Sustainability and Circular Economy for Bioplastics by R9 ideology



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Bioplastics

- **Bioplastics are polymers that are derived from bio-based feedstock (from plants), these polymers are biodegradable or compostable or both. For example PLA, PHA and starched based plastics.**
- **However these feedstocks are also used to make bioplastics which are neither biodegradable nor compostable, e.g., bio-PE and bio-PP.**
    - **These bio-based polymers have properties like a conventional thermoplastic materials and can be co-extruded or laminated with conventional plastics.**
- **Bioplastics are produced as powders and granules in moderate quantities only (as compared to conventional thermoplastics and thermosets).**
- **Extrusion (blown, cast, sheet), injection molding, blow molding, compression moulding, injection-blow molding and other processes are used to fabricate different plastic articles from bioplastics (film, sheet & containers).**

What is R9 ideology? and how it connects to Sustainability and Circular Economy for bioplastics (or conventional plastics)

- **R9 ideology is based on explanation/exploration of different methods from R1 to R9 (as shown below).**

- **R1 to R9**
  - **R1: Range of Materials (PLA, PHA Cellulose, bio-PE and bio-PP).**
  - **R2: Recovery (& segregation into relatively clean streams is essential).**
  - **R3: Reduce (thinner gauges & foamed products).**
  - **R4: Reuse (depending upon the service life, viscoelastic materials).**
  - **R5: Reclaim (post industrial).**
  - **R6: Recycle-Thermoplastic. (Thermoset-chemical recycling).**
  - **R7: Recoup energy (fuel or electricity).**
  - **R8: Reverse (ceiling temperature) into monomers or chemicals.**
  - **R9: Research**

R1-Range of materials

- Thermoplastics
- Partially cross-linked Polymers (UV, Thermal, E-beam)
- Thermosets
- Cross-linked Rubbers
- Composites
- Laminates
- Reinforced Plastics
- Compatible & Non-compatible polymer blends
- Interpenetrating Network Polymers, IPN
- 3D printed parts……

R2-Recovery: Having very similar polymer streams (segregation) is important for Recycling

- **Thermoplastics polymers have a wide range of viscosities within the same resin identification code (RIC). For example LDPE resin has RIC 4, but available in wide range of viscosities (mainly granules or powder) for different extrusion processes (blown, cast, extrusion coating) and molding processes, e.g., 0.3MI, 1MI, 3MI, 10MI, 25MI and 40MI.**
- **Mixing of 'LDPE streams from plastic articles produced from high viscosity resins (0.3MI)' with 'LDPE streams of plastic articles produced from low viscosity resins (25MI)' to make recycled granules (flakes) could cause an issue at the time of processing on a standard equipment.**
- **Having a clean stream of polymers (segregation) is also important for recycling from the facilities where a wide rage of plastic articles from different polymers are used.**
  - **For example in a hospital set-up, a cross-contamination of halogenated polymers (PVC rigid, blisters, tablet packaging) with blue bin polymers (PE or PP materials) could cause severe issues during processing.**

R3: Reduce, R4: Reuse

- **R3-Reduce: Lighter gauge and Foamed products. I'll provide two case studies on foamed applications for the bio-based products, where the weight reduction adds to the sustainability.**

- **R4:-Reuse: Plastics are viscoelastic materials, so during 'Service or Reuse" of the plastic article, 'Thermal & Mechanical stresses', could cause chemical changes leading to structural or mechanical failure of the product. Thus limiting the life span (months or years) of the article, what to do with this plastic product?**

  - **This plastic product (if melt process-able) can be either recycled, chemical or physical (R6), and if not it has to be used into other applications (R7-9 approach) and certainly should be avoided from landfills.**

R5: Reclaim and R6: Recycle (Physical & Chemical)

- **R5:-Reclaim: Industrial sector (trim). In industrial set up the incoming polymer's purity and quality is known, so it can be added into same or different manufacturing process.**
- **R6:-Recycle-Physical: Thermoplastics, melt process-able like bio-PE, bio-PP.**
- ***R6:-Recycle:-Chemical: Thermoset, natural fiber-based epoxy composites.**

R7: Recoup Energy, R8: Reverse and R9: Research

- **R7: Recoup Energy**
  - **Incineration, Pyrolysis and/or High Temperature Treatment of conventional polymers and bioplastics can be used to make electricity or fuel.**
    - **But, what about CO2 (GHG) being generated? CO2 is also a by product of combustion (natural gas, fossil fuel and lignin).**
- **R8: Reverse (ceiling temperatures for polymers)**
  - **Polyester and Polyamides shows a reversible reaction and can be converted into monomers.**
  - **Some polymer heated to its ceiling temperatures revert back to monomers.**
    - **Excellent method to recover monomers and chemicals.**
- **R9: Research**
  - **We need to look into potential applications to utilize the mixed plastic waste (MPW) because the consumption of conventional and bioplastics is in millions of tonnes. Therefore after Recovery besides the above methods; new processes and applications should to be developed to use the recovered plastics.**

Literature References for R9-Research

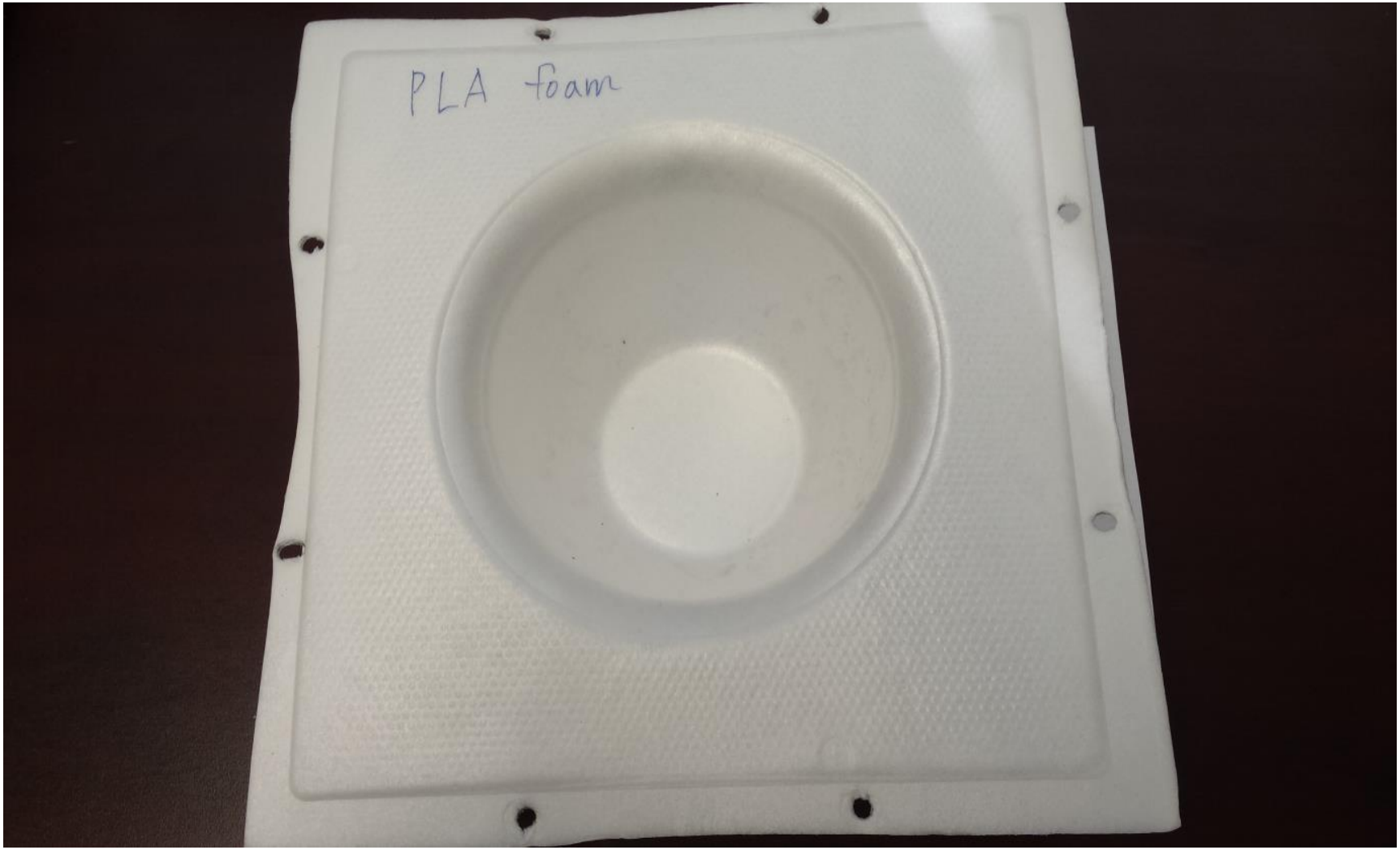
- **Dow tackles ocean based waste: Plastic waste mixed into asphalt for making road. CEN.ACS.ORG January 8, 2018.**

- **LyondellBasell to recycle plastics. CEN.ACS.ORG December 4, 2017.**

- **Polymer ready for repeat recycling. Polymers with promising properties can be easily converted back to its monomer and repolymerized. Reference: CEN.ACS.ORG April 30 2018.**

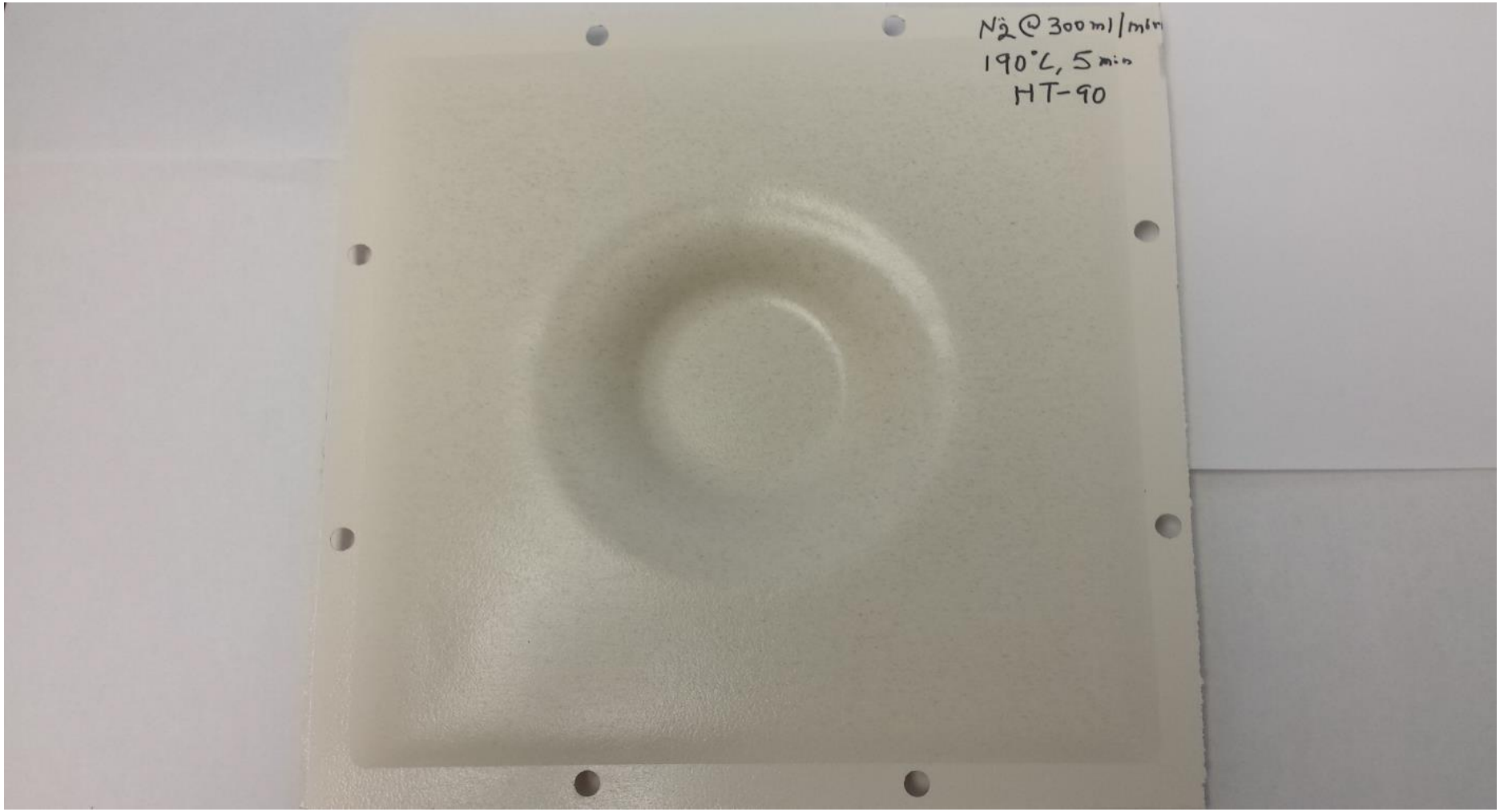
- **Robust demand should continue in 2018: Hydrocarbons and CO2 are winning the global battle to fill home refrigerators. Reference, CEN.ACS.ORG, January 8, 2018.**

R3-Reduce: PLA Low density foam sheet (Thermoformed), Tandem Equipment (annular die). Courtesy of Macro Engineering & Technology Inc.



R3-Reduce: Cellulose derived material (high density foam sheet, using nitrogen gas as foaming agent), Sheet Line

Courtesy of Macro Engineering & Technology Inc.

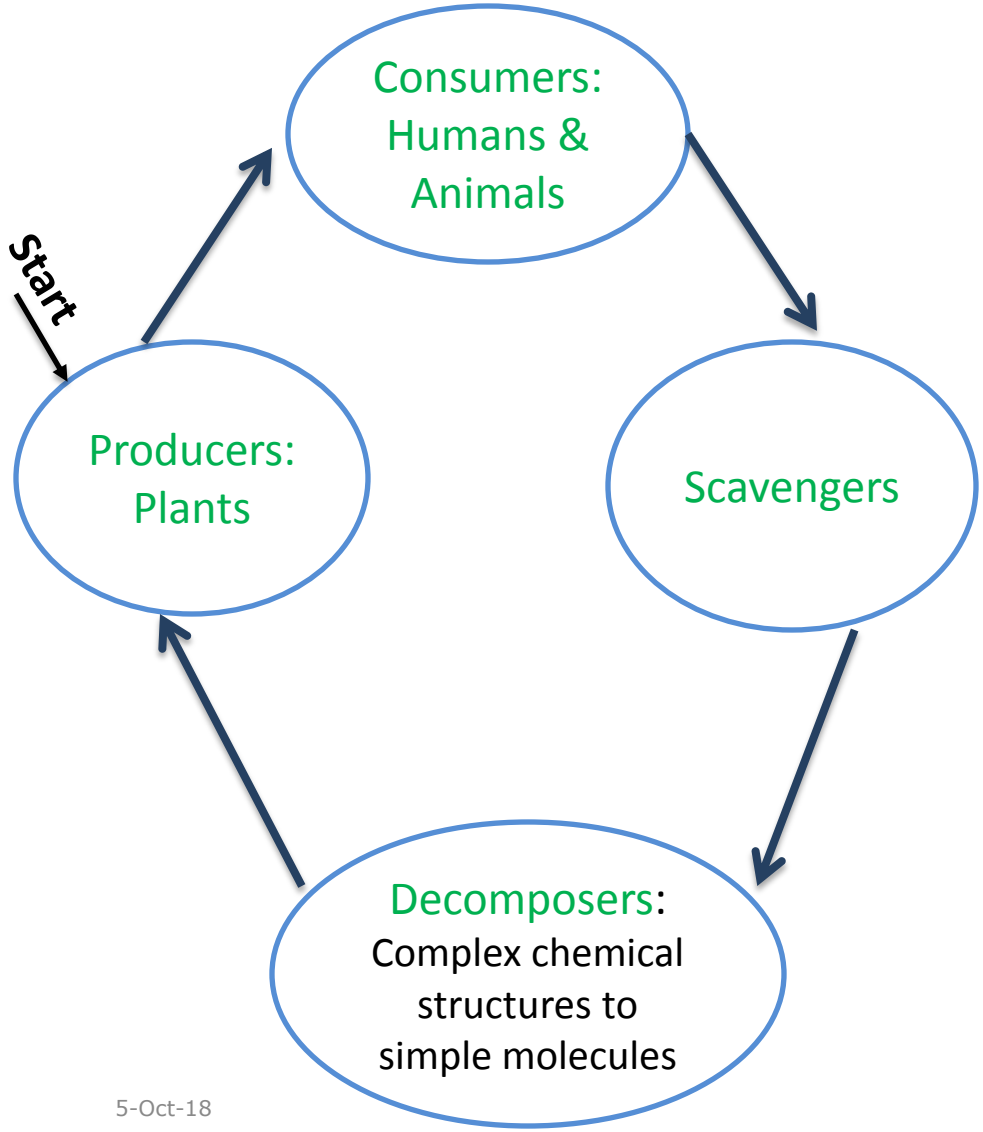


R9-Research to be Conducted: To partially/fully attain Circular Economy and Sustainability for plastics (bioplastics)

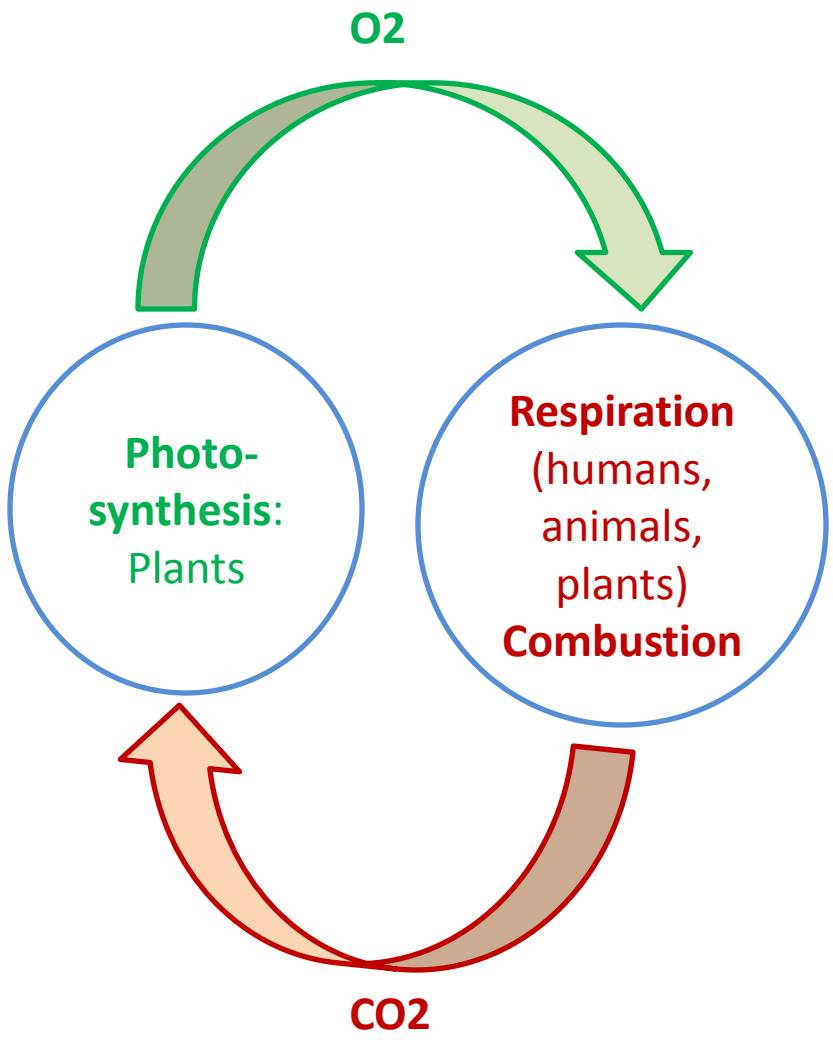
- In this section we will look at two Natural cycles (Nature's Cycle 1) and (Nature's Cycle 2), occurring for millions of years.
- An attempt is made to correlate 'Plastic's Cycle in the Present Economy' with Nature's Cycle 1. Some information on how 'Nature's Cycle 2' is being impacted by human activities is discussed.
- Using R9 ideology, 'Plastic's Cycle in the Present Economy' and 'Nature's Cycle 2' are combined to make a "Cyclic model" to shows methods to reduce plastic waste to landfills and redirecting it to useful products to partially/fully attain Circular Economy and Sustainability for conventional & bio-plastics (commercial research dependent)
- My company supports Canadian Government's and CPIA's effort for 'Zero Plastics Waste' (keeping plastics within economy and out of landfills & the environment. The above "Cyclic model" will show, how partially/fully it could be done (research dependent).

Nature's Cycle 1 and Cycle 2:

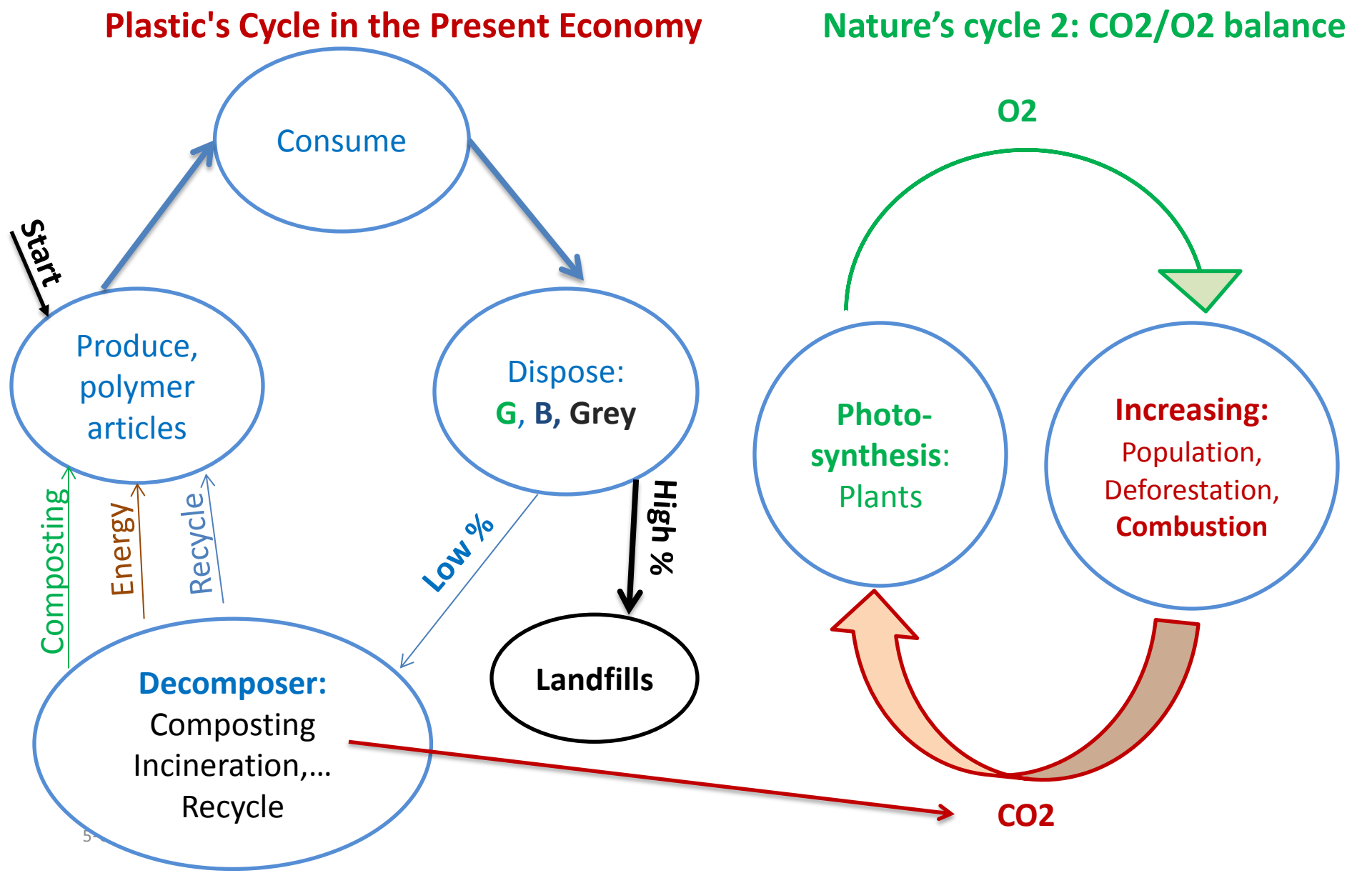
Nature's Cycle 1



Nature's Cycle 2: CO2/O2 balance



Hypothesis: Plastic's Cycle for the Conventional & Bioplastics in the Present Economy

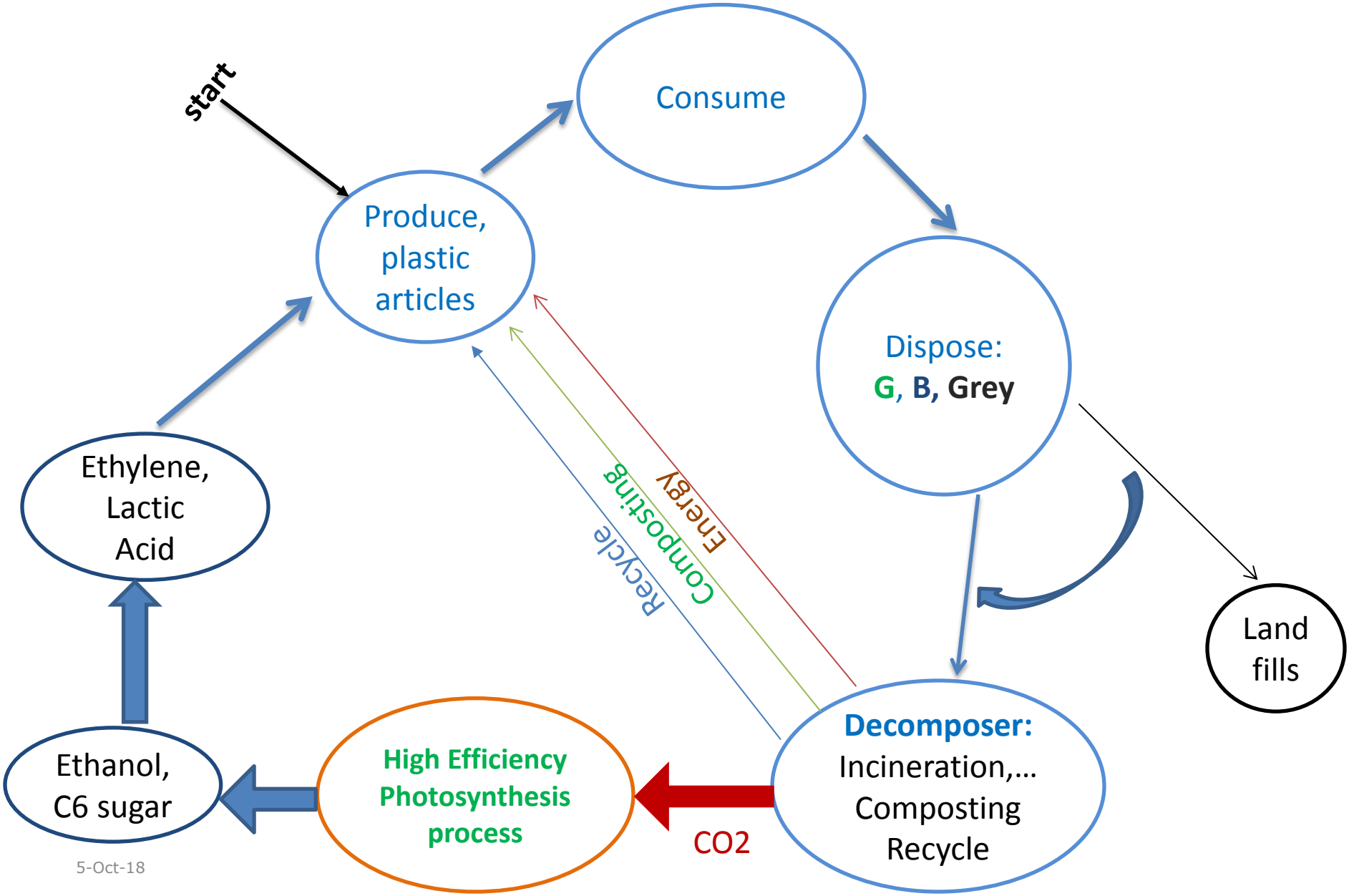


References on Recycling and high landfills

- **UNSUSTAINABLE: Only 14% of plastic packaging is recycled, 14% for incineration, 32% Environment and 40% Landfills. "Recycling Needs a Revamp" CEN.ACS.ORG, page 24-25 (& cover page), June 18, 2018.**

- **Recycling and Sustainability: Plastic recyclers from Europe reports 60 million tons of plastic consumption (27 countries) with 24 million tons (40%) related to packaging. This is a large opportunity for recycling to attain sustainable solutions OR "a concern for Resource depletion". Plastic Engineering, www.4spe.org, page 9, May 2018.**

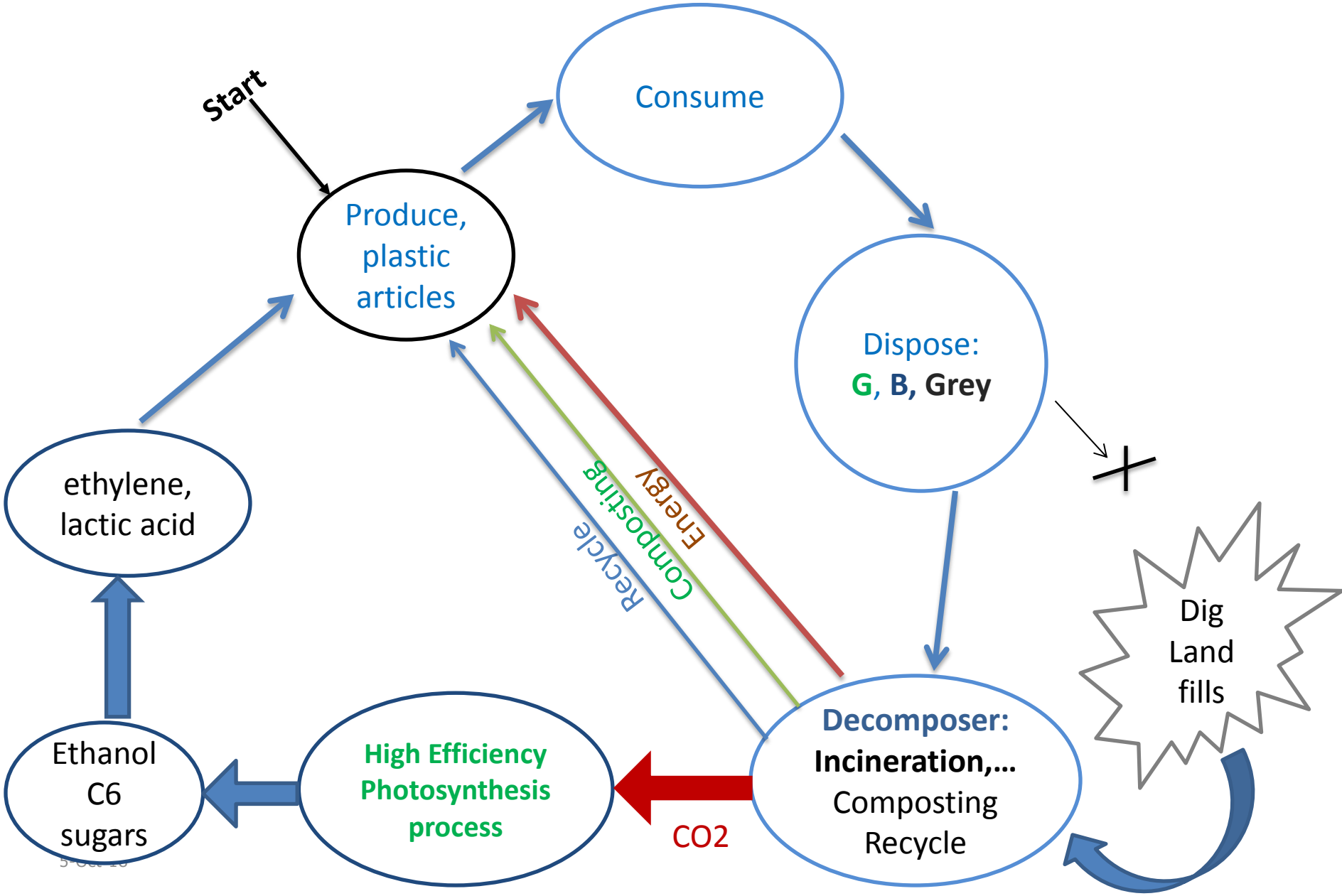
Cyclic model: by combining "Plastic's cycle in the Present Economy " with 'Nature Cycle 2' to attain "Sustainability and Circular Economy". (Research dependent)



Literature References: CEN and ASU report on utilizing CO2

- Seed partners unveil photosynthesis trait: Report mentions a trait in hybrid corn increase the efficiency of photosynthesis and in turn increases the plant's ability to fix Carbon (from atmosphere) into sugar. CEN.ACS.ORG, page 14, May 21, 2018.
- Making bioprocessing zippier: This article mentions a biocatalyst which breaks down biomass (cellulose) (30 times faster as compare to native enzyme) into glucose, an important feedstock to make other chemicals like ethanol. CEN.ACS.ORG, July 2, 2018.
- Arizona State University (ASU) biofuel research, part of $10 M Department of Energy Funding. Two projects to focus on algae and cyanobacteria (uses CO2, water and sunlight to make biofuel). Source: asunow.asw.edu/20160516-asu-news-biofuel-research department-energy-funding.
- Carbon capture projects funded by DOE. Capturing CO2 from fossil-fuel-plants. Reference CEN.ACS.ORG, February 26, 2018.

A Cyclic model shows how resources can be put back into “Circular Economy” and have “Zero Plastic Waste” to landfills.



Conclusions

- **R9 ideology methods (R1 to R9 can be used depending upon the type of materials) by putting these resources back into the Circular economy and thus obtaining the sustainable solutions.**

- **Based on the concept of R9 ideology we can work on improving the efficiency of photosynthesis, which can fix more CO2 and convert the process to make 'non-renewable resources' into 'renewable resources' (ethanol, alkanes or C6 sugars) leading to a truly sustainable effort. This could solve the CO2 (GHG) emission issues as well.**

- **My company supports Canadian Government's and CPIA's effort for 'Zero Plastics Waste' (keeping plastics within economy and out of landfills & the environment), rather if we work on above, we can dig out the old landfills and put back the Resources into Circular Economy .**

References

References from American Chemicals Society (ACS) and Plastic Technology (SPE) magazines.

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Questions? **Commercial research in Bio-Sciences, Engineering and Bio-Technology is required to capture CO2 to make chemicals, monomers & fuel; in order to convert 'Non-Renewable' resources to 'Renewables' to achieve 'Sustainability and Circular Economy'… Grow more trees, maintain O2/CO2 balance. O2 is the life of the planet.**

