GCF GREEN CELL FOAM™
biodegradable

ENVIRONMENTAL PROFILE/LIFE CYCLE ASSESSMENT (LCA)

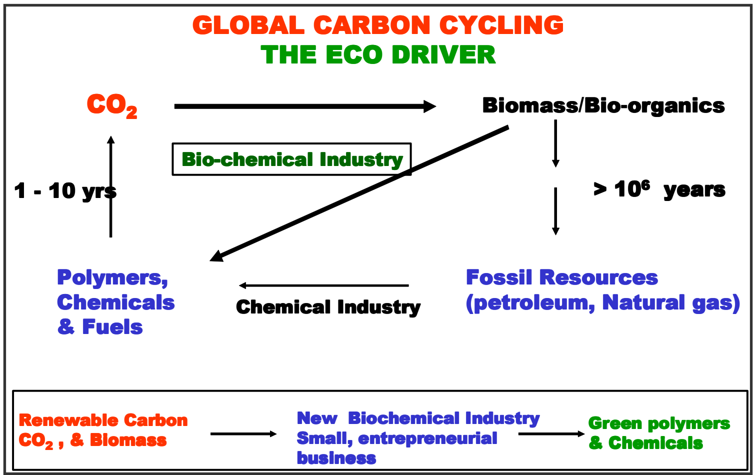
BACKGROUND

Biobased materials reduce the consumption of nonrenewable resources and reduce the environmental impact associated with the creation of synthetic materials, such as increased CO2 emissions. The U.S. Government has expressed the desire to use its buying power to promote usage of biobased materials, as evidenced in Presidential Orders 13101 and 13123 and the Farm Security and Rural Investment Act of 2002.

KTM Industries has created a family of starch foam products that have an enhanced performance window and provide a reduced environmental footprint when compared to the products they replace – namely synthetic foam cushion packaging and insulation coolers. A key driver in today's market place is a product's "environmental footprint" – the measure of the burden or impact that a product, operation or corporation places on the environment. Using Life Cycle Assessment (LCA) methodology, one can compute holistic environmental foot prints of a product. Some key metrics that need to be measured in this process are:

- Green House gas emissions (COX, VOCs)
- Energy Consumption
- Total waste production (mitigated by reduction in use, recycling and/or composting)
- Toxic waste generation
- Regulated Air pollutants release – air emissions(SOCs/NOX, particulates)
- Water discharges

GREEN HOUSE GASES – RESOURCE UTILIZATION BY KTM INDUSTRIES



The use of annually renewable biomass, like corn, as opposed to petrochemicals (oil or natural gas) as the feedstock for the production of polymers, chemicals, and fuels needs to be understood from a global carbon cycle basis. The attached figure illustrates the rationale for the use of annually

renewable resources (biomass feedstocks) for managing our carbon resources and thereby our CO_2 emissions more effectively.
Carbon is present in the atmosphere as CO_2. Plants fix this carbon by photosynthesis using sunlight as the energy source and grow. Over geological time frames (>10^6 years) these plant material are fossilized to provide our petroleum/natural gas. We consume these fossil resources to make our polymers, chemicals & fuel and release the carbon back into the atmosphere as CO_2 in a short time frame of 1-10 years. The CO_2 emissions problem is merely a kinetic rate issue. The rate at which biomass is converted to fossil resources is in total imbalance with the rate at which they are consumed and liberated (>10^6 years vs. 1-10 years). Thus, we put out more CO_2 than we sequester as fossil resources. However, if we use annually renewable crop or biomass feedstocks, the rate at which CO_2 is fixed is equal to the rate at which it is consumed and liberated. Thus, the use of annually renewable crop/biomass feedstocks to produce the polymer materials, chemicals, and fuel as an adjunct to fossil resources would begin to move the rate of CO_2 fixation more in balance with the rate at which CO_2 is released. Furthermore, if we manage our biomass resources effectively by making sure that we plant more biomass (trees, crops) than we utilize, we can begin to start reversing the CO_2 rate equation and move towards a net balance between CO_2 fixation/sequestration and release due to consumption.

Thus the use of renewable crop/biomass feedstock allows for:

- Sustainable development of carbon based polymer materials
- Control and even reduce CO_2 emissions and help meet global CO_2 emissions standards – Kyoto protocol
- Provide for an improved environmental profile

ENERGY SAVINGS – Life Cycle Assessment (LCA)

In addition to the above, Life Cycle Assessment (LCA) tools have been used to quantify the energy savings and the GHG (greenhouse gas) emissions reductions obtained by using crop feedstocks like starch.

Table 1 attached below shows the energy requirements for three standard petroleum feedstock based plastics, and a thermoplastic starch or thermoplastic starch blend pellets. The energy numbers is divided into process energy and feedstock energy (the energy inherent in the product)

Table 1	Cradle to factory gate fossil energy requirements, in GJ/ton plastic		
	Process energy	Feedstock energy	TOTAL
Thermoplastic starch (Nuudles®, Eco-Foam®)	25	0	25
Plastic starch + 15% PVOH	26	6	32
Plastic starch + 50% polyester	32	20	52
HDPE	31	49	80
PET(bottle grade)	38	39	77

PS (general purpose)	39	48	87

Data for petrochemical polymers from APME (1999)
Data for starch polymers from Fraunhofer, ISI (1999)

The feedstock energy (energy inherent in the product) arises due to the kinetic in-balance of the geological time frames required to fix CO_2 and its release after use (see earlier discussions on global carbon cycling, and the biological carbon cycle). As explained earlier the feedstock energy for biobased products is zero because the rate at which CO_2 is fixed annually by crops is equal to or greater than the rate of release after use (see earlier section for detailed discussions). The more important point to be made is that since biobased products is in its infancy, process energy costs is expected to decrease significantly as was the case of polyethylene, and polystyrene, thereby contributing to an even greater reductions in energy usage.

ENVIRONMENTAL IMPACTS - Life Cycle Impact Assessment (LCIA)

This section examines the product from an environmental perspective using impact categories and category indicators connected with LCI (Life Cycle Inventory) results. For each impact category, the category indicator is selected and the category indicator result is calculated. The collection of the indicator results, referred to as the LCIA profile, provides information on the environmental issues associated with the inputs and outputs of the product system. It also provides information for the lifecycle interpretation phase.

The typical impact categories selected are:

1. resource depletion; abiotic & biotic
2. global warming
3. ozone depletion
4. human toxicity
5. ecotoxicity
6. photochemical oxidant
7. acidification
8. eutrophication
9. degradation of ecosystems and landscapes

In the case of starch polymer pellets energy requirements are mostly 25%-75% below those for polyethylene (PE) and greenhouse gas emissions are 20%-80% lower. These ranges originate from the comparison of different starch/copolymer blends, different waste treatment and different polyolefin materials used as reference. Regarding the latter, APME data for LLDPE (72.3 MJ/kg) and LDPE (80.6 MJ/kg) were assumed. The lower APME values serve also as reference for the comparison with the other biopolymers (below). Starch polymers (both TPS and copolymers) score better than PE also for all other indicators listed in Table 2 with eutrophication being the sole exception. The lower the share of petrochemical copolymers, the smaller the environmental impact of starch polymers.

Table 2 – LCIA Data

Plastic type	Cradle to gate non-renewable energy use MJ/functional unit	Waste treatment for emission calculations	GHG emissions [kg CO_2 eq/ functional unit]	Ozone precursors [g ethylene eq]	Acidifi - cation [g SO_2 eq]	Eutrophi-cation [g PO_4 eq]	Ref
HDPE	80	Incineration	4.84	n/a	n/a	n/a	APME
LDPE	91.7	80% incinerate 20% landfill	5.20	13.0	17.4	1.1	Carbotech, 1996
Starch	25	Incinerate	1.14	n/a	n/a	n/a	Fraunhofer,

pellets							ISI 1999
Starch pellets	25	100% composting	1.14	5.0	10.6	4.7	

Final Disposal Impacts

The final disposal/waste system has an important role in the overall eco balance of all materials. This is particularly the case for biodegradable materials. If a biobased material is recycled through composting, and the compost applied to land, then significant emission and energy savings can accrue, because of the value of the compost to sustainable agriculture. An LCA study done by the International Nutrition and Agricultural Consultancy group on fertilization with compost as opposed to NPK (Ammonium Nitrate-based) chemical fertilizer in agricultural production systems clearly demonstrates the environmental benefits of compost fertilization in a number of areas. The study showed that in a potato system, composting provided a clear advantage in all effect categories over the chemical NPK fertilizer. The compost application provided an environmental relief potential between 26% (fossil energy carriers) and 91% (photooxidants) over that of the chemical fertilizer application. Similarly, in the winter wheat system, compost fertilization shows clear advantages in all the effect categories with relief values ranging between 76% and 90%.