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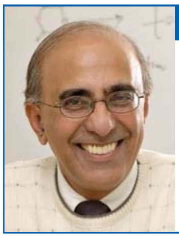
Value Proposition for Using Bio Feedstocks

Reducing Carbon Footprint & Improving Environmental Performance

Biodegradable – The use of biomass/renewable feedstock for manufacture of chemicals, intermediates, plastics and fuels offers the intrinsic value proposition of a carbon neutral footprint in harmony with the rates and time scales of the natural biological carbon cycle.



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Using bio content values, one can calculate the intrinsic CO_2 reductions that can be achieved by incorporating bio content into a product. However, it is equally important to report on the total environmental footprint using lifecycle assessment (LCA) methodology to ensure that the intrinsic carbon value proposition is not negated during the conversion, use, and disposal life cycle phases of the product.

Biodegradability is an end-of-life option that allows one to harness the power of microorganism present in the selected biological disposal environment (composting, anaerobic digestors, soil and marine) to completely remove the plastic product from the environmental compartment via the microbial food chain in a timely, safe, and efficacious manner. However, degradable, partial biodegradable, or eventually biodegrade are not acceptable options. Releasing small or even invisible degradable fragments in to the environment without requiring complete removal via microbial assimilation (entering the microbial food chain) can cause serious health and environmental consequences based on data published in Science and other peer reviewed journals.

The Zero Carbon Approach

Carbon is the major basic element that is the building block of polymeric materials and fuels, biobased products, petroleum based products, biotechnology products and even life itself. Therefore, discussions on sustainability, sustainable development, environmental responsibility centers on the issue of managing carbon-based materials in a sustainable and environmentally responsible manner. The burning issue of today is increasing man-made CO_2 emissions with no offsetting fixation and removal of the released CO_2. Reducing our carbon footprint is a major issue facing us today. The use of annually renewable bio feedstocks for manufacture of products offers an intrin-

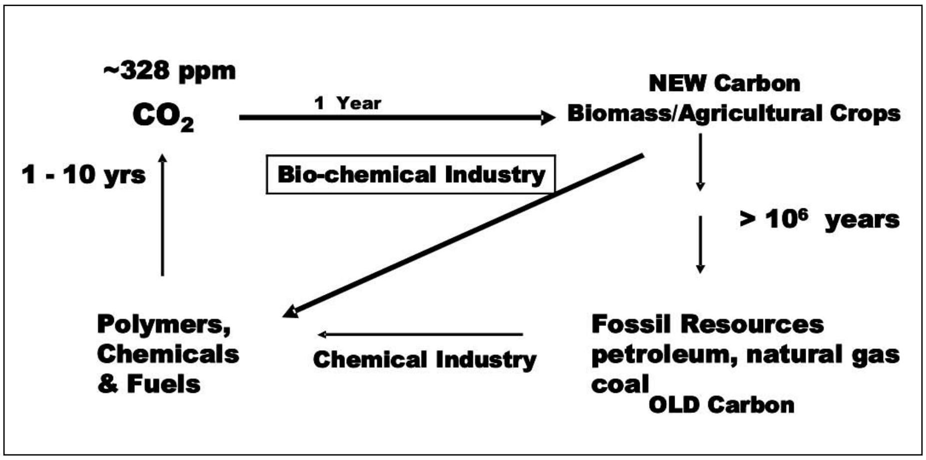

Fig. 1: Global carbon cycle

Terminology

Biobased or biomass-based plastics – organic material/s containing in whole or part biogenic carbon (carbon from biological sources)

Organic material/s – material(s) containing carbon based compound(s) in which the carbon is attached to other carbon atom(s), hydrogen, oxygen, or other elements in a chain, ring, or three-dimensional structures.

Bio content – The bio content is based on the amount of biogenic carbon present, and defined as the amount of bio carbon in the plastic or product as fraction weight (mass) or percent weight (mass) of the total organic carbon in the plastic or product.

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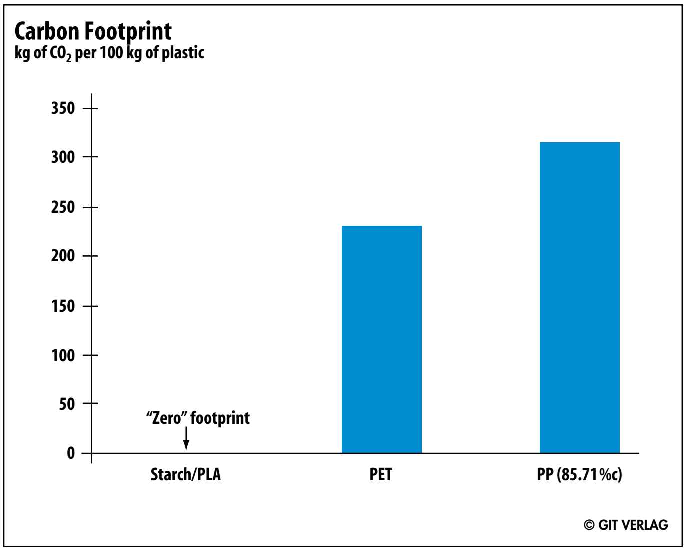

Fig. 2: Intrinsic carbon value proposition for using "Bio feedstock"

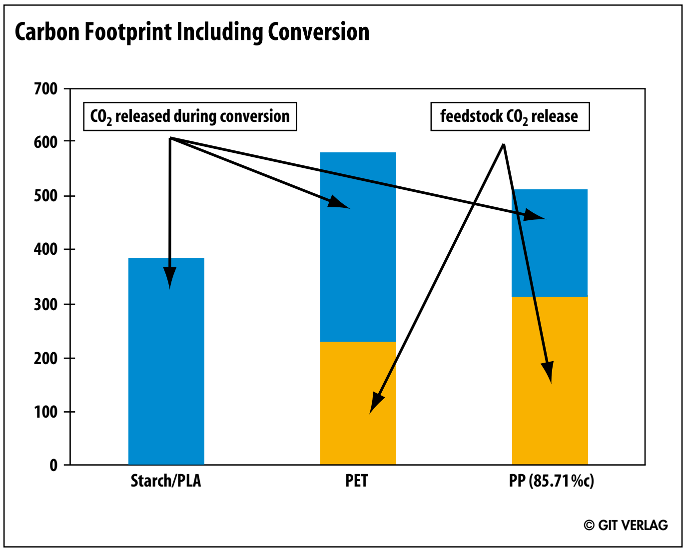

Fig. 3: Total carbon footprint including conversion to product

sic zero or neutral carbon footprint value proposition.

The intrinsic zero carbon value proposition is best explained by reviewing and understanding nature's biological carbon cycle. Nature cycles carbon through various environmental compartments with specific rates and time scales (fig. 1). Carbon is present in the atmosphere as inorganic carbon in the form of CO_2. The current levels of CO_2 in the atmosphere are around 380 parts per million (ppm). This life sustaining heat-trapping value of CO_2 in the atmosphere is changing to life threatening because of increasing manmade carbon (CO_2) and other heat trapping gas emissions. While one may debate the severity of effects associated with this or any other target level of CO_2, there can be no disagreement that uncontrolled, continued increase in levels of CO_2 in the atmosphere will result in a slow perceptible rise of the earth's temperature, global warming and with it associated severity of effects affecting life on this planet as we know it.

It is necessary to try and maintain current levels – the zero carbon approach. This can best be done by using renewable biomass crops as feedstocks to manufacture our carbon based products, so that the CO_2 released at the end-of-life of the product is captured by planting new crops in the next season. Specifically, the rate of CO_2 release to the environment at end-of-life equals the rate of photo synthetic CO_2 fixation by the next generation crops planted – a zero carbon foot print. In the case of fossil feedstocks, the rate of carbon fixation is in millions of years, while the end-of-life release rate into the environment is in one to ten years – the math is simple and shows that this is not sustainable and results in more CO_2 release than fixation, resulting in a increased carbon footprint, and with it the attendant global warming and climate change problems.

> *"Not all biobased products are biodegradable and not all biodegradable products are biobased."*

Intrinsic Carbon Value Proposition

Based on the above carbon cycle discussions and basic stoichiometrics, for every 100 kg of polyolefin (polyethylene, polypropylene) or polyester manufactured from a fossil feedstock, there is a net 314 kg CO_2 (85.7% fossil carbon) or 229 kg of CO_2 (62.5% fossil carbon) released into the environment respectively at end-of–life. However, if the polyester or polyolefin is manufactured from a biofeedstock, the net release of CO_2 into the environment is zero because the CO_2 released is fixed immediately by the next crop cycle (fig. 2). This is the fundamental intrinsic value proposition for using a bio/renewable feedstock and is typically ignored during LCA presentations. Incorporating bio content into plastic resins and products would have a positive impact – reducing the carbon footprint by the amount of biocarbon incorporated, for example incorporating 29% biocarbon content, using say cellulose or starch into a fossil based polyolefin resin offers an intrinsic CO_2 emissions reduction of 42%. These are significant environmental benefits that accrue for using bio-based plastics.

However, another important consideration that must be taken into account is the CO_2 emissions that arise from the conversion of the feedstock to product, CO_2 emissions during product use and ultimate disposal. The major contributory component in this step is the fossil carbon energy usage. Currently, in the conversion of biofeedstocks to product, for example corn to polylactic acid (PLA) resin, fossil carbon energy is used.

The CO_2 released per 100 kg of plastic during the conversion process for biofeedstocks as compared to fossil feedstock is in many cases higher, as in the case of PLA. However, in the PLA case, the total (net) CO_2 released to the environment taking into account the intrinsic carbon footprint as discussed earlier is lower, and will continue to get even better, as process efficiencies are incorporated and renewable energy is substituted for fossil energy (fig. 3). For PLA and other biobased products, it is important to calculate the conversion carbon costs using LCA tools, and ensure that the intrinsic neutral or zero carbon footprint is not negated by the conversion carbon costs and the net value is lower than the product being replaced from feedstock to product or resin manufacture.

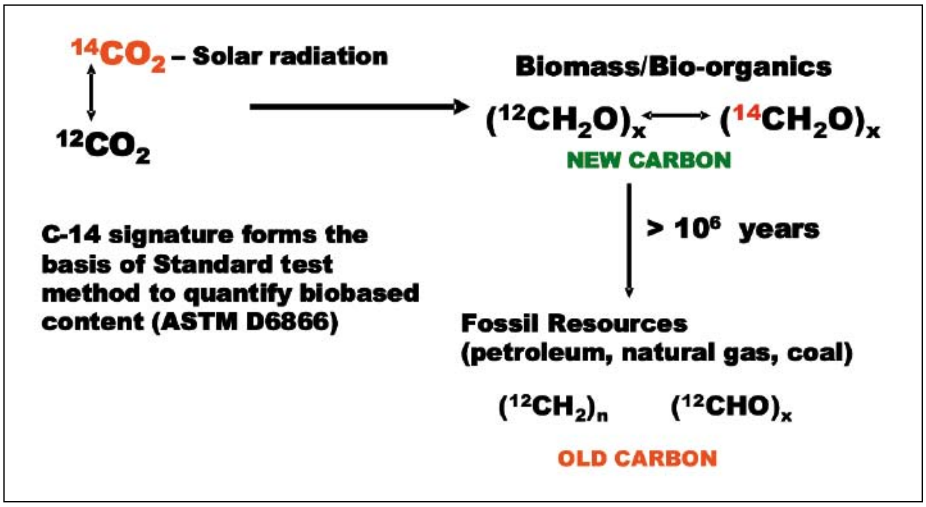

Fig. 4: Carbon-14 methodology to quantify biobased carbon content

Biocarbon Content Determination:

In order to calculate the intrinsic CO_2 reductions from incorporating biocarbon content, one has to identify and quantify the biobased carbon content.

As shown in figure 4, ^{14}C signature forms the basis for identifying and quantifying biboased content. The CO_2 in the atmosphere is in equilibrium with radioactive $^{14}CO_2$. Since the half life of carbon is around 5,730 years, the fossil feedstocks formed over millions of years will have no ^{14}C signature. Thus, by using this methodology one can identify and quantify biobased content. ASTM has codified this methodology into a test method to quantify biobased content. This involves combusting the test material in the presence of oxygen to produce CO_2 gas. The gas is analyzed to provide a measure of the products. ^{14}C/12C content is determined relative to the modern carbon-based oxalic acid radiocarbon standard reference material (SRM) 4990c, (referred to as HOxII).

Biodegradability

Confusion exists between the terms biobased and biodegradability, and they are erroneously used interchangeably. Not all biobased products are biodegradable and not all biodegradable products are biobased. Biobased refers to the feedstock used for manufacture of the product – bio/renewable v.s. fossil feedstock and relates to a products carbon footprint.

Biodegradability is an end-of-life option that allows one to harness the power of microorganism present in the selected disposal environment to completely remove the plastic product from the environmental compartment via the microbial food chain in a timely, safe, and efficacious manner. Because it is an end-of-life option, and harnesses microorganisms present in the selected disposal environment, one must clearly identify the "disposal environment" when discussing or reporting on the biodegradability of a product – so it is biodegradability under composting conditions (compostable plastic), biodegradability in soil, biodegradability in an anaerobic digester, marine biodegradability (fig. 5).

Furthermore, time to complete biodegradation or more accurately, time to complete microbial assimilation of the test plastic in the selected disposal environment is an essential requirement. Merely stating that it will eventually biodegrade or it is partially biodegradable or it is degradable is not acceptable; the operative word here is complete.

Degradable Vs. Biodegradable

Unfortunately, there are products in the market place that are designed to be degradable – they fragment into small pieces and may even degrade to residues invisible to the naked eye. However, there is no data presented to document complete biodegradability within the one year or even a specified time. It is assumed that the breakdown products will eventually biodegrade.

Designing products to be degradable or partially biodegradable poses serious health and environmental risks. Releasing small or even invisible degradable fragments in to the environment without requiring complete removal via microbial assimilation (entering the microbial food chain) can cause serious health and environmental consequences. This data published in Science and other peer-reviewed journals makes it all the more urgent to ensure that there is verifiable scientific substantiation based on national and international standards that all of the plastic substrate is completely assimilated by microorganisms present in that disposal environment.

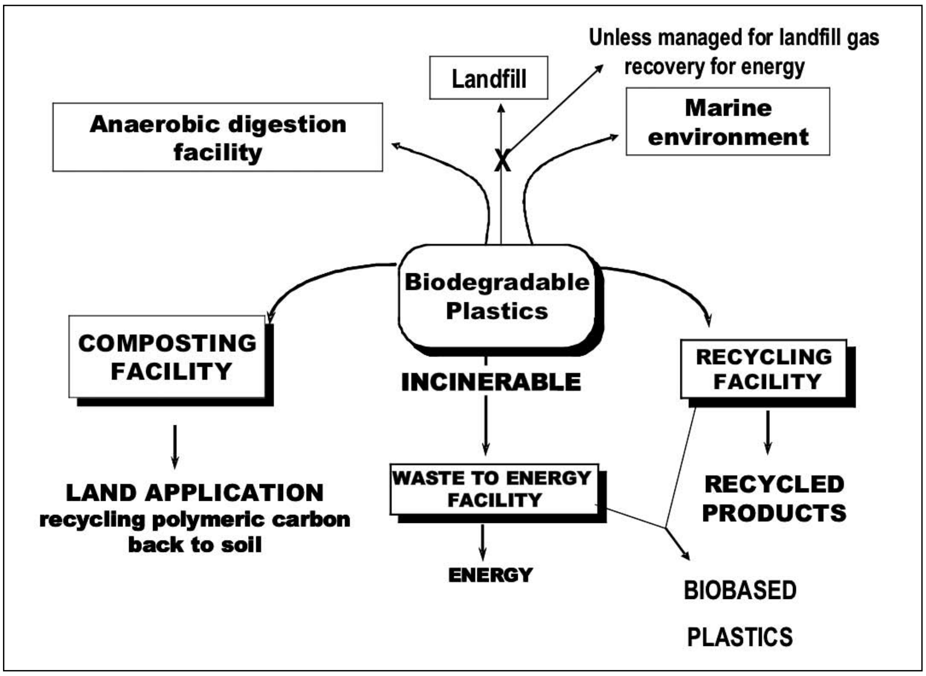

Fig. 5: End-of-life options for biodegradable plastics – Integration with disposal infrastructures

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