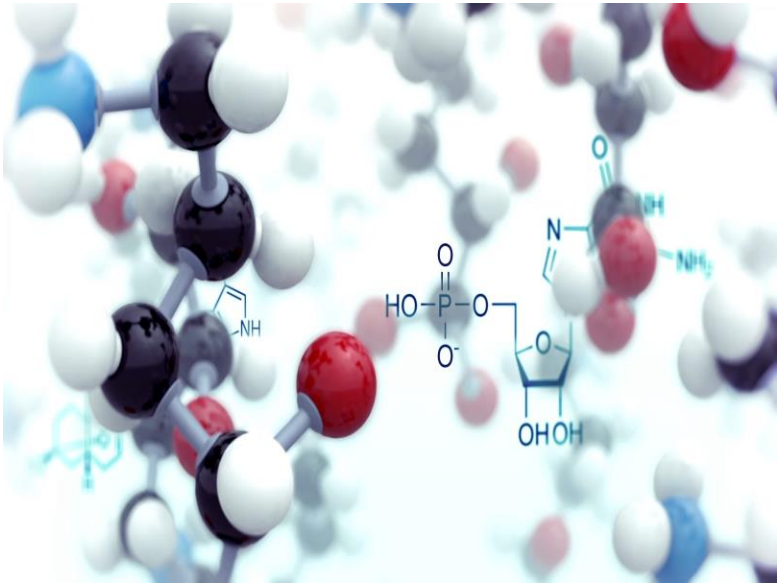
A Circular Food Economy: Measurement Perspectives and Challenges

NMI Director Meeting, October 2023

Session: Measurement supporting the global food system - Climate Change and Food Safety & Security



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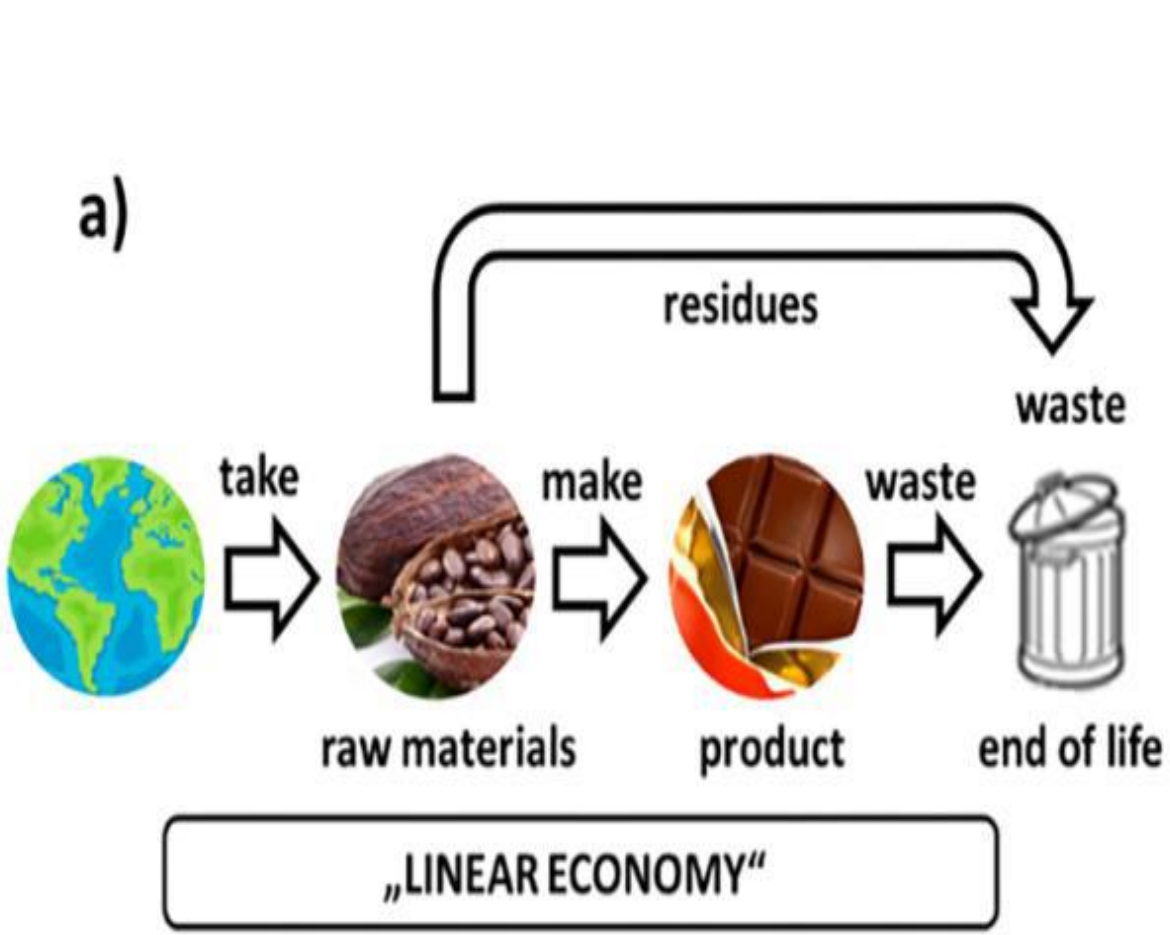
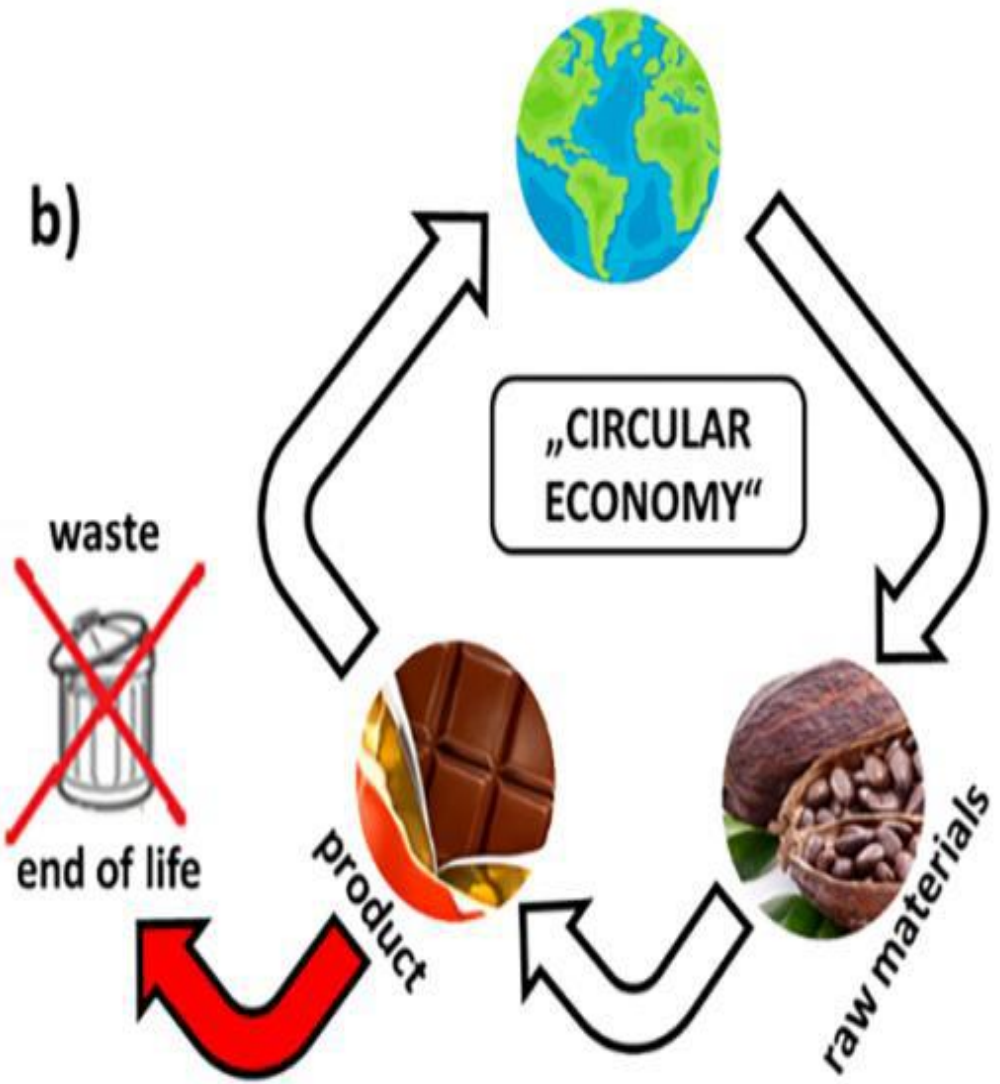
Linear vs circular economy

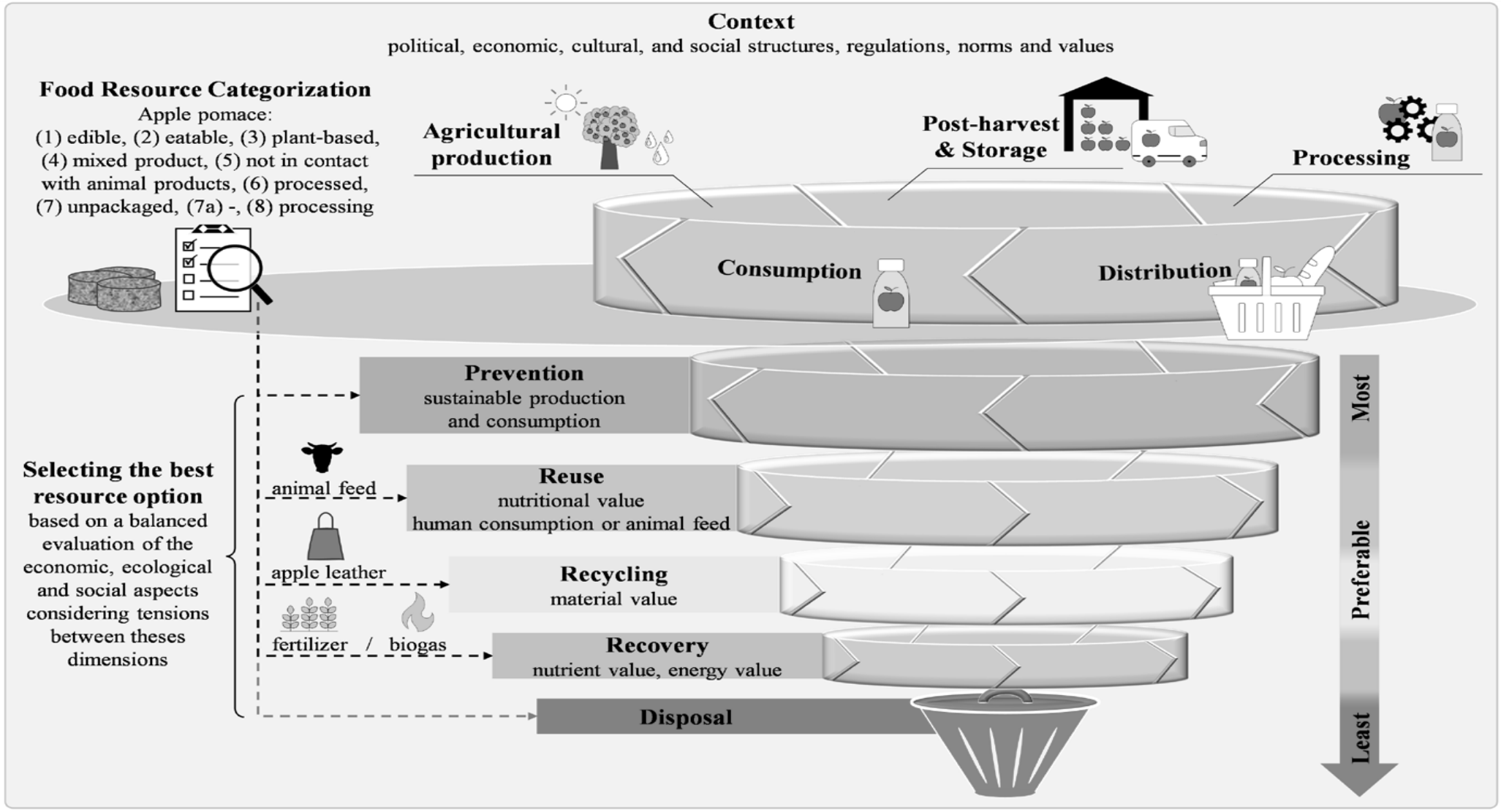




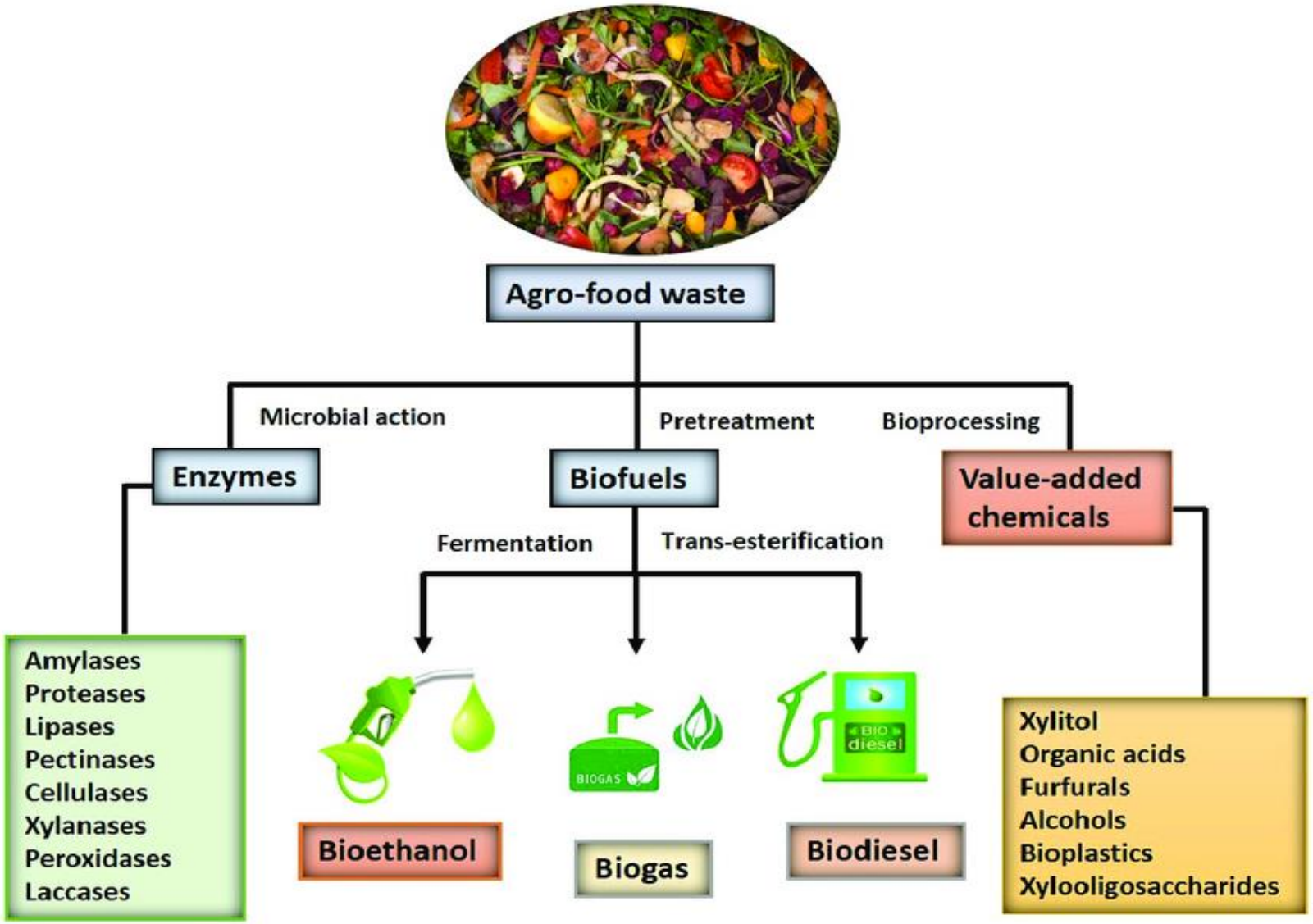
Food wastage and the circular economy

- Besides changes in food type and consumption (i.e. diet), and food production methods and patterns, reducing food wastage is of major interest in enabling sustainable development
- Food wastage includes:
  - **food loss** (i.e. ‘decrease in mass or nutritional value of food intended for human consumption’ mainly caused by [production] inefficiencies in the food supply chains) and
  - **food waste** (i.e. ‘food appropriate for human consumption being discarded’ mainly caused by consumption patterns) (FAO, 2013)
- By reducing food wastage, the direct and indirect economic, social and ecological costs can be reduced significantly (FAO, 2014)

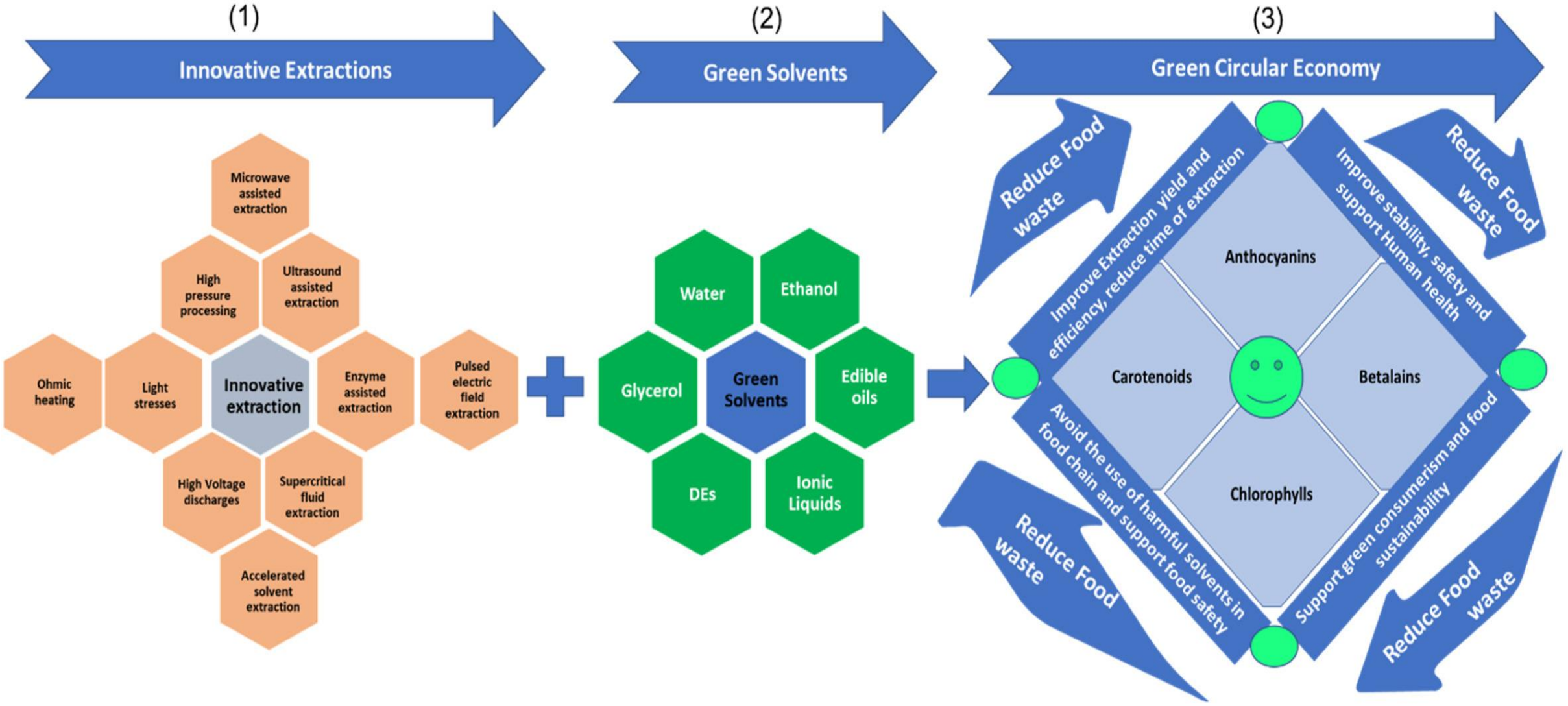
Selecting the best resource option in a circular food economy



The circular economy and green chemistry



The circular economy and green valorization technologies



Chemistry challenges to be addressed in a circular food economy (1)

Alternative Farming/Production Means: Crop rotation, new genome technologies (NGTs) etc

Sustainable Soil Enhancers: Finding or creating sustainable pesticide, herbicide and agrochemical alternatives that provide crop protection and replenish soil health (NPK utilization efficiency), without adverse effects

Packaging Materials: i) Developing and recycling biodegradable or compostable food packaging with similar protective properties to existing ones, without compromising food safety. ii) Novel solvent systems, tolerant to additives and impurities for recycling multilayer polymers through selective dissolution

Chemistry challenges to be addressed in a circular food economy (2)

Sustainable Food Additives, Preservatives and Coatings: i) Transitioning to greener synthetic routes for their production and using bio-based raw materials, with aim of reducing food waste. ii) Creating safe, effective, and palatable (edible) coatings to extend the shelf life of perishables

Eco-friendly Disinfectants: In food processing and storage, disinfectants that are effective, yet biodegradable and non-toxic

Alternative Protein Sources: Extracting and processing proteins from novel sources requires development and optimization of (new) chemical processes

Biowaste Transformation (Residue Management): Efficiently converting organic food waste into valuable products, e.g. bioplastics, biofuels or compost, often involves complex chemical processes

Chemistry challenges to be addressed in a circular food economy (3)

Chemical Contaminants and Nutrient/Antinutrient Profiles in Recycling Streams: i) Ensuring the absence of ptlly accumulated harmful chemicals (e.g. heavy metals, pathogens, pharmaceuticals etc) in treated, reused or recycled inputs, especially in food packaging. ii) Maintaining consistency of nutrient content

Standardisation/certification. i) Screening and Reference measurement procedures. ii) (Certified) Reference materials

Data-Driven Analysis and Design/Modelling. Digital twin/simulation of chemical reactions within soil and water compartments

Agreed Uniform ‘Green’ Measures. i) (Improved) Sustainability impact factors/measures. ii) Comparable LCA approaches (across entire food chain)

Metrology needs for new genome technologies (NGTs)

- Detecting products resulting from NGTs
  - Technical detection of small alterations
  - Qualifying the source of the mutation (gene editing, traditional breeding or natural mutagenesis)
  - Off-target mutations
    - Site of interest
    - Flanking regions
    - Genetic background
    - (Linked) off-target mutations
    - Epigenetic and epi-transcriptomic changes
    - Documentary evidence: supplier, origin, pedigree etc
  - Screening and Quantitation
  - Reference materials
  - 'Weight-of-evidence' approaches and minimum qualifying information (concept of collective information gathering that is accepted as providing a unique 'signature' of the NGT product)

Edible insects as an alternative protein source

NUTRITION - Pros	Cons
Good sources of protein and fat	Nutritional value varies depending on the species, developmental stage and type of feed
Meet essential amino acids requirements	Contain chitin which reduces protein digestibility
Rich in polyunsaturated fatty acids, vitamins and minerals, such as zinc, iron and B vitamins	Still unknown how processing and cooking techniques affect their nutritional value

SAFETY - Pros	Cons
Safe for consumption when reared in controlled envt.	Possibility of allergy in people allergic to crustaceans
Can be made safe for consumption after processing	Ptl. contaminated with pesticides, toxins or pathogens

SUSTAINABILITY - Pros	Cons
Require less feed than livestock and can grow on biowaste	Still unclear of environmental impact of large-scale production
Rearing can potentially reduce GHG emissions	Research still needs to identify efficient species and biowaste sources to use in rearing
Can use in animal feed reducing crop production need	Production still expensive due to high manual labour

Cultured meats as alternative protein sources

NUTRITION - Pros	Cons
Nutritional composition can be tailored to create healthier and personalised products	Complex meat products such as steak will be hard to mimic in terms of structure and taste

SAFETY - Pros	Cons
Food-borne diseases can be eliminated and fewer antimicrobials used	Safety checks required before approval and reaching market

SUSTAINABILITY - Pros	Cons
Relieve the burden of producing crops for feed	Projected high energy use and cost when produced on large-scale
Decrease the need for livestock production	Not animal-free - animal serum in some culture media

Mycoproteins (algae, fungi, bacterial fermentation) as alternative protein sources

NUTRITION - Pros	Cons
Good sources of protein, polyunsaturated fatty acids and fibre	Nutritional value varies depending on the species, growth conditions, harvest location and season
Rich in bioactive peptides and antioxidants such as sterols and carotenoids	Low digestibility in raw and unprocessed state
One of the few veg. sources of vitamin B12 and iodine	

SAFETY - Pros	Cons
Safe for consumption when grown in a controlled environment	Ptl. contamination with heavy metals, e.g. Cd / As

SUSTAINABILITY - Pros	Cons
Higher yield/unit area than other high-protein crops	Sustainability depends on type of production / species
Can grow on biowaste and with no use of fertilisers	Efficiency of aquaculture systems needs improvement
Cultivating results in a lower carbon footprint than growing plants and meat	Production systems reliant on the environment cheaper but less efficient

Plant-based protein as an alternative protein source

NUTRITION - Pros	Cons
Legumes and cereals combined can provide comparable protein content to meat	Anti-nutrients such as lectins and phytates in plants reduce protein digestibility and the bioavailability of micronutrients
Usually contain more fibre and less saturated fat and cholesterol than meat	Sophisticated meat analogues may contain high amounts of added fat and sodium

SAFETY - Pros	Cons
Considered safe for consumption when cooked or processed	Possibility of allergy in people allergic to plant proteins such as soy or gluten

SUSTAINABILITY - Pros	Cons
Lower carbon footprint and land use compared with animal rearing	Highly processed products, such as meat substitutes, may require high energy costs

Summary of metrology needs for alternative protein sources

- To understand potential allergenic, microbial pathogen or other safety risks
  - Develop referee capability for presence/absence using highly sensitive modern molecular biology approaches (qPCR, dPCR or NGS)
  - Optimisation of mitochondrial gene detection for testing for vegan foods and labelling for traceability of alternative proteins
  - Development of laboratory-based assays for detection of universal insect, mammalian, animal, plant, fish and poultry targets
- To understand the potential nutrient, antinutrient and safety issues that might arise from the use of alternative protein streams
  - Quantity of vital amino acids, (diversity of) protein content, vitamins and micronutrients present
  - Quantity of anti-nutritional factors such as secondary metabolites
  - Quantity of (residue) contaminants such as mycotoxins, growth factors, hormones, PAHs and heavy metals
- To undertake Life Cycle Assessments and Availability Analysis on alternative protein streams