainability
- Products reused, remanufactured, recycled and redesigned with recovery in mind
- More durable products designed for shared ownership
- Spare capacity built into supply chains to ensure resilience

2050 & beyond: A resource constrained world

- Products use smaller amounts of materials and energy
- Material is not land-filled but kept in a 'productive loop'
- Cleaner and quieter factories close to consumers, suppliers and academic institutions
- Supply chains with spare capacity at all stages

A circular approach to valorising flower waste



Solution – An end-to-end platform for converting flower waste into high-value terpene esters



Flower waste

Sustainable, abundant feedstock



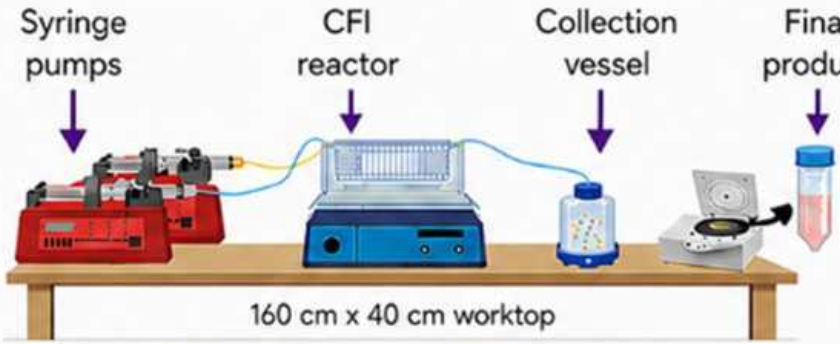
Ultrasound-assisted extraction

Efficient recovery of crude flower oil



Crude flower oil

Feed for continuous processing



Coiled flow inverter (CFI) reactor

Continuous production of terpene esters

5–7× increase in productivity

compared with batch processing



Terpene esters

High-purity, consistent ingredients for fragrance applications

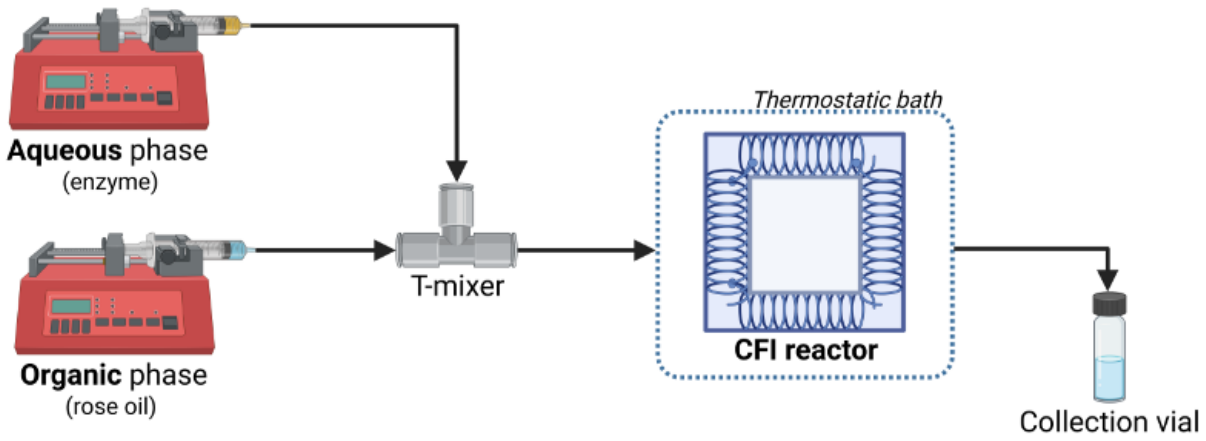
Process optimisation

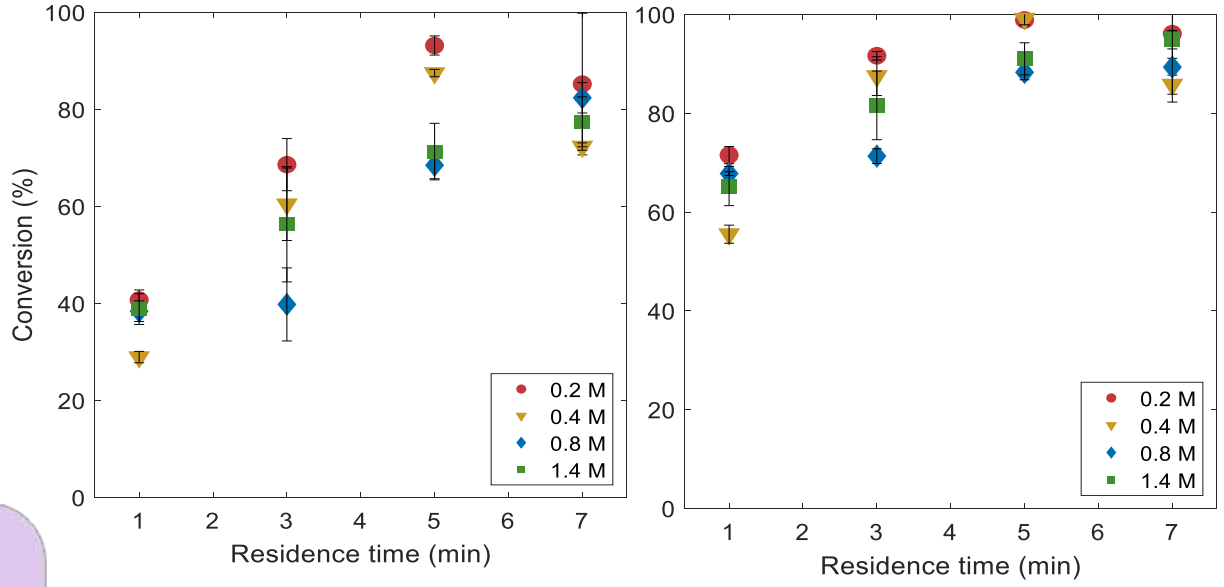
Predicts optimum operating conditions for mixed feedstock

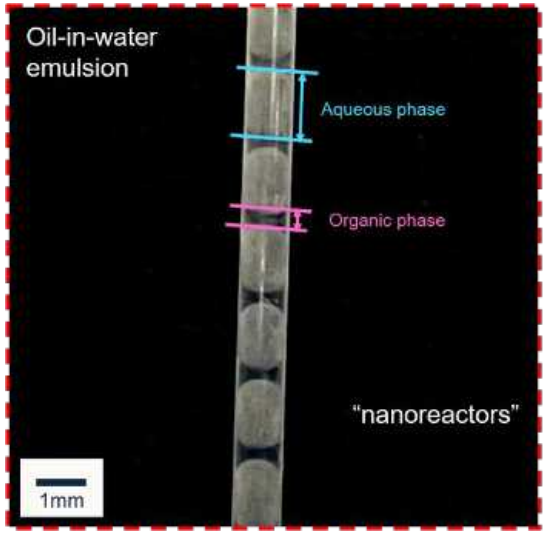
- Mixed feedstock composition
- Enzyme selectivity
- Temperature
- Residence time
- Solvent

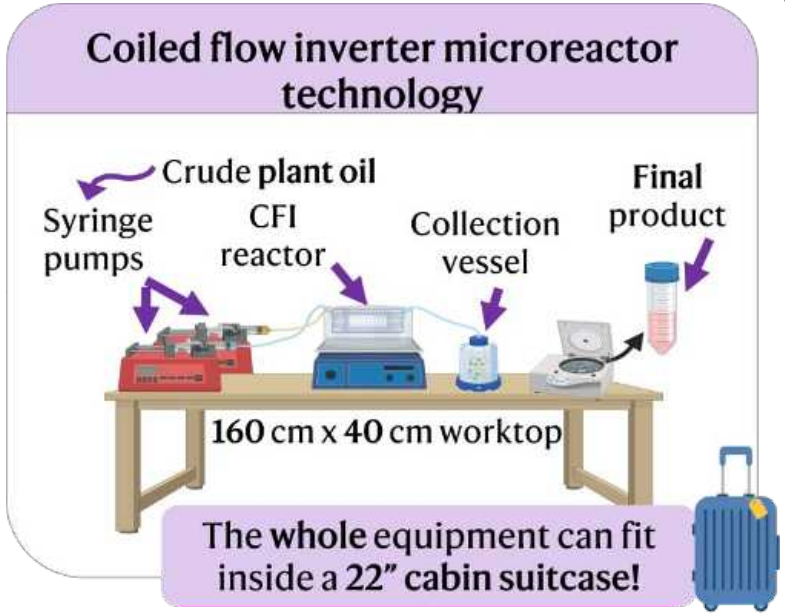
- Integrated, continuous and optimised platform
- Higher productivity
- Consistent quality
- Reduced processing time

Continuous production of terpene esters









Conversion vs. **residence time** profile of citronellol (left) and geraniol (right) at varied concentration, **60 °C**, and aqueous to organic ratio of **9:1.**

Mode	Productivity ($g.day^{-1}$)	
	Minimum	Maximum
Batch	23.7	45.0
Continuous	132.6	158.7

THE UNIVERSITY of ADELAIDE

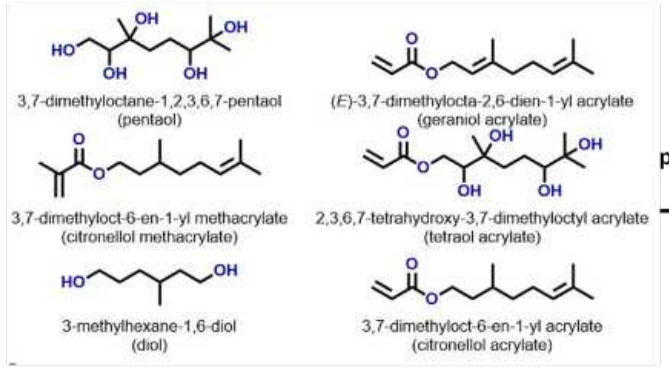
Synthesis of bio-based monomers and polymers



extraction



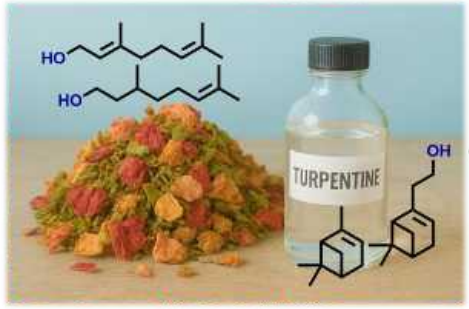
functionalisation



polymerisation/ application

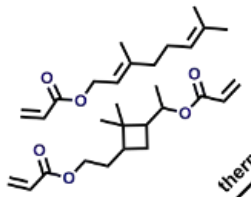


Personal and home care formulations

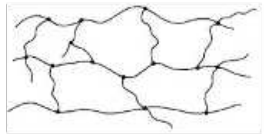


biomass-derived terpenes

functionalisation



thermosets

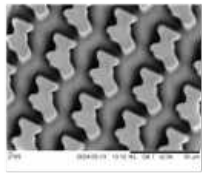


polymers

polymethacrylates
polyacrylates
polyesters
polyethers

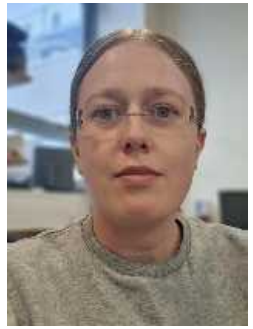
novel plant-derived polymers

3D printing





Biofilm resistant materials for neonatal care



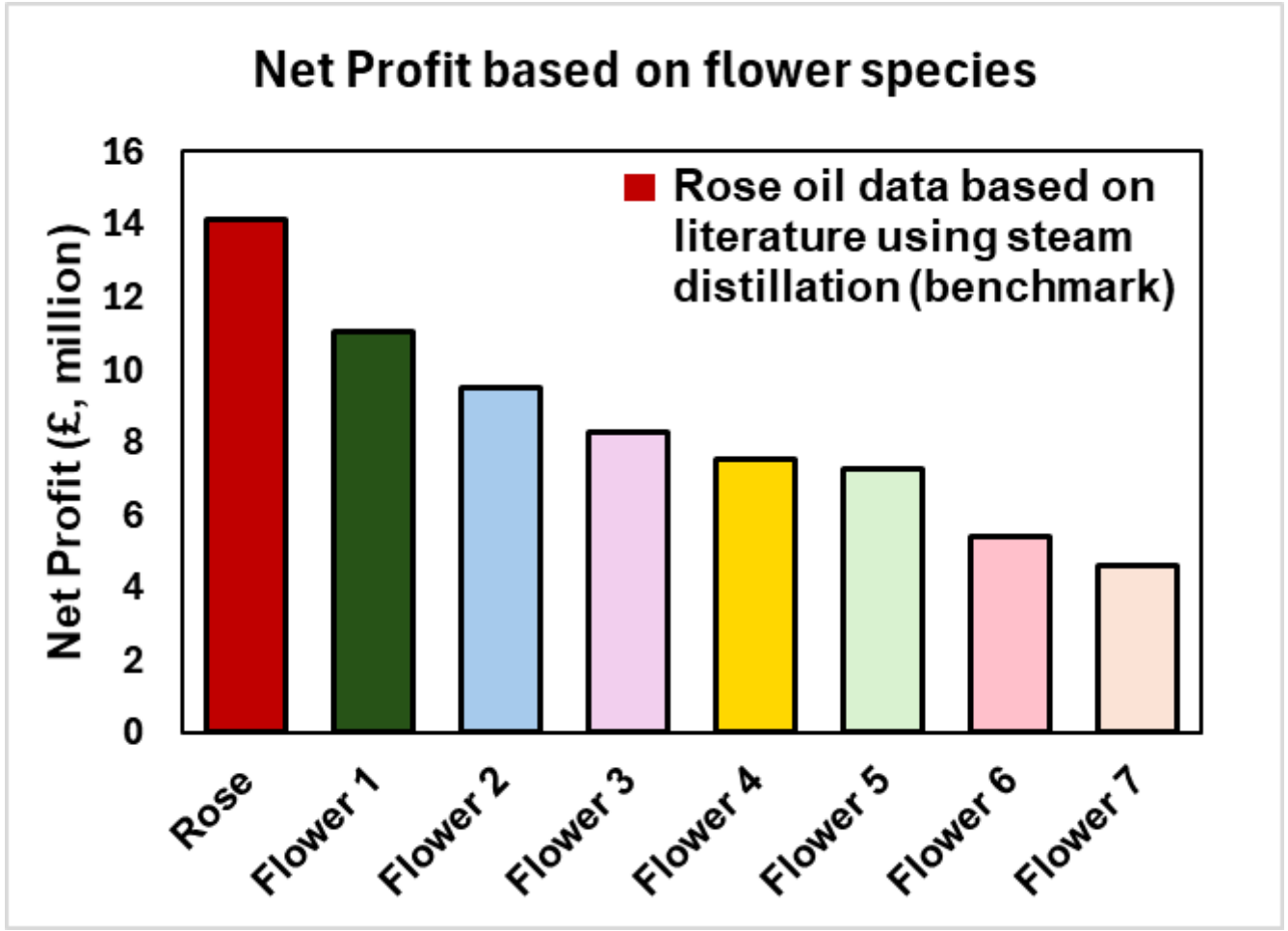
Monika Dabrowska
Research Fellow



Shyam Rana
PhD student

Engineering and Physical Sciences Research Council | AIM Doctoral Training Programme | Medical Research Council | Supergen Bioenergy

Economic assessment based on flower oil quantity and quality



There is potential for horticulture waste originating in the UK, which is non-purpose grown, as an alternative feedstock for high value, fragrance ingredients

Impact assessment – oil refinery process using purpose grown rose flowers

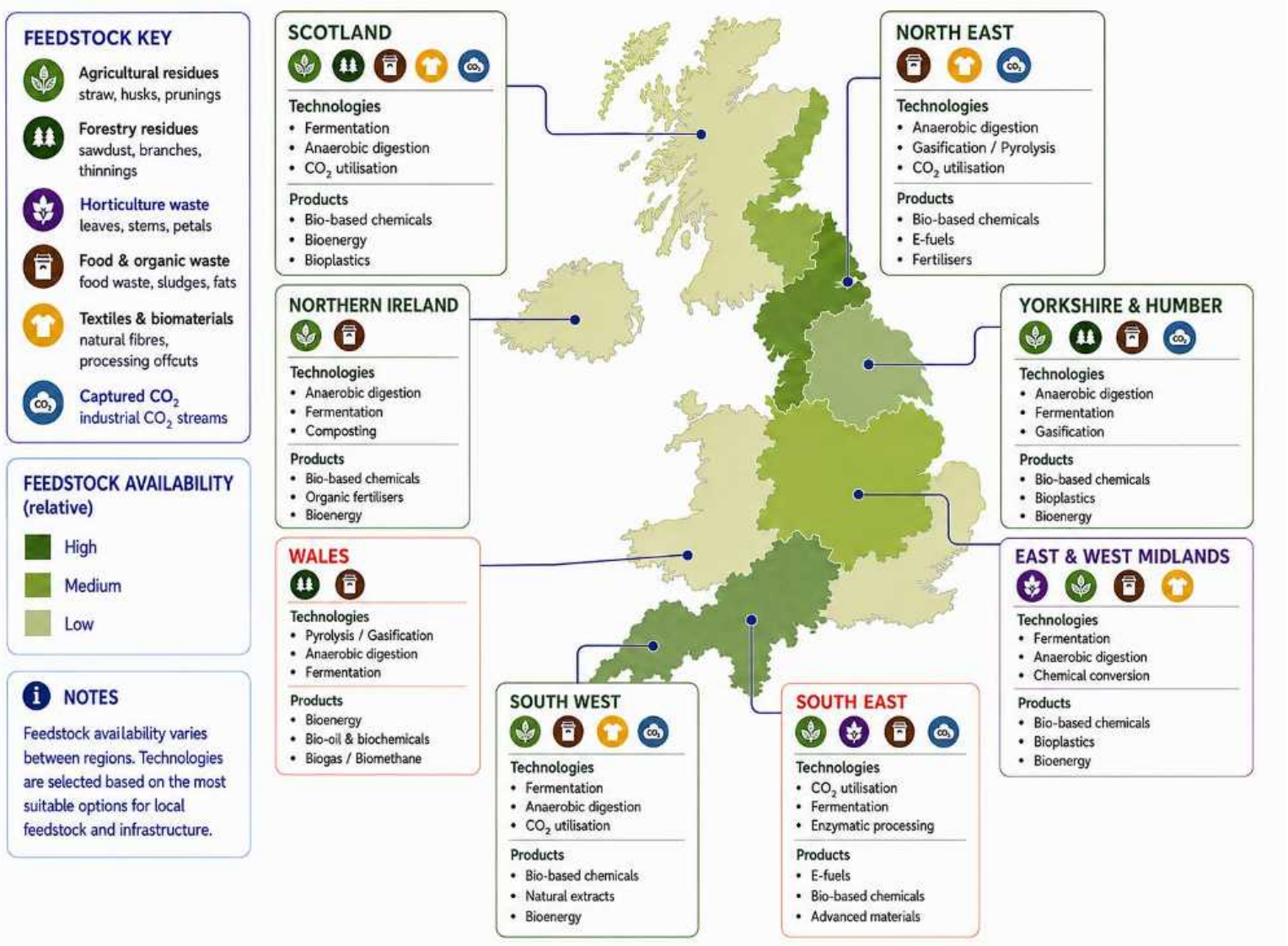
Impact category	Unit	Flower production	Oil production	Oil refinery	Transport	Waste	Net emission
Global warming	kg CO_2 eq	1699.9	404.06	12.461	1.9822	4.1389	2122.6
		80.1%	19.04%	0.59%	0.09%	0.2%	100%

Key observations

- Over 99% of the global warming impact from flower production and subsequent oil production
- The high share of the impact from production is the result of the low yield (0.05%) of the oil distillation process which requires large quantities (1:2000 kg) of rose flowers
- Transesterification process contributes only to 0.59% of the total impact
- Transportation and waste treatment (vinyl acetate as waste solvent) is negligible

Vision for a circular UK Bioeconomy

Mapping regional feedstock availability with appropriate technologies to process them



Acknowledgement



Academic collaborators:
Prof. Rob Stockman
Prof. Derek Irvine
Dr Samantha Bryan
Dr Ioanna Dimitriou
Prof. Jonathan Hirst

Visiting researchers:
James Richardson
Araminta Praud
Rhea Satpute
Federica Bianciot
Dr Max Winslow
Dr Aiden Cranney
Dr Ross Amory
Dr Bethany Husband

University of Nottingham UK | CHINA | MALAYSIA
UK Research and Innovation
Royal Academy of Engineering
The Royal Society
BB Net Biomass Biorefinery Network
bridgefarm
Unilever
Supergen Bioenergy
CRODA SMART SCIENCE TO IMPROVE LIVES