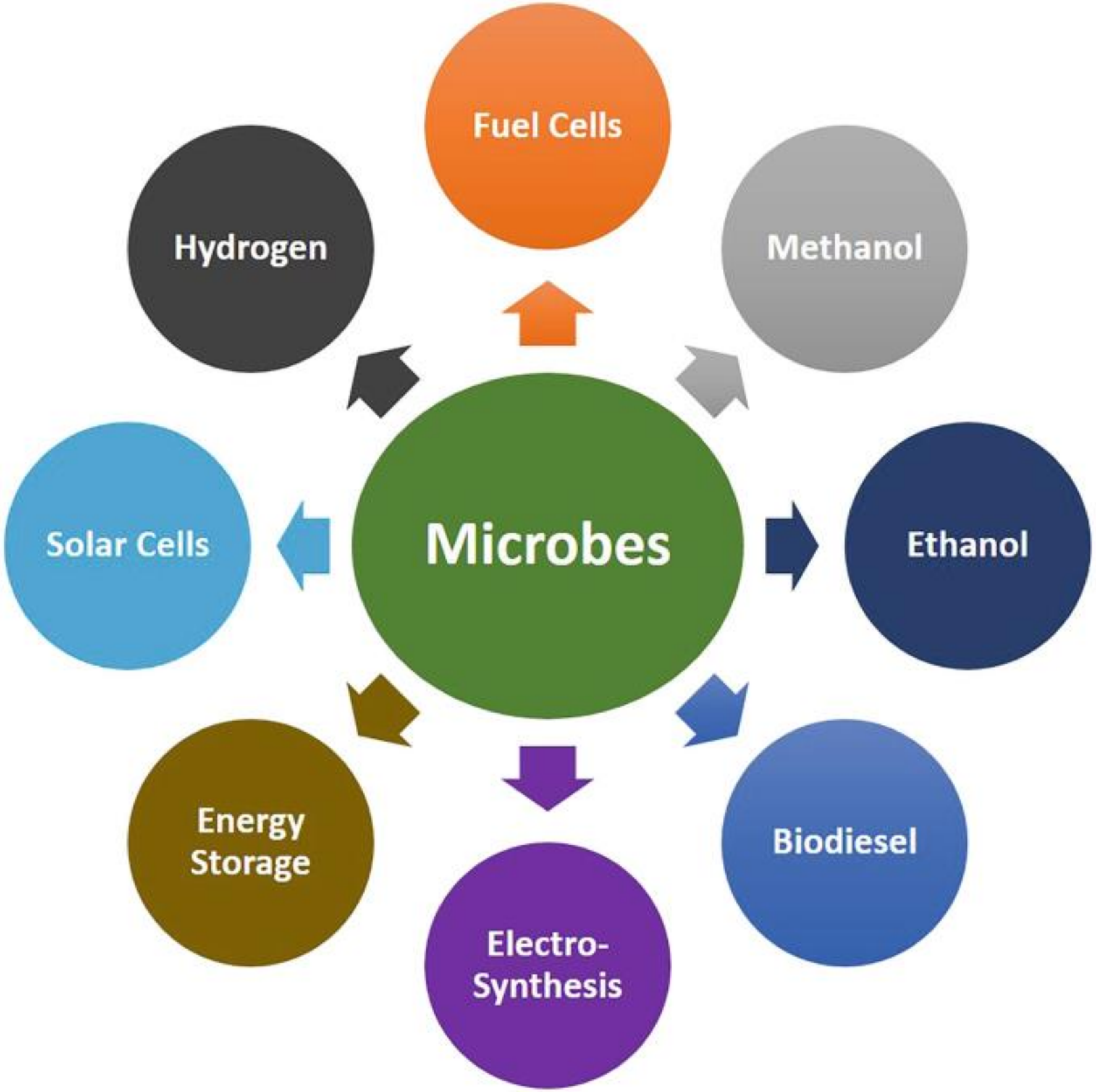
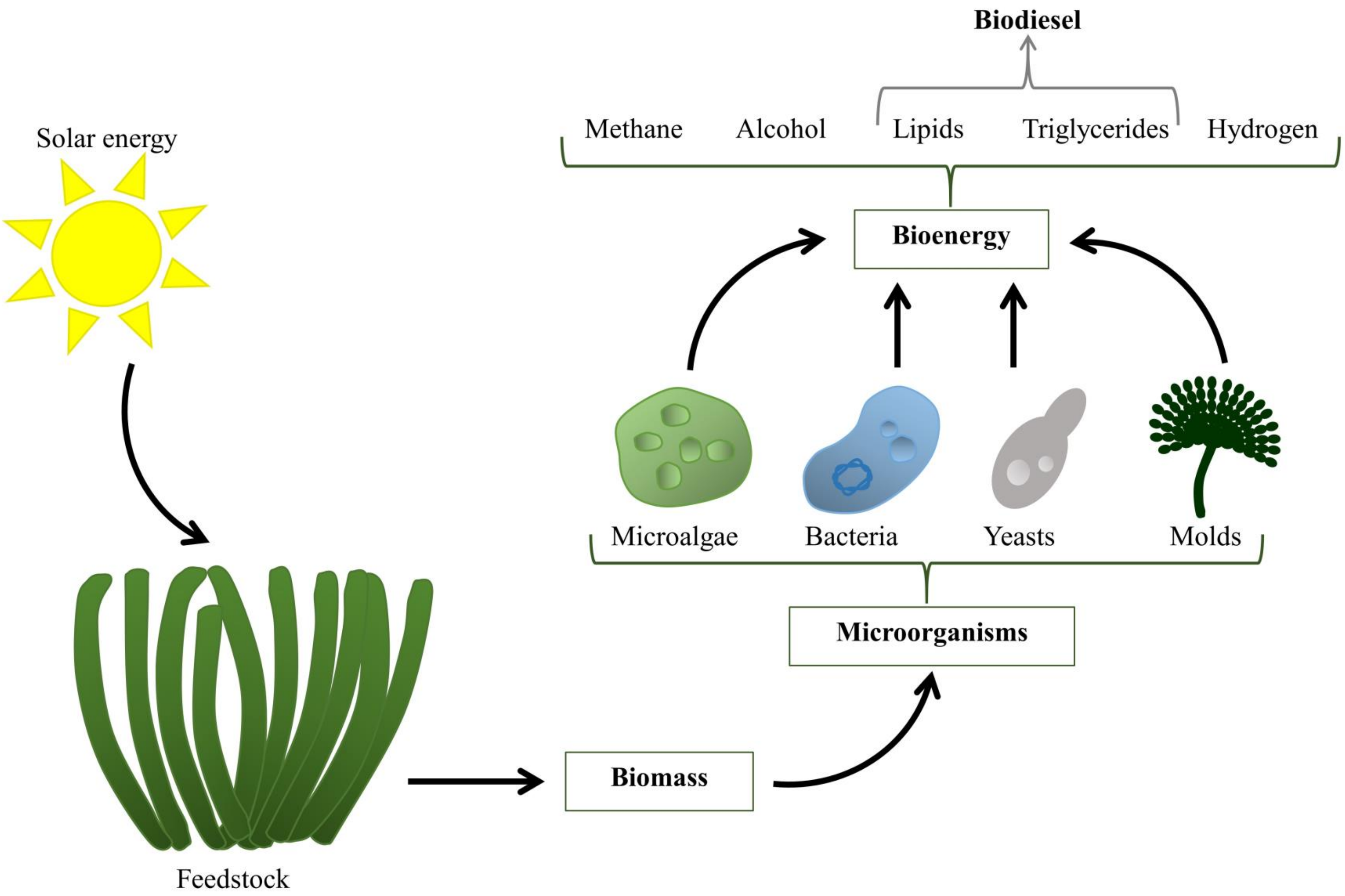
Microbes in Alternative Energy

Introduction

- In their most obvious role in energy conversion, **microorganisms can generate fuels**, including ethanol, hydrogen, methane, lipids, and butanol, which can be burned to produce energy. Alternatively, bacteria can be put to use in microbial fuel cells, where they carry out the direct conversion of biomass into electricity.
- For example, **microbes can be used to convert sunlight, carbon dioxide, and nitrogen into a renewable fuel sources**.
- Microbes are being used **to produce ethanol** for biofuels which is produced from lignocellulose, a mixture of cellulose, hemicellulose, and lignin, which make up the plant cell wall. The enzyme which breaks down cellulose is cellulase.


Fuel Cells
Hydrogen
Methanol
Solar Cells
Microbes
Ethanol
Energy
Storage
Biodiesel
Electro-
Synthesis



Biodiesel
Methane
Alcohol
Lipids
Triglycerides
Hydrogen
Solar energy
Bioenergy
Microalgae
Bacteria
Yeasts
Molds
Microorganisms
Biomass
Feedstock

aper provide a detailed overview of the diverse landscape of MFC application, as depic
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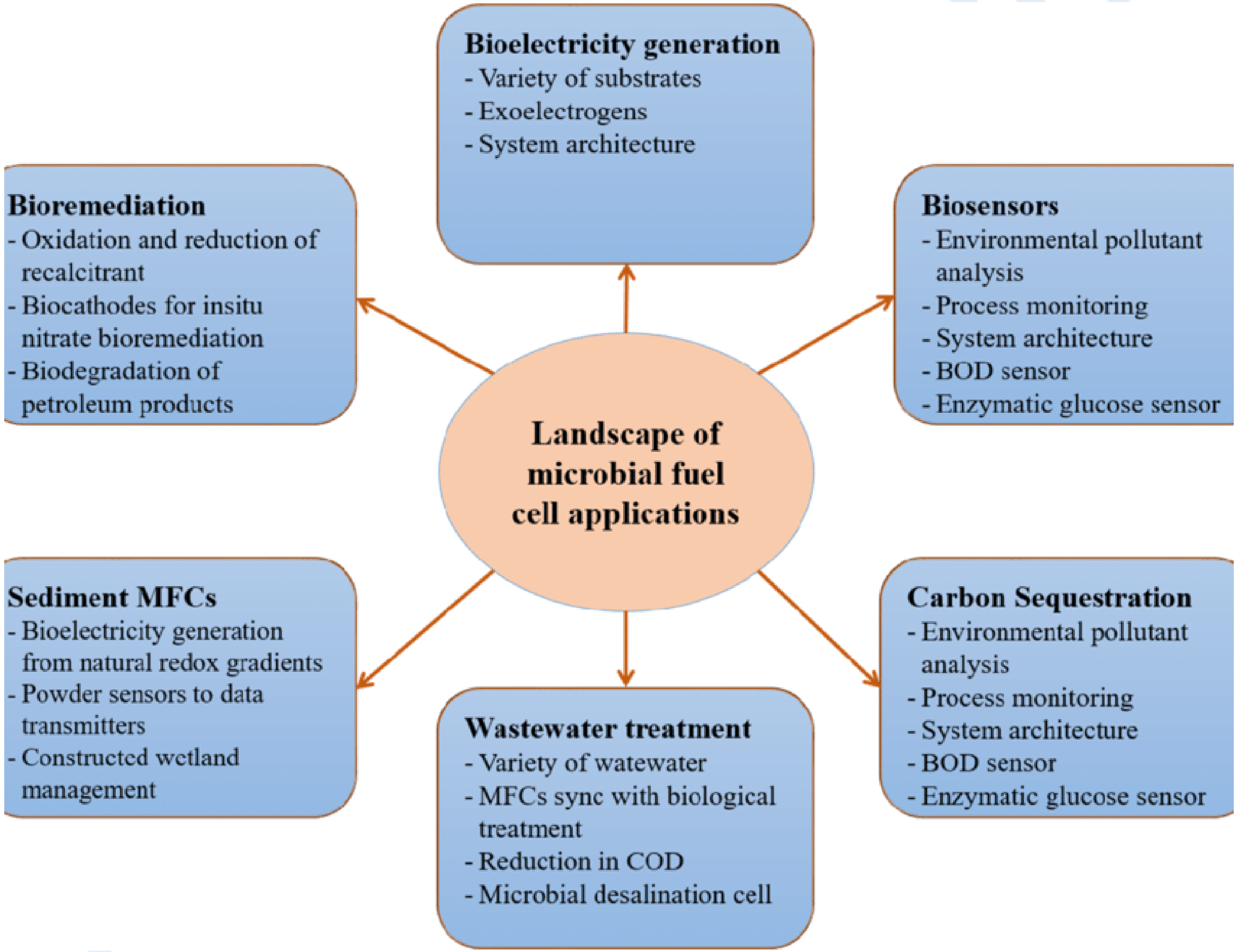
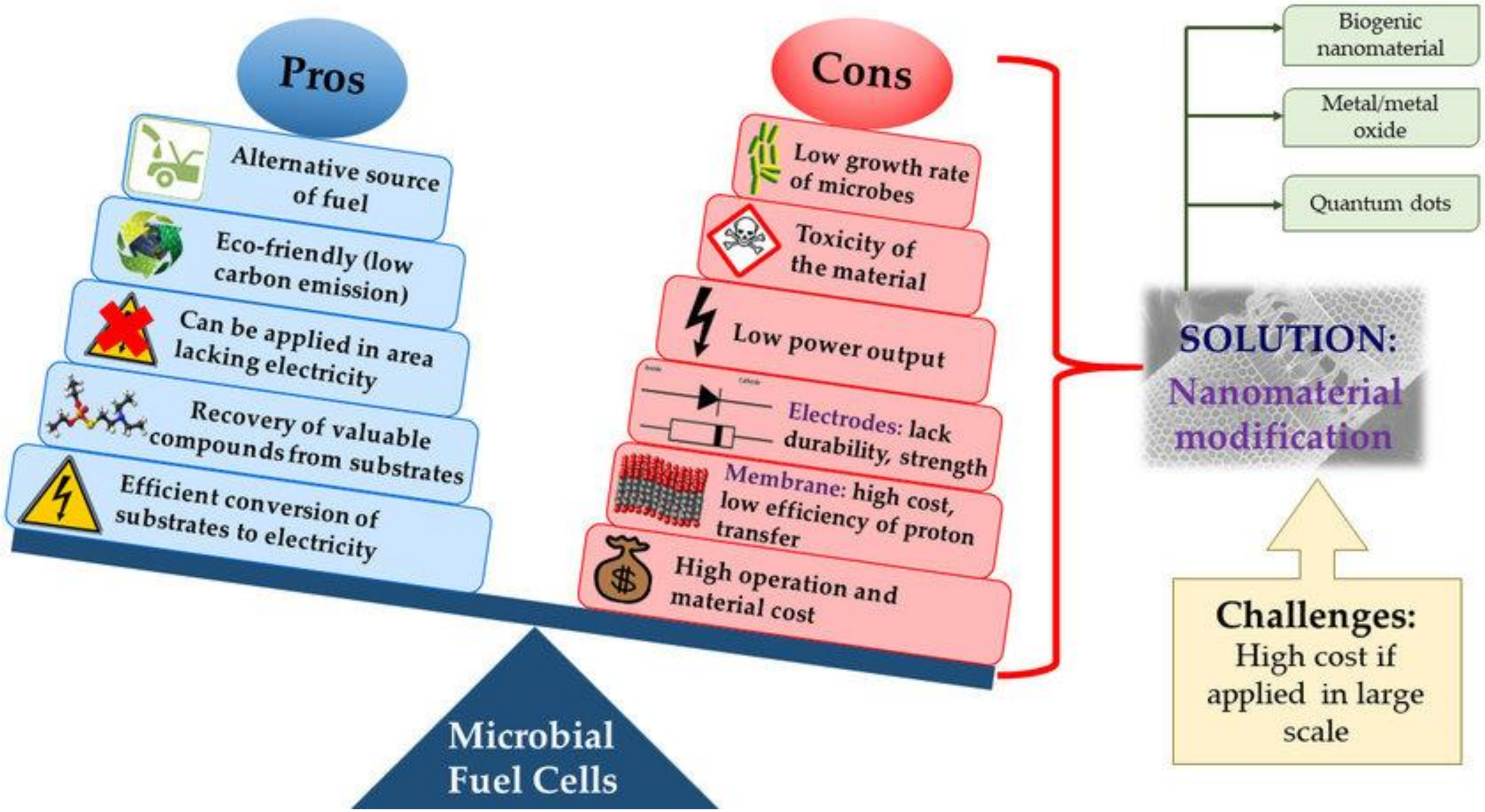
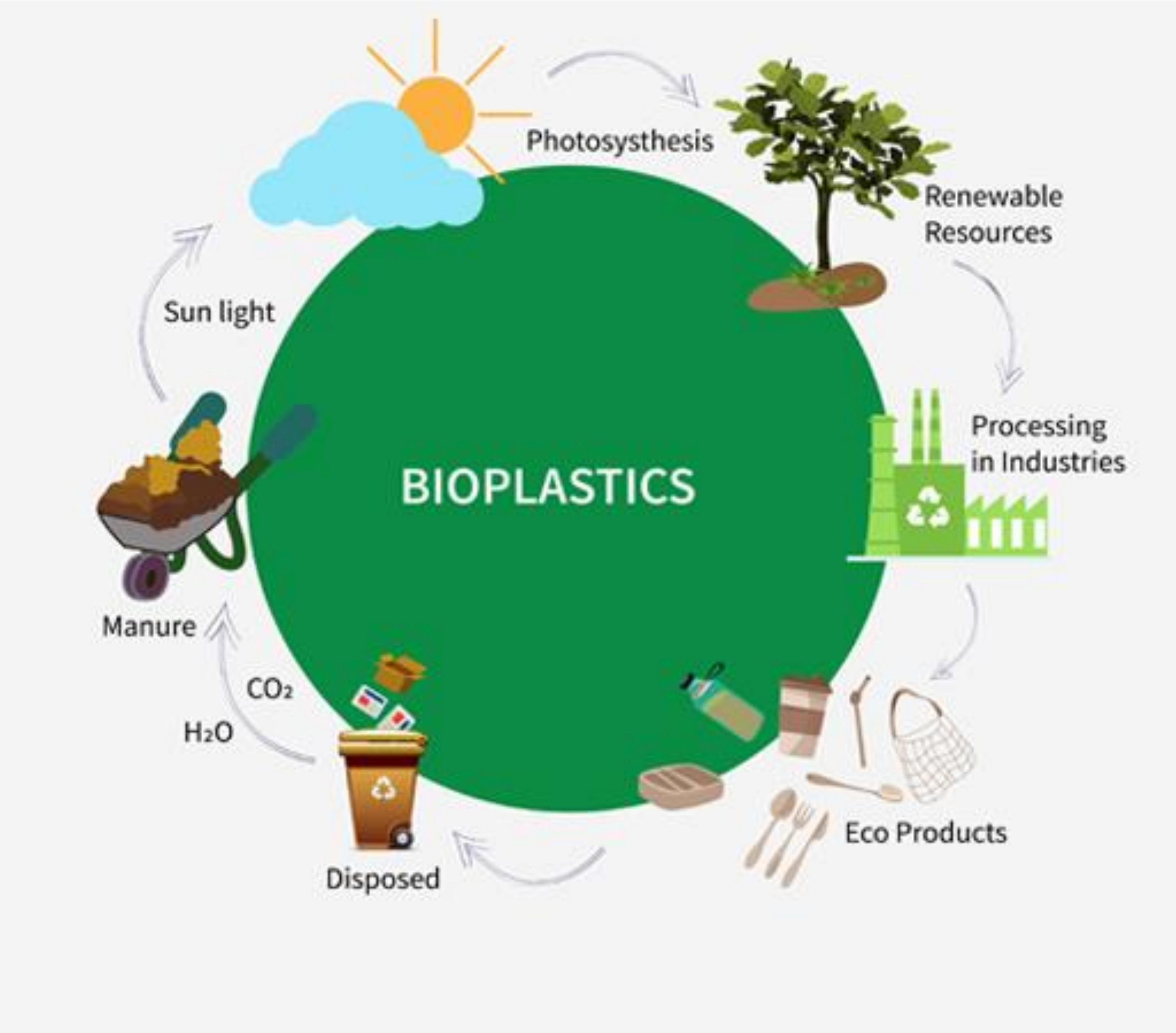
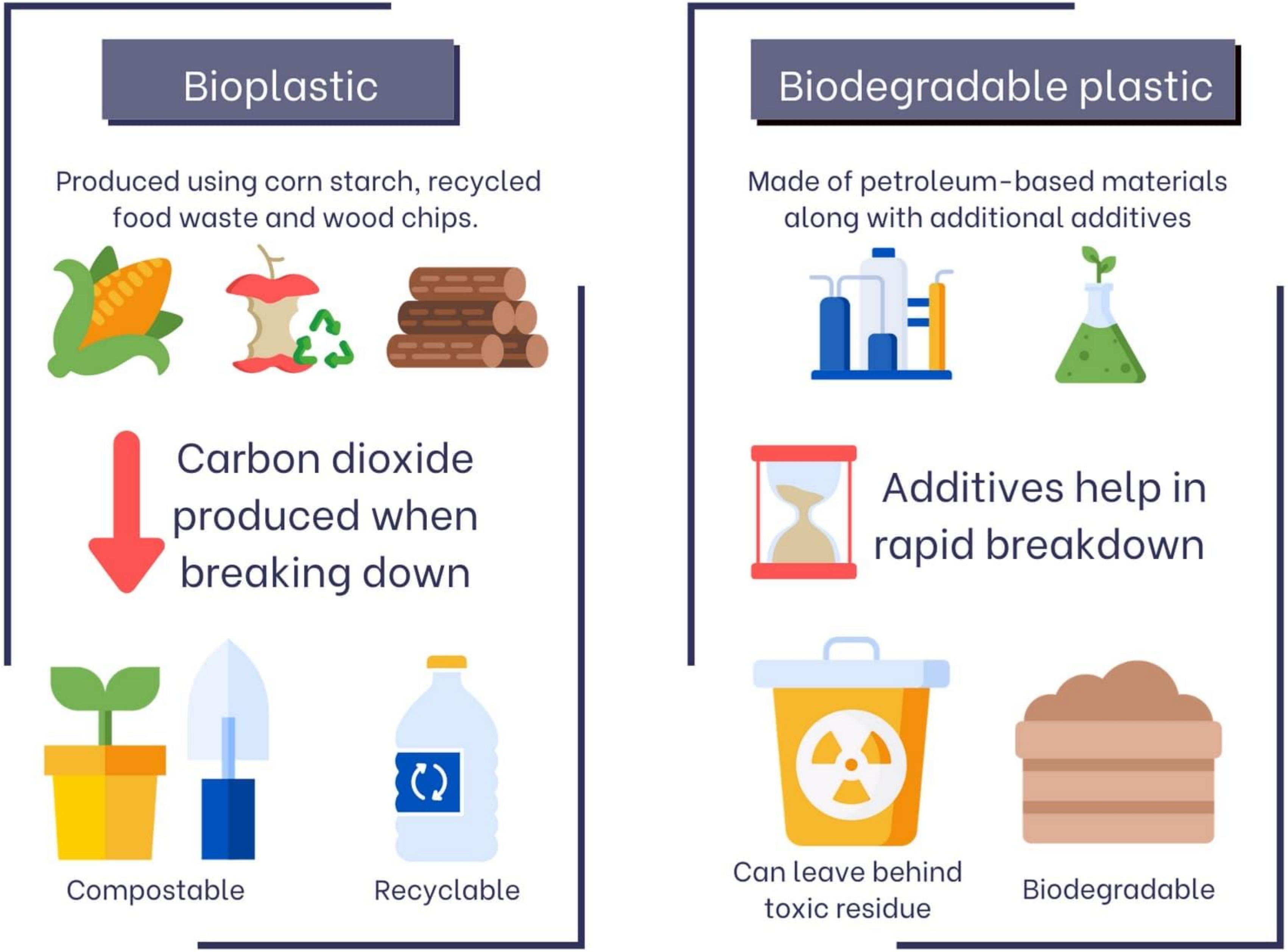


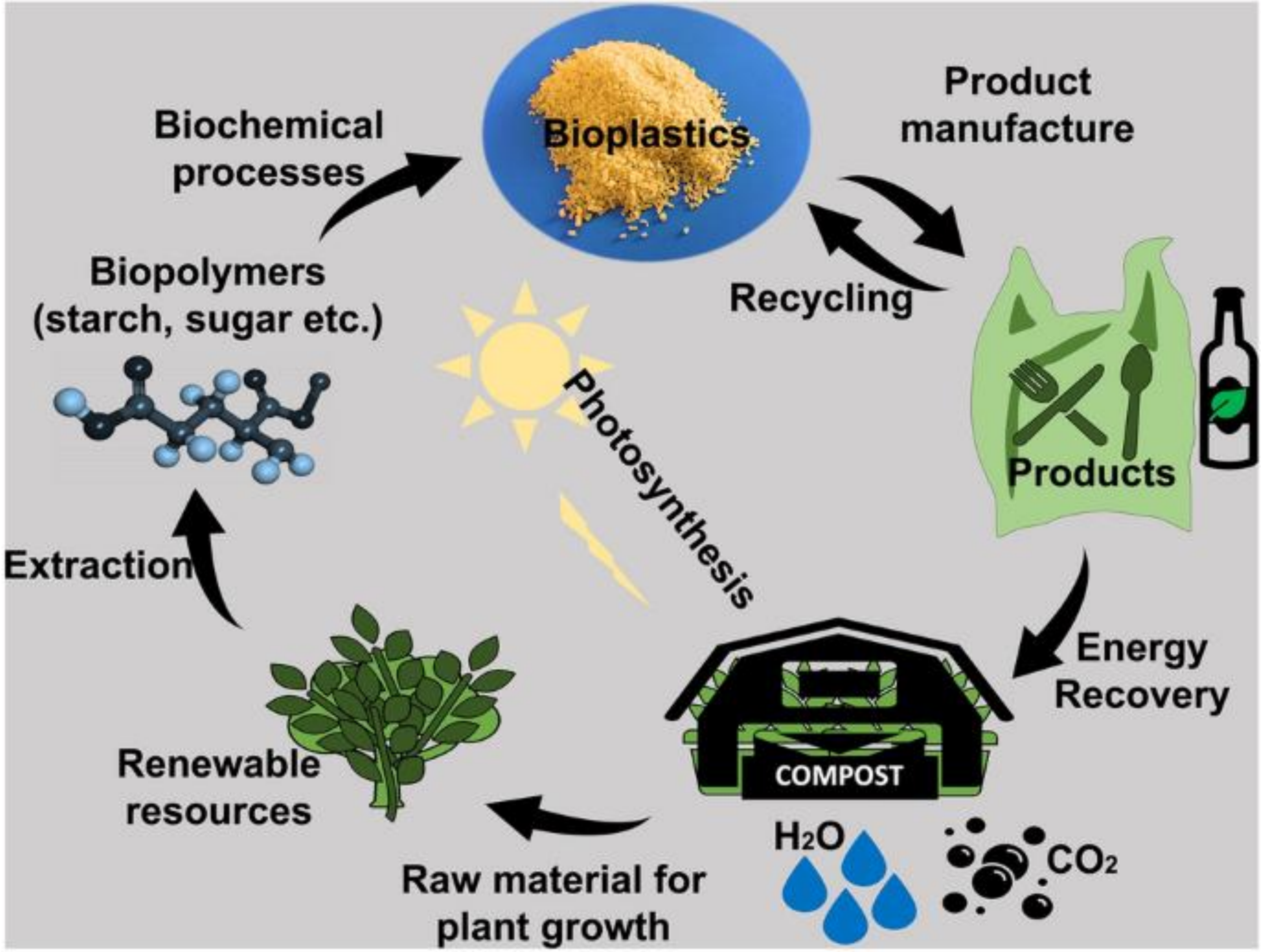

Pros
Alternative source of fuel
Eco-friendly (low carbon emission)
Can be applied in area lacking electricity
Recovery of valuable compounds from substrates
Efficient conversion of substrates to electricity
Cons
Low growth rate of microbes
Toxicity of the material
Low power output
Electrodes: lack durability, strength
Membrane: high cost, low efficiency of proton transfer
High operation and material cost
Microbial Fuel Cells
SOLUTION:
Nanomaterial modification
Biogenic nanomaterial
Metal/metal oxide
Quantum dots
Challenges:
High cost if applied in large scale

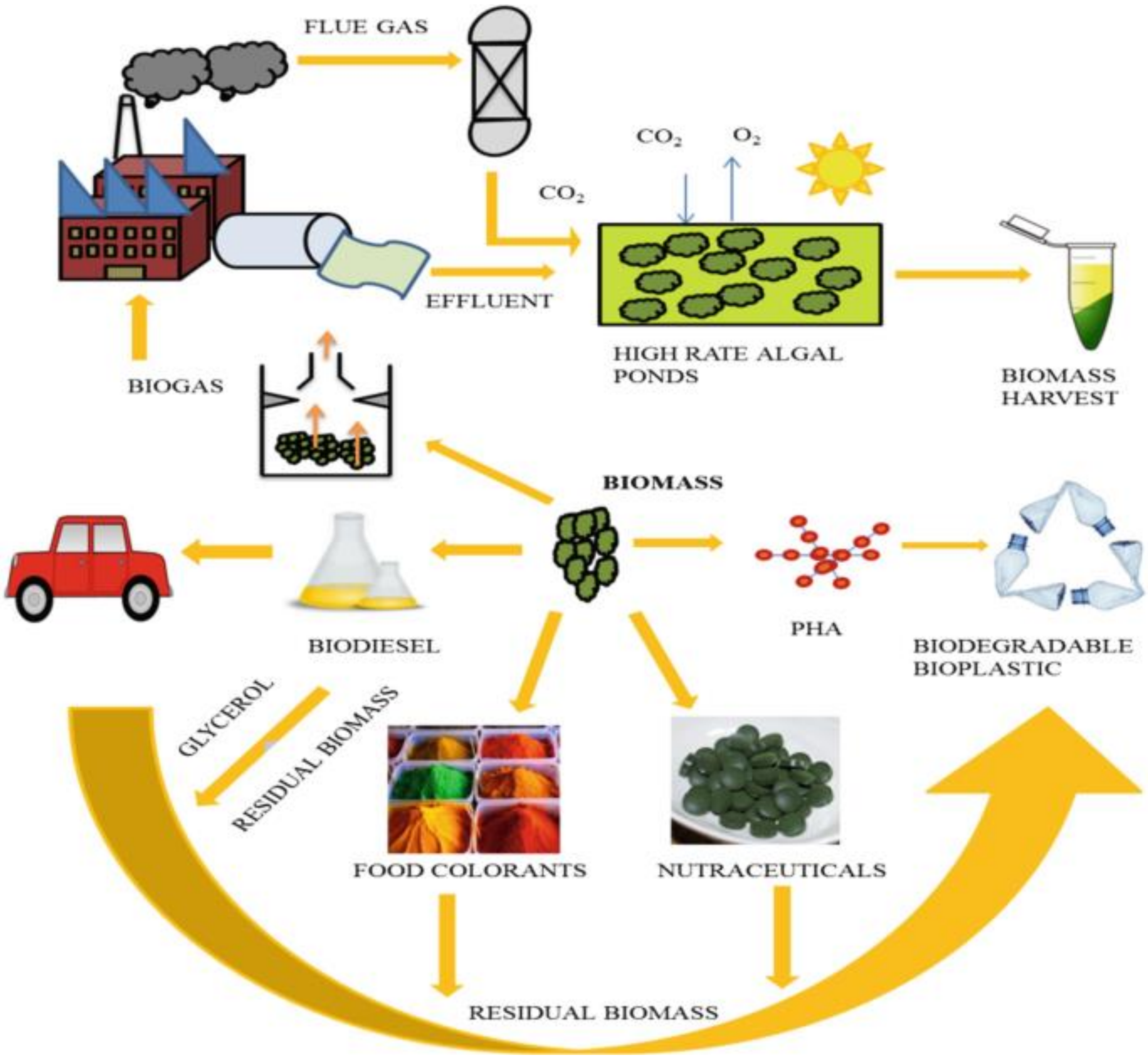
Bioplastics

- A type of plastics which are made up of renewable biomass sources, e.g. vegetable fats and oils, corn starch, pea starcher microbiota, etc.
- Since bioplastics are plant-based products, the consumption of petroleum for the production of plastic is expected to decrease by 15–20% by 2025.
- Bioplastics are partly biobased, biodegradable, formulated with biological substances.
- Examples of biomass used in bioplastics include **corn, sugarcane, tapioca, or other forms of cellulose.**
- Degenerated by bacteria or other (living) biological factors.
- Commonly used as disposable items including packaging materials, dining utensils, food packaging and insulation.
- They are divided into three categories:
  - **Category 1**: polymers directly extracted/removed from biomass e.g. polysaccharide, proteins, etc.
  - **Category 2**: Polymers produced by classical synthesis using renewable bio-based monomers e.g.: poly acetic acid, a bio polyester polymerized from lactic acid monomers.
  - **Category 3**: polymers produced by microorganism or genetically modified bacteria.

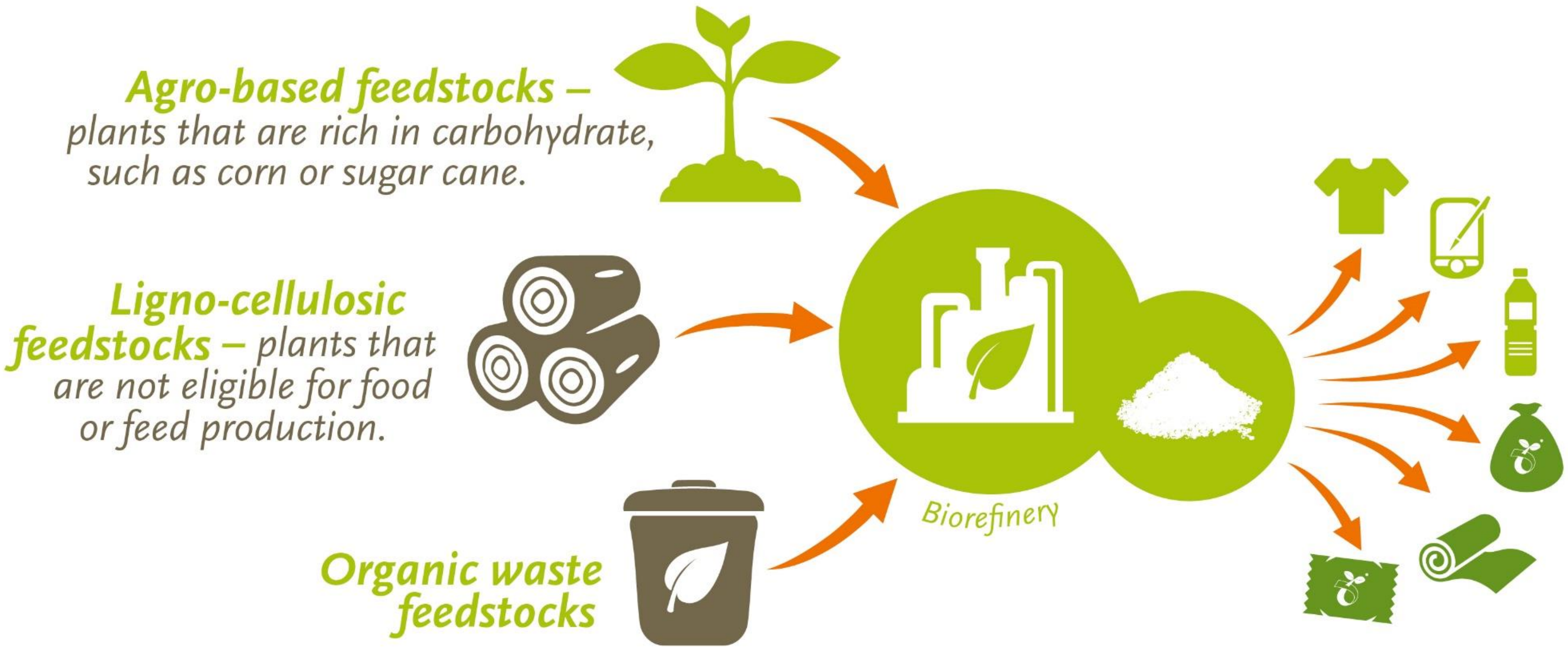

Photosysthesis
Renewable
Resources
Processing
in Industries
BIOPLASTICS
Eco Products
Disposed
CO_2
H_2O
Manure
Sun light


Bioplastic
Produced using corn starch, recycled food waste and wood chips.
Carbon dioxide produced when breaking down
Compostable
Recyclable
Biodegradable plastic
Made of petroleum-based materials along with additional additives
Additives help in rapid breakdown
Can leave behind toxic residue
Biodegradable


Bioplastics
Product manufacture
Recycling
Biochemical processes
Biopolymers (starch, sugar etc.)
Photosynthesis
Products
Extraction
Energy Recovery
COMPOST
Renewable resources
H_2O
CO_2
Raw material for plant growth


FLUE GAS
CO_2
CO_2
O_2
EFFLUENT
BIOGAS
HIGH RATE ALGAL PONDS
BIOMASS HARVEST
BIOMASS
BIODIESEL
PHA
BIODEGRADABLE BIOPLASTIC
GLYCEROL
RESIDUAL BIOMASS
FOOD COLORANTS
NUTRACEUTICALS
RESIDUAL BIOMASS

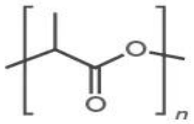
Bio-based plastics are made from **a wide range** of renewable **BIO-BASED feedstocks.**



THE CHEMISTRY OF BIODEGRADABLE PLASTICS

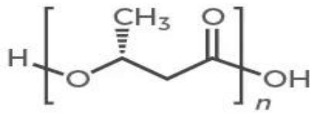
COMMON BIOPOLYMERS & SOURCES

POLYLACTIC ACID (PLA)



Obtained from fermented plant starch from corn, cassava, sugar cane or sugar beet.

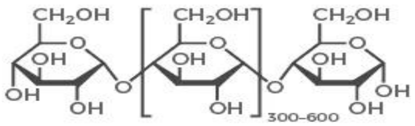
POLYHYDROXYALKANOATES (PHAs)

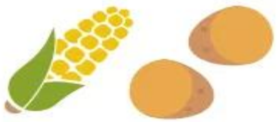


← *poly-(R)-3-hydroxybutyrate (P3HB)*

Extracted from bacteria, which produce it via the fermentation of sugar or lipids.

THERMOPLASTIC STARCHES (TPS)





Starches from plant materials are heated with water, then mixed with plasticisers or other polymers.

EVERYDAY USES OF BIOPOLYMERS

Biodegradable coffee cups are paper cups with a PLA lining to make the paper waterproof.

PLA has the second largest production volume of any biopolymer (behind TPS). It is also used in plastic films, bottles, and food containers.

PLA and TPS both find use in the manufacture of plastic cutlery that's biodegradable.

TPS is also used in food waste bags and some magazine wrappers. PHAs have fewer uses, but have medical uses such as in surgical sutures.

ADVANTAGES AND DISADVANTAGES

GLOBAL PLASTIC PRODUCTION

CONVENTIONAL PLASTICS
333
million tonnes

BIODEGRADABLE & BIOPLASTICS
2.11
million tonnes

Use of bioplastics is increasing, but they still account for less than 1% of the global plastics market (as of 2018).

CONDITIONS FOR BIODEGRADING

MOISTURE | OXYGEN | MICROORGANISMS | pH | TEMPERATURE

Compostable plastics need specific conditions to break down – and take much longer to do so completely if they go to landfill instead of being recycled. However, they still break down faster than conventional plastics.

Biodegradable plastics are more expensive than plastics derived from fossil fuels on weight basis, and require land to grow raw materials. However, the greenhouse gas emissions associated with their production are lower.

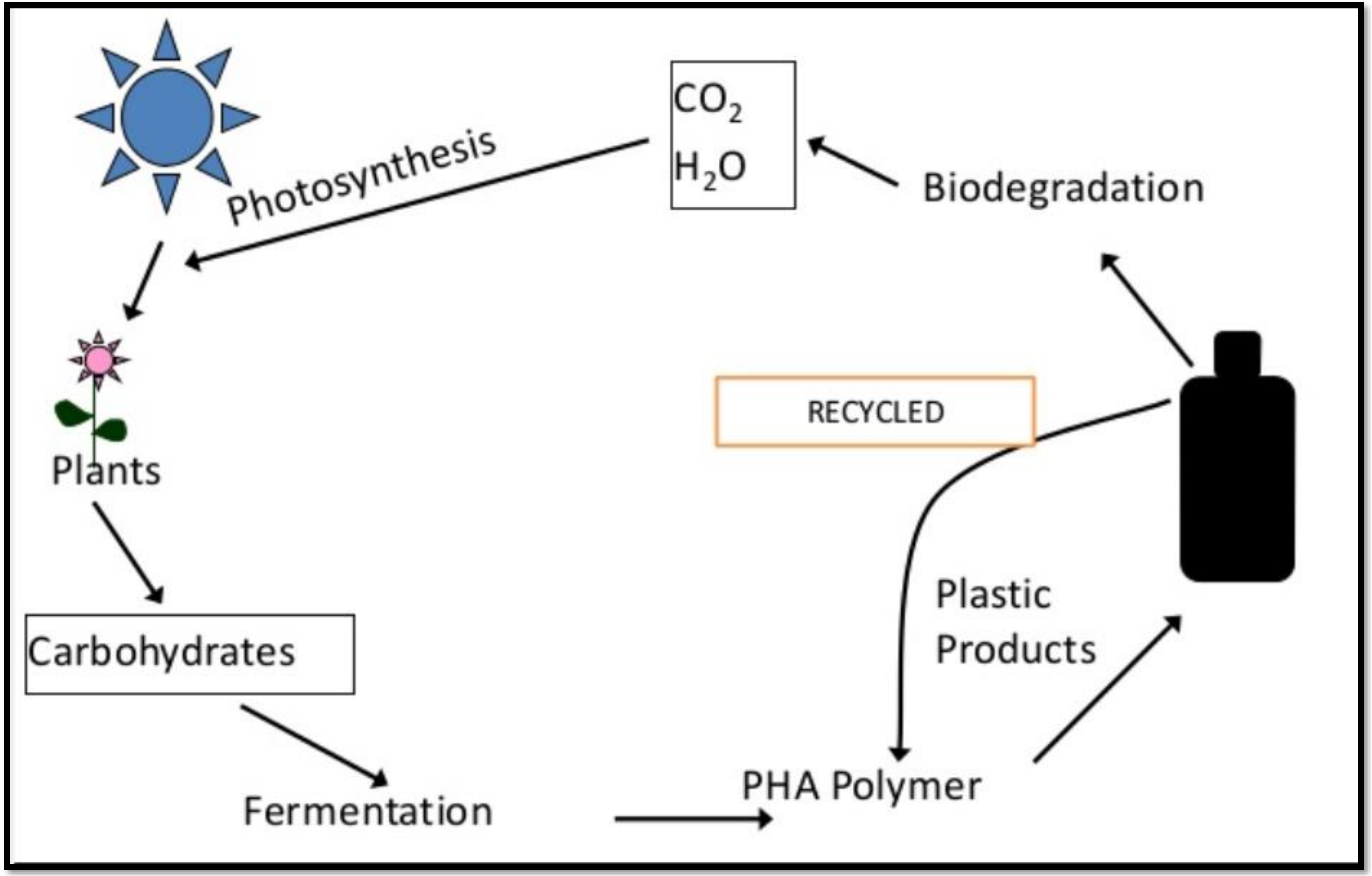

ADVANTAGES OF BIOPLASTIC
Reduces Carbon Footprint
Degrades within 3- 6 months
Made from Renewable Energy
Does not change the scent or Flavor of Food
Help in Increasing the Soil Fertility
NON TOXIC
No additives that are Harmful to Health like Phthalates or Bisphenol A
Reduces Non- biodegradable Waste that contaminates the Environment
www.bharatcompostables.com

Advantages:

- They are cheaper than chemical method.
- This method is better than chemical reactions due to its substrate specificity, stereospecificity and mixed reaction conditions.
- The environment pollution is reduced.
- It is easy to apply recombinant DNA technology to bring about a desired improvement in microbes involved in biotransformation.
- It is easy to scale up the process due to limited number of reactions.

Types of bioplastics synthesized by micro-organisms are:

- Polyhydroxyalkanoates (PHA)
- Poly(lactic acid) (PLA)
- Poly(butylenes succinate) (PBS)
- Polyethylene (PE)
- Poly(trimethylterephthalate) (PTT)
- Poly(p-phenylene) (PPP)



Carbon cycle of bioplastics

Polyhydroxyalkanoates (PHAs)

- Polyester accumulated inside microbial cells as carbon and energy source storage.
- It is classified into two different type based on the number of carbon atoms in the monomer:
  - **short chain length, *scl*** polymers consisting of 3-5 carbon atoms containing monomers, e.g. *Cuprivadus necator* and *Alcaligenes latus.*
  - **medium chain length, *mcl*** polymers consisting 6-14 carbon atom containing monomers, e.g. *Pseudomonas putida* and *Pseudomonas mendocina*.
- Biosynthesis of PHA is conducted by microorganisms grown in an aqueous solution containing sustainable resources such as starch, glucose, sucrose, fatty acids and even nutrients in waste waters under 30-37 degree C and atmospheric pressure.
- To produce PHA, a culture of microorganism such as *Alcaligenes eutrophus* is placed in a suitable medium and fed appropriate nutrients so that it multiplies rapidly.
- Once the population has reached a substantial level, the nutrient composition is changed to force the microorganisms to synthesize PHA.
- The yield of PHA obtained from the intracellular inclusions can be as high as 80% of the organisms dry weight.
- The biosynthesis of PHA is usually caused by certain deficiency conditions (e.g. lack of macro elements such as phosphorus, nitrogen, trace elements, or lack of oxygen) and the excess supply of carbon sources.

- Polyesters are deposited in the form of highly refractive granules in the cells, depending upon the microorganism and the cultivation conditions.

Properties of PHA

- PHA has the most diverse structural varieties, resulting in the most variable molecular weights ranging from $10x10^4$ to $10x10^6$.
- Melting temperature (Tm) of 60 and 177 degree C.
- Glass transition temperature (Tg) of 4 to 50 degree C. [When an amorphous polymer is heated, the temperature at which the polymer structure turns "viscous liquid or rubbery" is called the *Glass Transition Temperature*]
- Thermodegradation temperature (Td) of 227 and 256 degree C.
- They are very flexible and have an elongation break ranging form 2 to 1000%, a tensile strength of 17-104 MPa.

Biodegradability:

- Intracellular degradation (mobilisation of PHA (dehydrogenase reactions)
- Extracellular degradation of PHA (PHA depolymerases)
- Blending of PHA with other polymers resulting in: totally biodegradable blends and non-totally biodegradable blends.

Synthesis of Polyhydroxyalkanoates (PHAs)