Bioplastics – Next Generation Polymer Materials for Reducing Carbon and Enviromental Footpring

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CHEMICAL ENGINEERING
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Outline

- Introduce basic concepts and principles related to bioplastics - biobased - biodegradable plastics and products
  - Value proposition for “bio”
  - Terminology/definitions

- Carbon and Environmental footprint
  - Material carbon footprint
  - Process carbon footprint
  - Total environmental footprint
  - Natural carbon cycle

WHAT IS THIS ALL ABOUT?
Framing the question

CARBON!! – burning issue of the day!

- Carbon footprint/profile of product, company, country
- Managing Carbon!!
  - WHAT ARE YOU DOING TO REDUCE YOUR PRODUCTS CARBON FOOTPRINT OR PROFILE – **zero carbon or carbon neutral footprint**
  - Environmental footprint or profile (Other than carbon) – LCA methodology
    - **CARBON FOOTPRINT VALUE PROPOSITION!**

The "VALUE PROPOSITION"

- Use bio/renewable feedstock (as opposed to petro/fossil feedstock to manufacture plastic products (biobased or biomass based plastics):
  - Reduces our carbon footprint and moves us to zero carbon or carbon neutral footprint
    - Reduce CO_2 emissions --- global warming climate change
    - Document using biocarbon content using ASTM D6866
  - Provides a positive environmental footprint/profile

The "VALUE PROPOSITION" FOR BIODEGRADALBE PLASTICS

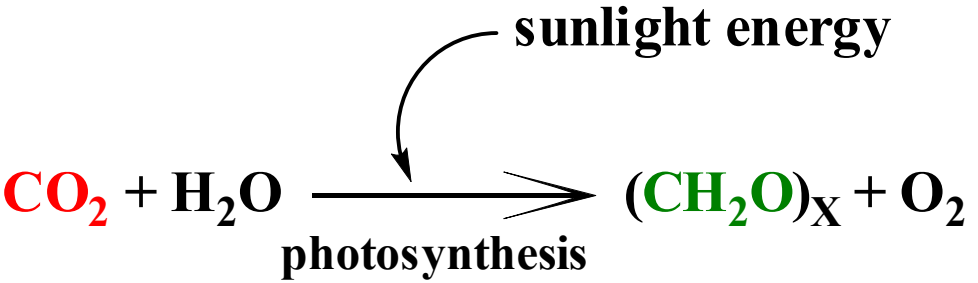
- Using biodegradability as an end-of-life option to completely remove single use short life disposable plastics from the environmental compartment in a safe and efficacious manner via microbial assimilation (microbial food chain)
- Degradable, partial biodegradable not acceptable – serious health and environmental consequences
    - Disposal environment (e.g. composting, anaerobic digestor, marine, etc.)
    - Time to complete biodegradation

Specification Standards ASTM D6400, D6868, D7021

TERMINOLOGY

BIOBASED (BIOMASS OR RENEWABLE BASED)

- Organic material containing in whole or part biogenic (biological sources) carbon
- Refers to using biomass or crop feedstock (New carbon) vs petroleum or fossil feedstock (Old carbon)
- Reducing carbon footprint



TERMINOLOGY

BIODEGRADABILITY – END-OF-LIFE scenario

- need to identify the (end-of-life) disposal system like composting, anaerobic digestion, marine, soil
- using microbes to completely utilize the carbon substrate and removing it from the environmental compartment -- enter into the microbial food chain
- Time to complete microbial utilization – no residue remaining

TERMINOLOGY

BIOMATERIALS -- Biomedical applications

Refers to:

Any material (metal, plastic, ceramic) implanted in the body

- **design and engineering considerations different**
- **biodegradability considerations different**

Terminology (Contd)

BIOPLASTICS

BIOBASED OR BIOMASS BASED OR RENEWABLLY SOURCED PLASTICS OR PRODUCTS

NOT BIODEGRADABLE

BIODEGRADABLE (complete) AND BIOBASED PLASTICS OR PRODUCTS

BIODEGRADABLE (Complete) AND PETRO/FOSSIL BASED PLASTICS OR PRODUCTS

IMPORTANT:

Biodegradability MUST be defined/ constrained by:

- **the disposal system – composting, anaerobic digestor, soil, marine**
- **Time – 180 days ; max 1 year**
- **Complete utilization of the substrate carbon by the microorganisms as measured by the evolved CO_2 (aerobic) and CO_2 + CH_4 (anaerobic)**

Carbon Entry to Biotic world

- **Photosynthesis**

$$CO_2 + H_2O \xrightarrow{\text{Sunlight energy}} (CH_2O)_x + O_2$$

Plants, algae, marine biotic and some bacteria

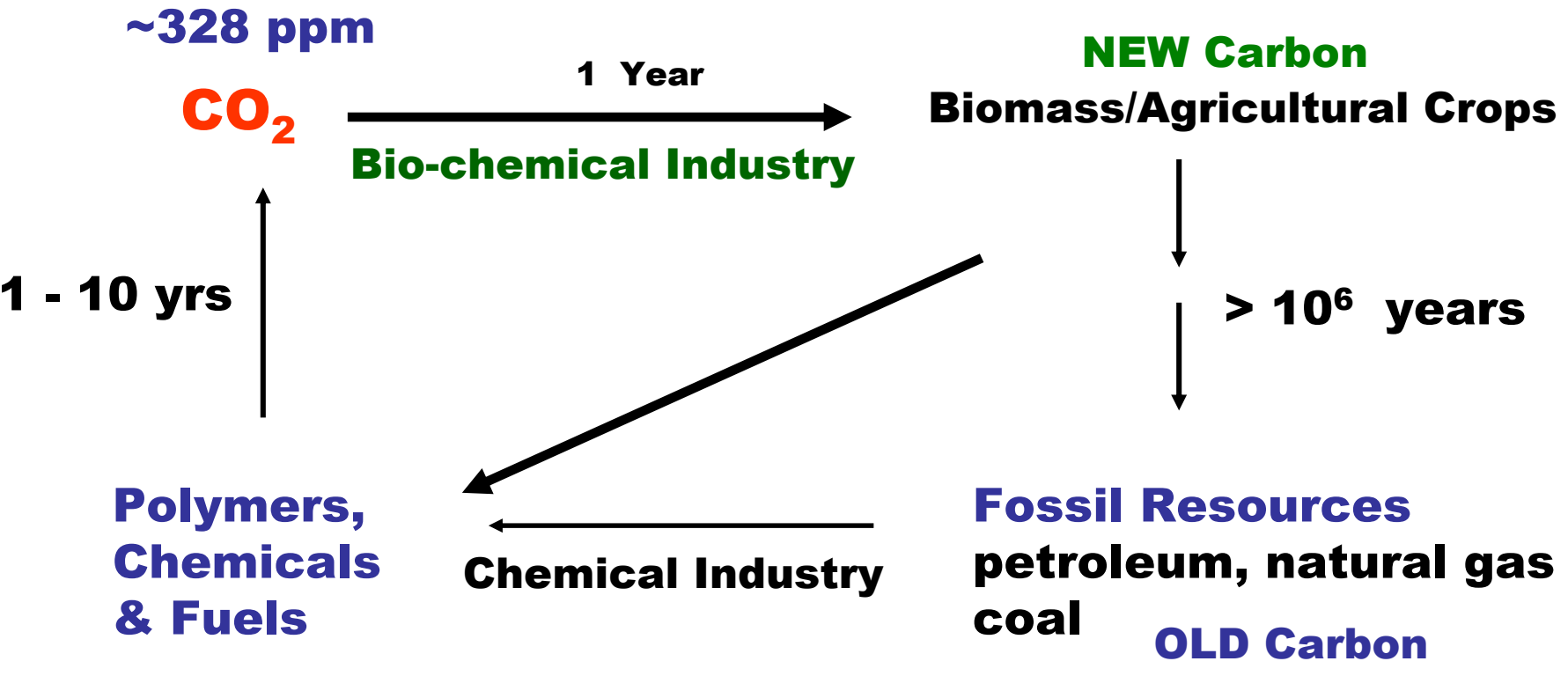
- **Chemoautotrophis**

$$2CO_2 + H_2O \longrightarrow 2HCO_3^- \xrightarrow{Ca^{++}} 2CaCO_3$$

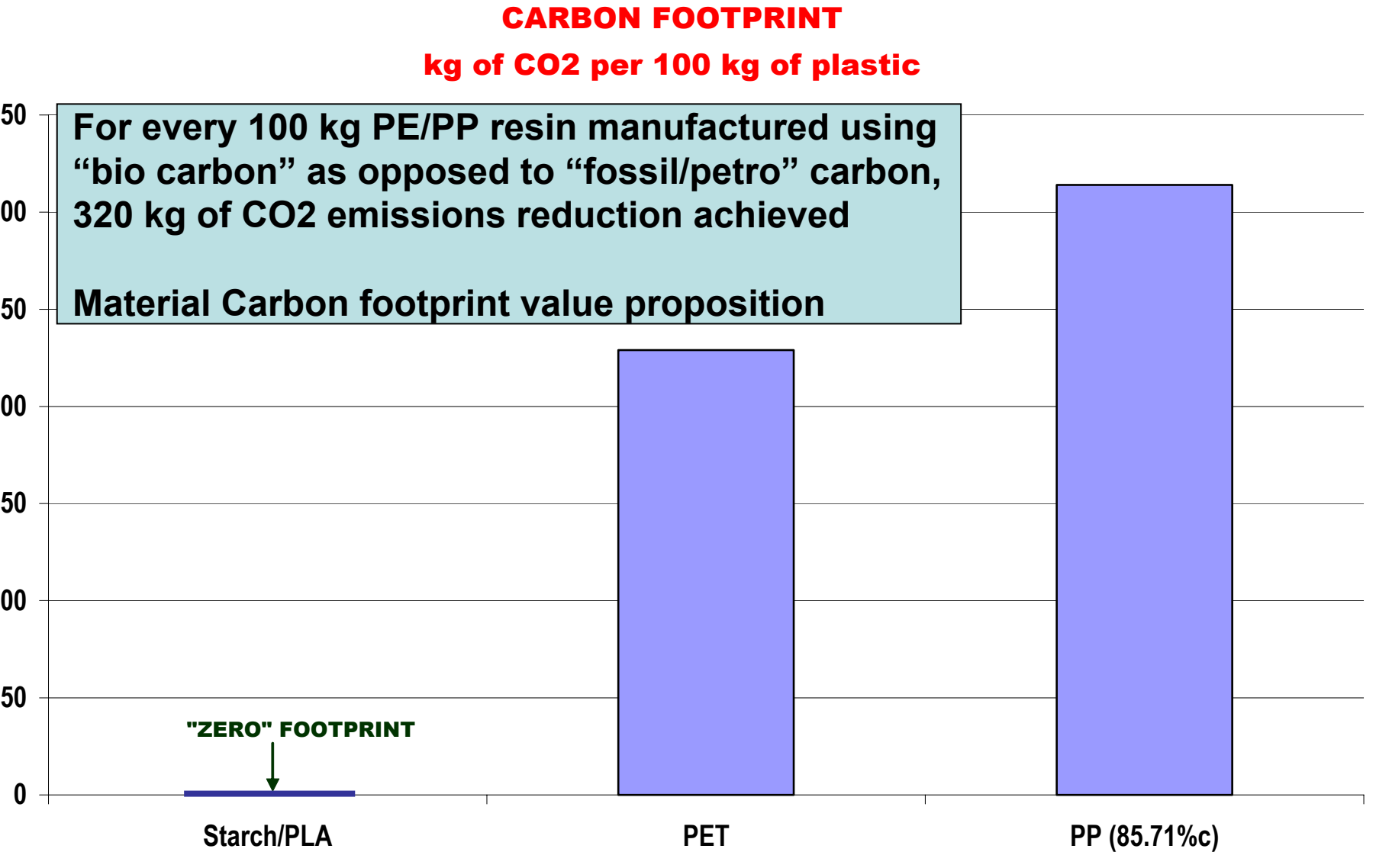
Clams, corals, shells, oysters and some algae

GLOBAL CARBON CYCLING

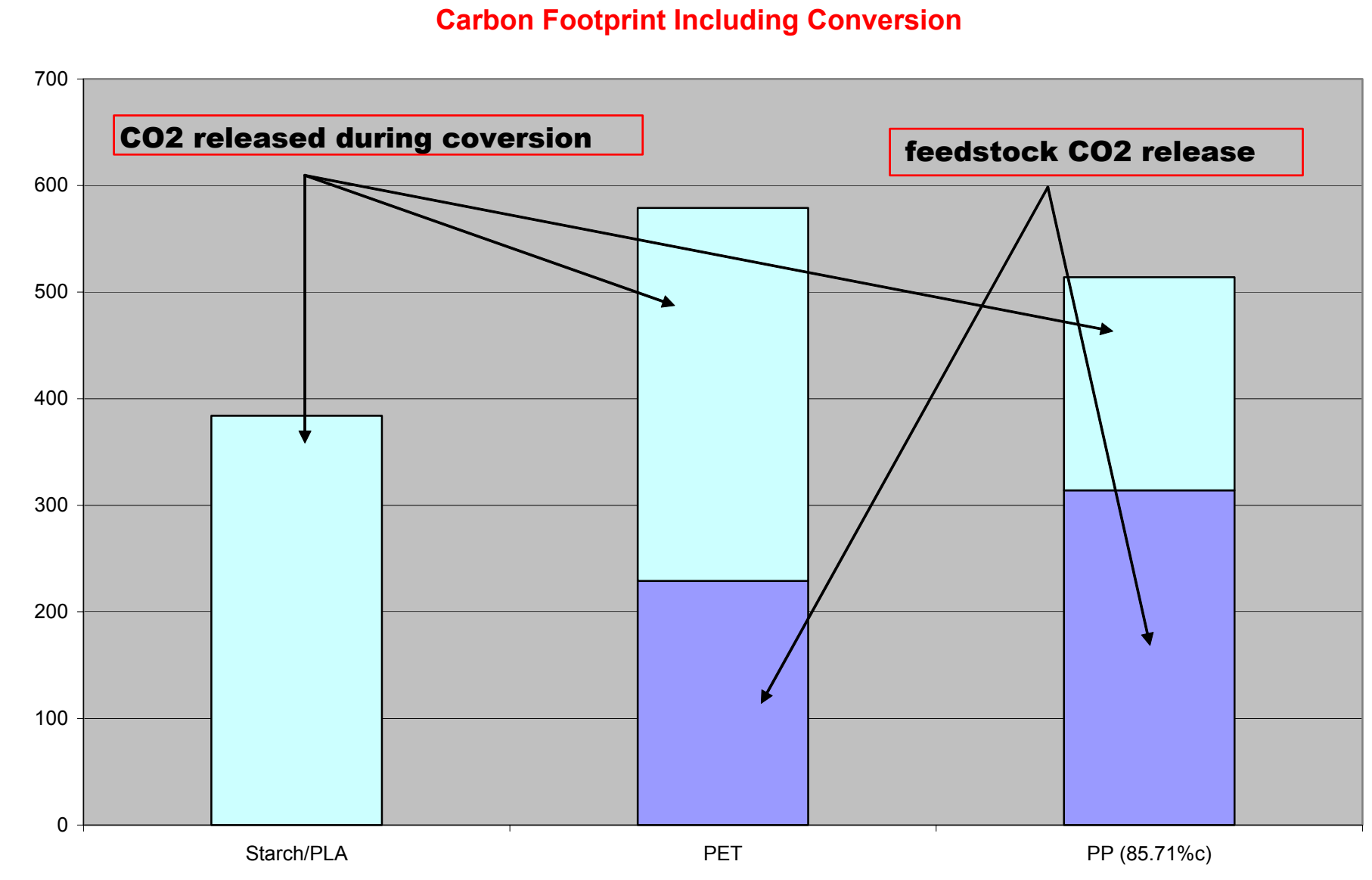
Global warming/climate change – WHY SHOULD WE CARE?



Intrinsic Carbon Value Proposition
Materials Carbon Footprint

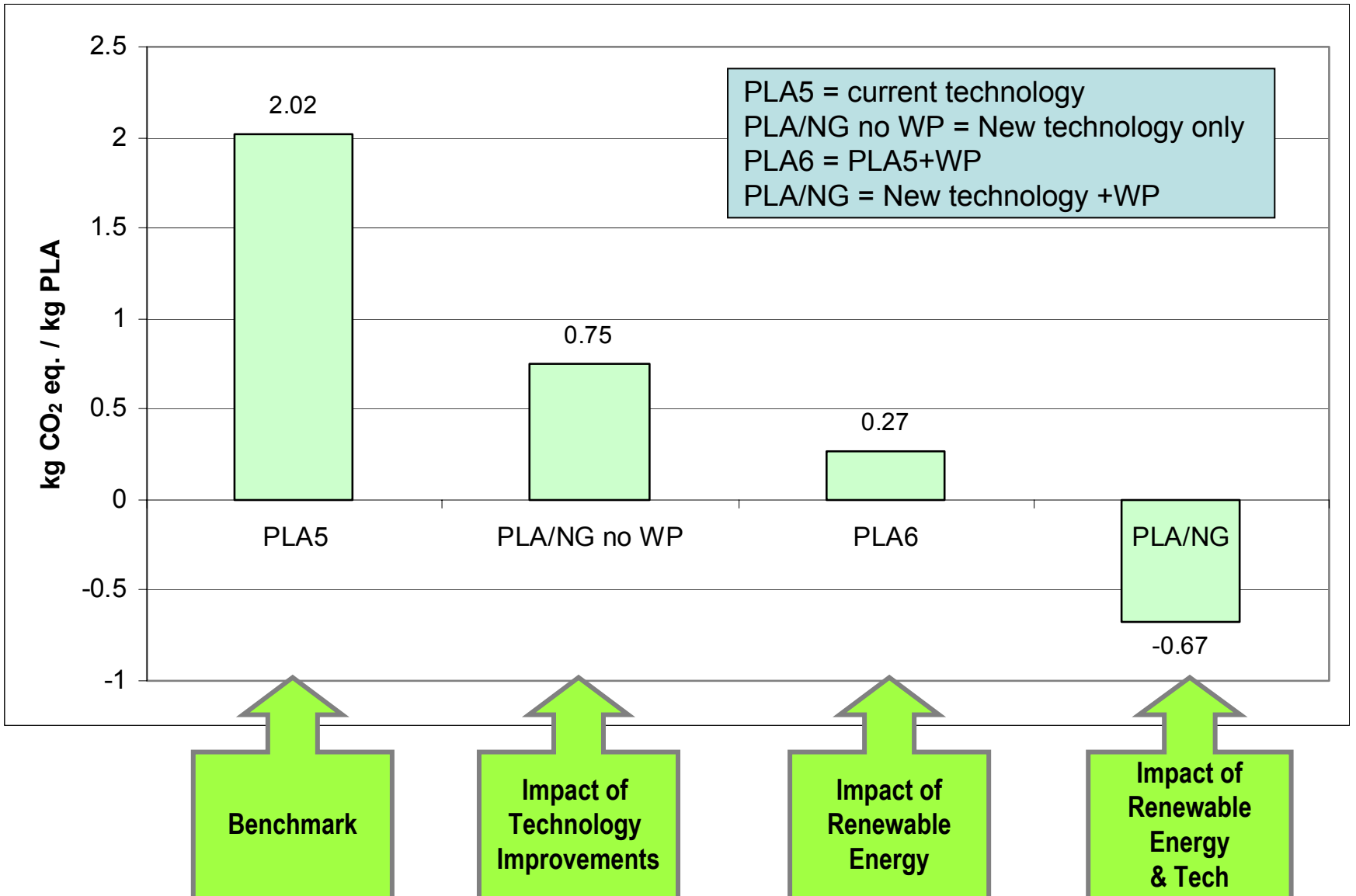


Material & Process (Total) carbon footprint



Results of the utilization of renewable energy and new technology on GHG

Vink et al, www.natureworksllc.com



TOOLS to compute and report on carbon and environmental footprint

Biobased carbon content determination:

Codified in ASTM D6866 to determine biocarbon content

- Use biobased carbon content to document carbon footprint reduction – INTRINSIC MATERIAL CARBON VALUE PROPOSITION
- Process carbon and total environmental footprint using LCA tools – ASTM D7075; ISO 1440

Standards
Identify & Quantify Biobased Content

$^{14}CO_2$ – Solar radiation

$\updownarrow$

$^{12}CO_2$

^{14}C signature forms the basis of Standard test method to quantify biobased content (ASTM D6866)

Biomass/Bio-organics

$(^{12}CH_2O)_x \longleftrightarrow (^{14}CH_2O)_x$

NEW CARBON

$\downarrow$ > 10^6 years

Fossil Resources
(petroleum, natural gas, coal)

$(^{12}CH_2)_n$ $(^{12}CHO)_x$

OLD CARBON

BIO OR BIOBASED CONTENT

Amount of biobased *carbon* in the material or product as fraction weight (mass) or percent weight (mass) of the total organic carbon in the material or product.

$$\%\ \text{BIO or BIOBASED CONTENT} = \frac{\text{BIO (Organic) CARBON}}{\text{TOTAL (Organic) CARBON}} * 100$$

On a carbon basis, not weight or mole or any other measure.

Reducing carbon foot print is the driver for using a bio/renewable feedstock (new carbon)

-- not oxygen or nitrogen or anything else

Therefore: biocarbon content is a true measure

BIOBASED CONTENT

EXAMPLE 1:

Product ‘A’ is a fiber reinforced composite with the composition 30% biofiber (cellulose) + 70% polypropylene (petroleum based organic)

Product ‘A’ biobased content = 18.5% -- not 30%!!!!

- Because biobased content is on a carbon basis
- 0.3*45.5/(0.3*45.5+0.7*85.7) = 18.5%

BIOBASED CONTENT

EXAMPLE 2:

Product ‘B’ is a fiber reinforced composite with the composition 30% biofiber (cellulose) + 70% polylactic acid (biobased)

Product ‘B’ biobased content = 100%

All carbon is biobased carbon

BIOBASED CONTENT -- EXAMPLES

Composite	Biofiber (cellulose)	Glass fibers	PLA	PP	Biobase content	Organic content
A	30%	--	--	70%	18.5%	100%
B	30%	--	70%	--	100%	100%
C	--	30%	70%	--	100%	70%

biobased content is based on carbon

Fundamental value proposition for biobased or biomass based plastic

The intrinsic carbon value proposition for biobased plastics:

- "material carbon" footprint – ASTM D6866
- "process carbon" foot print energy – convert feedstock to product (renewable/bio vs fossil/petro) - ASTM D7075/ISO 1440 (LCA methodology)

  - Reduced or neutral (zero) carbon footprint
  - Reduced GHG (CO_2) emissions

U.S. Farm Security and Rural Investment Act of 2002 (P. L. 107-171), Title IX Energy, Section 9002
FARM BILL

Federal Procurement of Biobased Products – the "biopreferred program" (www.biopreferred.gov)

- develop guidelines for designating biobased products
- publish a list & issue criteria for a designated biobased products list (DBL) for federal purchase;

Includes:

- **Definition, content verification, ASTM D6866**
- **environmental profile using LCA – ASTM Standard**
  - **ASTM D7075 "Standard practice for evaluating and reporting environmental performance of biobased products". -- LCA TOOLS/BEES analysis**
  - **To incorporate life cycle costing**
- **Biodegradability using ASTM D6400 and D6868 (paper coatings) D7021 (marine)**
- **performance requirements; and**
- **assurance that products are available.**