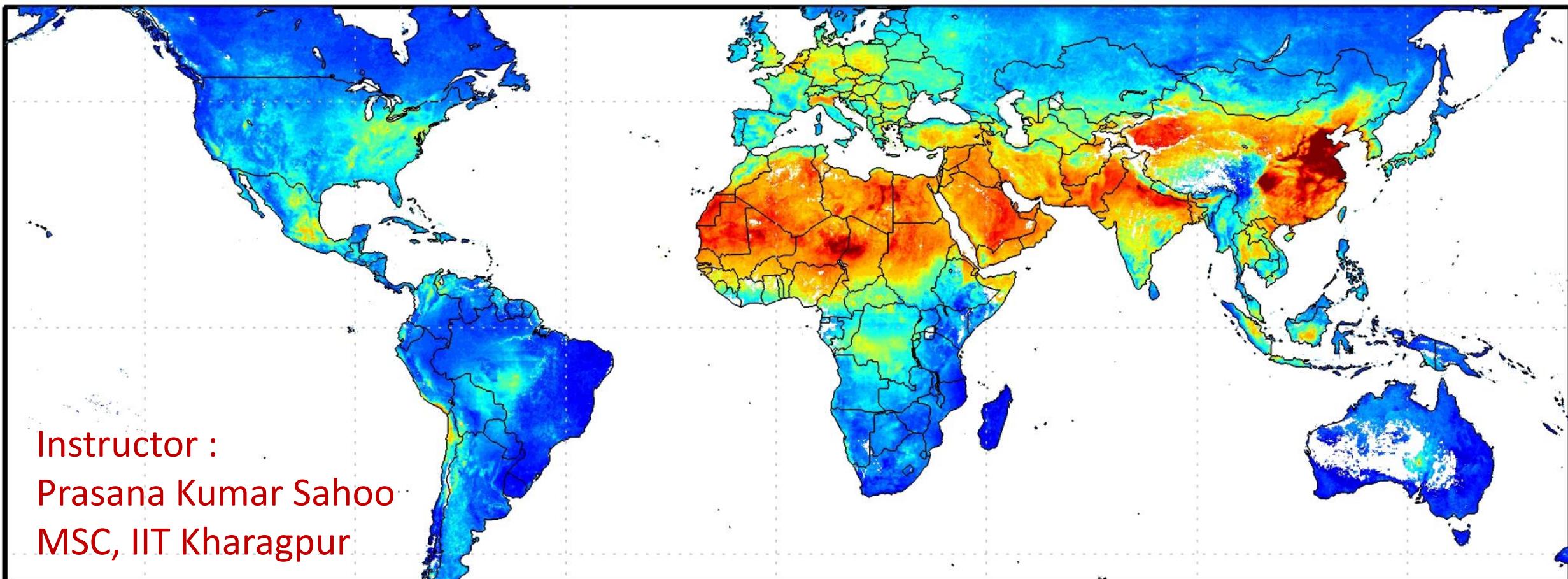




# Materials Science : Chapter 12

## Economic, Environmental, and Societal Issues in Materials Science and Engineering





# Learning Objectives

- 1.** List and briefly discuss three factors over which an engineer has control that affect the cost of a product.
- 2.** Diagram the total materials cycle, and briefly discuss relevant issues that pertain to each stage of this cycle.
- 3.** List the two inputs and five outputs for the life cycle analysis/assessment scheme.
- 4.** Cite issues that are relevant to the “green design” philosophy of product design.
- 5.** Discuss recyclability/disposability issues relative to (a) metals, (b) glass, (c) plastics and rubber, and (d) composite materials.



# Economic Considerations

Solar Roof Environmentally Economic Energy Generation



CAR Parking, Clean Air,  
Low Cost, For Society

## Engineering Disasters



### Eschede Train Disaster

On June 3, 1998, a high-speed train derailed near the village of Eschede in Germany, killing 101 people and injuring 88 more. **A single fatigue crack in one wheel failed, causing the train to derail at a switch.** A contributing factor was the use of welds in the carriage bodies that “unzipped” during the crash. Within weeks of the crash, all wheels of a similar design were replaced with mono block wheels.



# Engineering Disasters

The Deepwater Horizon was an offshore drilling unit with the ability to drill down to 30,000 feet. On April 20, 2010, while drilling an exploratory well, **the rig exploded**, killing 11 workers and setting the stage to release 4.9 million barrels of oil that devastated the area around the Gulf of Mexico. The National Commission on the BP Deepwater Horizon Oil Spill said “**several tests indicated the cement put in place after the installation ... was not an effective barrier to prevent gases from entering the well.**” These same gases allowed the explosion to occur.



## Fukushima Reactor Meltdown

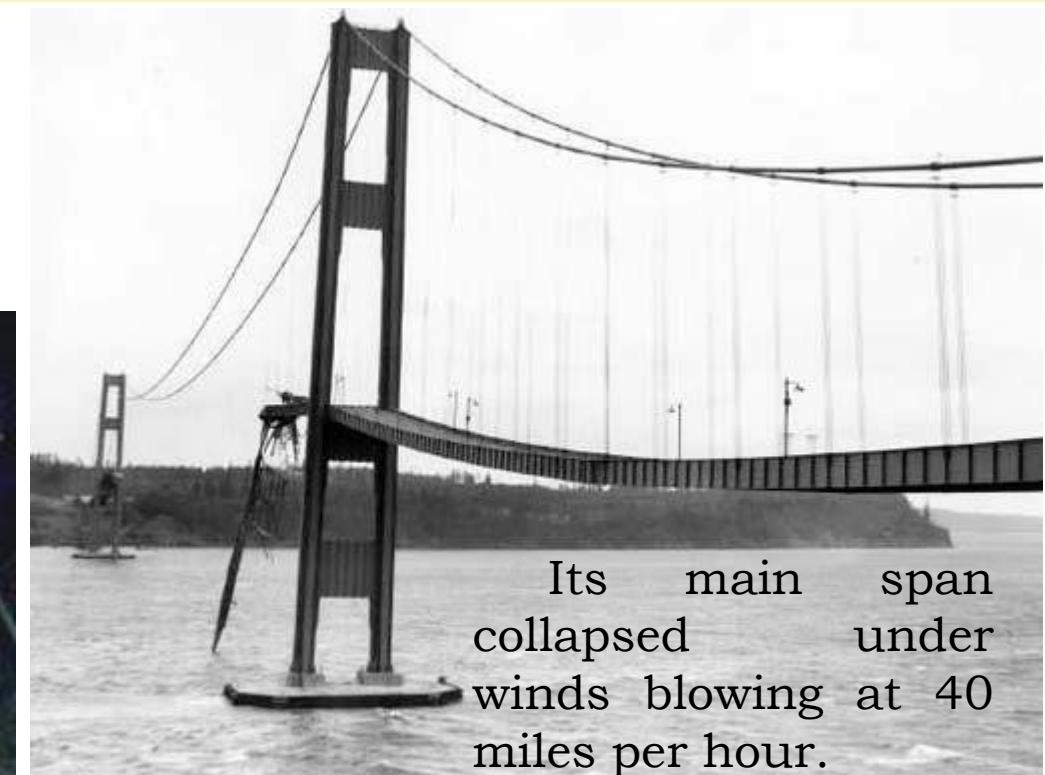


Following the earthquake and tsunami on March 11, 2011, the Fukushima reactor melted down, releasing radioactive material into the ground and ocean. While exacerbated by the earthquake, a report claims that the **meltdown was a manmade disaster caused by poor regulation.** Wrote Daily Tech, “The Fukushima nuclear disaster shows the danger of using **ancient reactor designs in flood-prone regions without proper precaution.** The accident stands as a stirring cry to decommission older reactors and move to modern designs.”



# Engineering Disasters

On January 28th, 1986, Space Shuttle Challenger was launched at 11:38am on the 6-day STS-51-L mission. During the first 3 seconds of lift off the o-rings (o-shaped loops used to connect two cylinders) in the shuttle's right-hand solid rocket booster (SRB) failed.



Its main span collapsed under winds blowing at 40 miles per hour.

Tacoma Narrows Bridge collapse – The third longest suspension bridge of the world at that time, Tacoma Narrows Bridge had been in operation for just more than five months before it crashed into the Puget Sound of Washington on November 7th, 1940.



# Environmental Issues



Fires that start in mounds of discarded tires are extremely difficult to extinguish





# Economics of Engineering

There are three factors over which the materials engineer has control and that affect the cost of a product;

- (1) Component design,
- (2) The material(s) used,
- (3) The manufacturing technique(s) that are employed.

These factors are interrelated in that component design may affect which material is used, and both component design and the material used will influence the choice of manufacturing technique(s).

Engineering Marvels



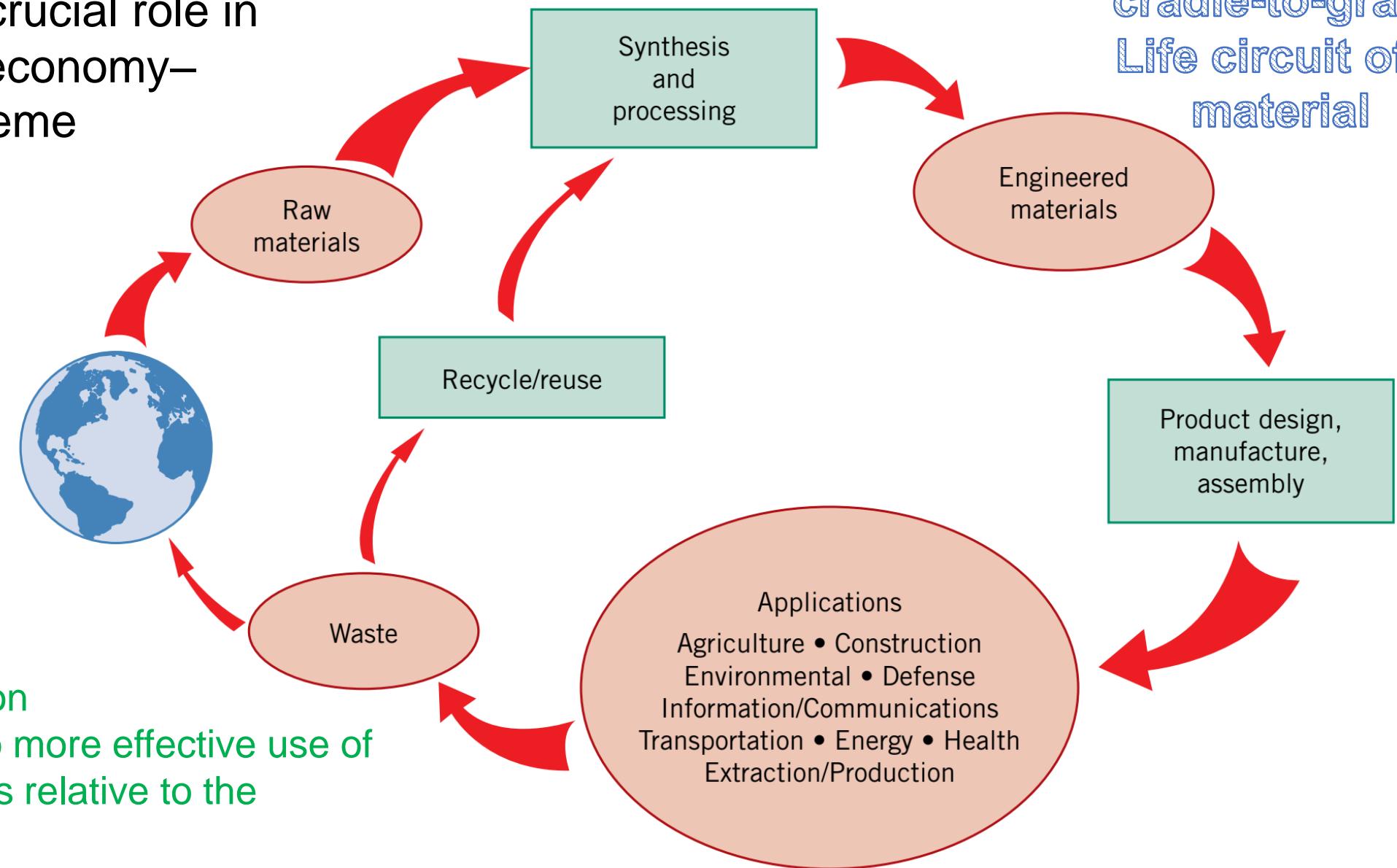


# Environmental and Societal Considerations

Materials play a crucial role in this technology–economy–environment scheme

“cradle-to-grave”  
Life circuit of a material

15 billion tons  
of raw materials  
are extracted  
from the Earth  
every year



Greater attention  
must be paid to more effective use of  
these resources relative to the  
materials cycle

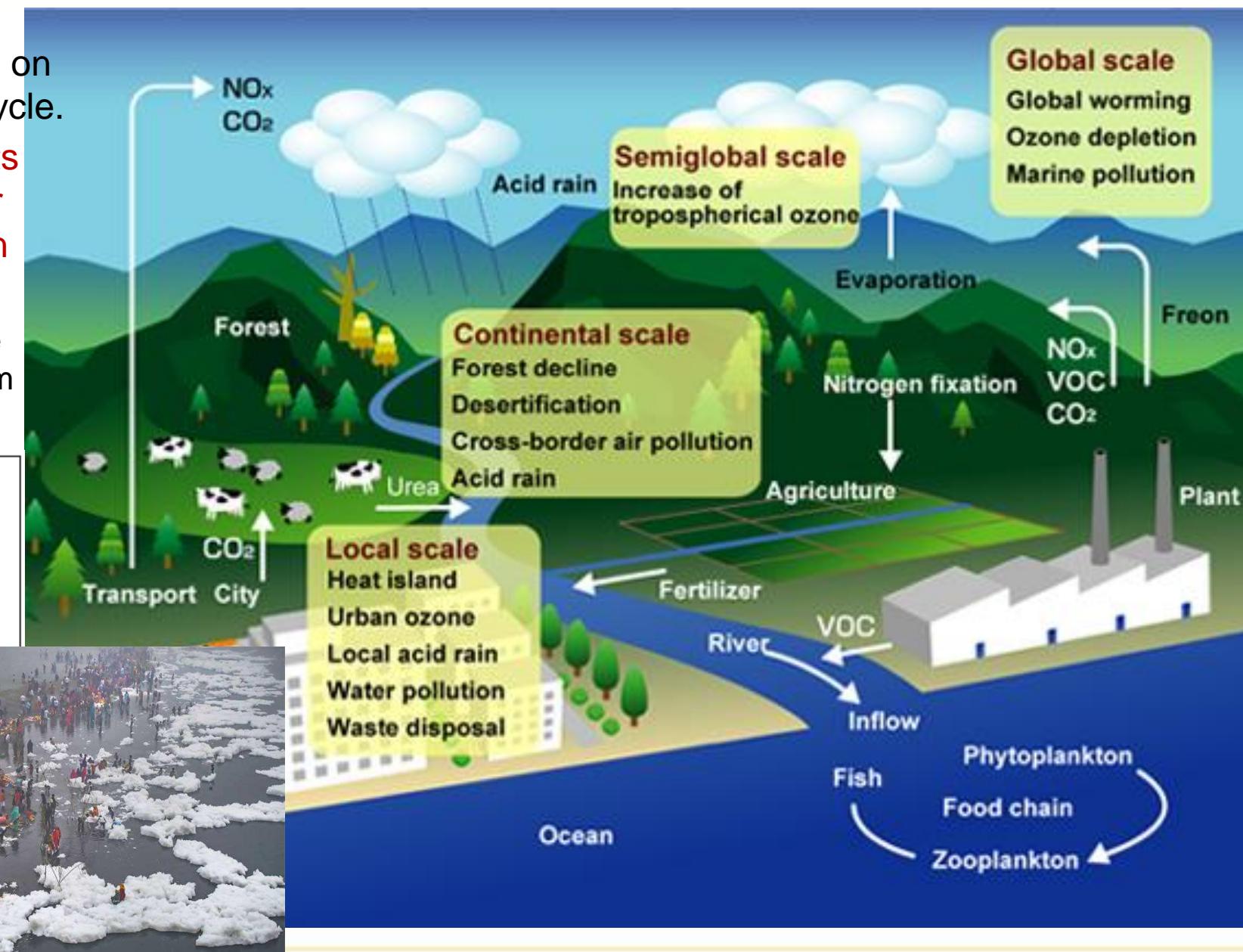
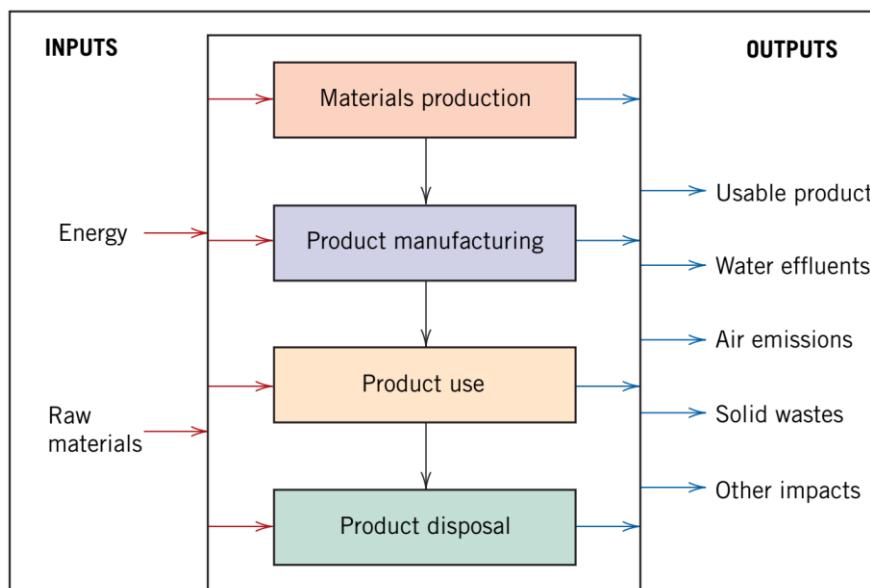


# Impacts on the natural environment

The condition of the Earth's atmosphere, water, and land depends to a large extent on how carefully we traverse the materials cycle.

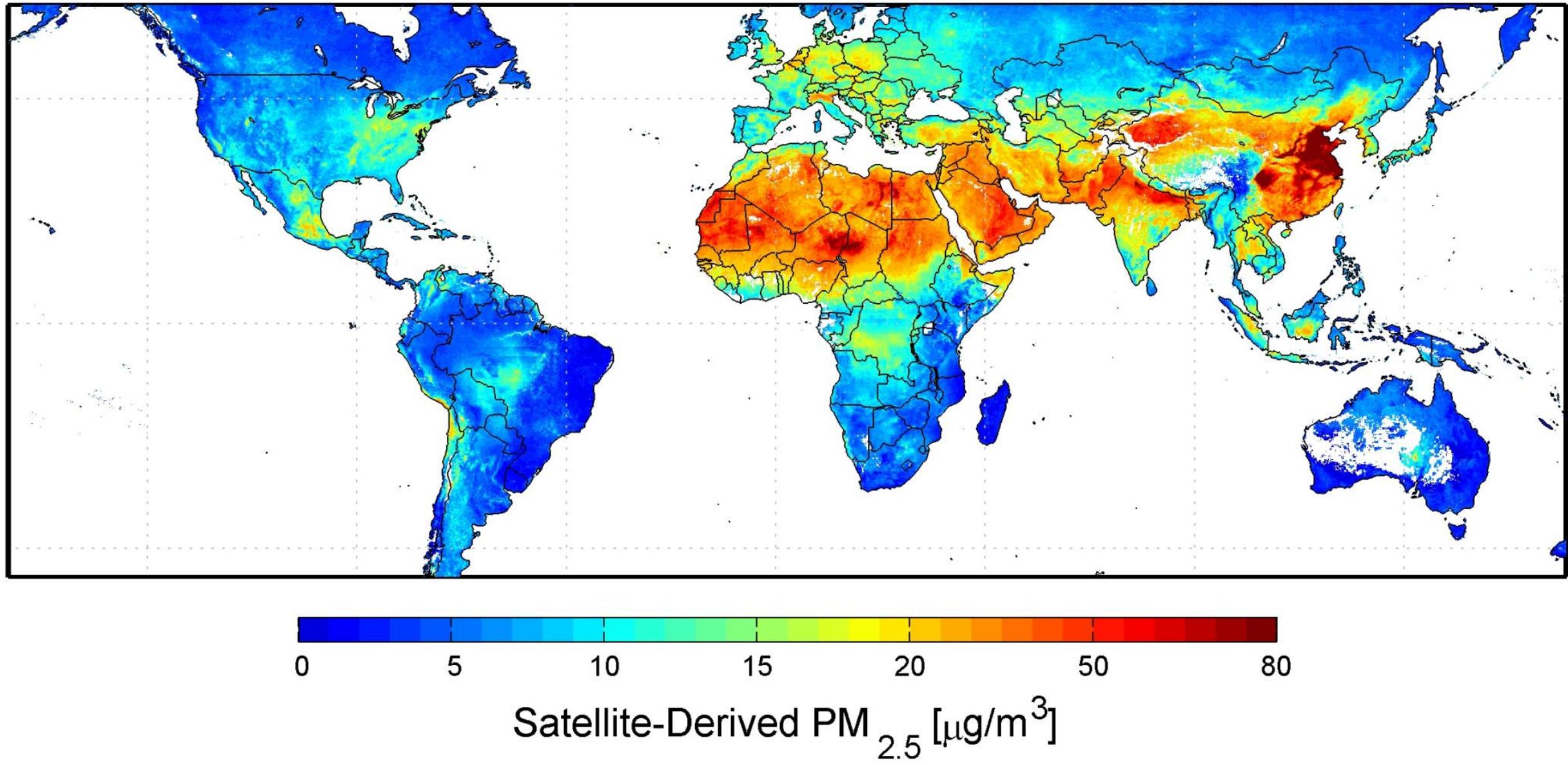
provision should be made for recycling its component materials, or at least for their disposal with little ecological degradation (i.e., it should be biodegradable)

28 times as much energy is required to refine natural aluminum ores as to recycle aluminum beverage can scrap





# Pollution Map





# The ultimate disposition of the materials used should be an important criterion

- From an environmental perspective, the ideal material should be either completely recyclable or completely biodegradable.
- ✓ Most metal alloys, to one degree or another experience corrosion and are also biodegradable. However, some metals (e.g., Hg, Pb) are toxic and, when placed in landfills, may present health hazards.
- ✓ Glass is an ideal recyclable material—it can be recycled multiple times without significant depreciation of quality
- ✓ Most polymers are not biodegradable and, therefore, do not biodegrade in landfills
- ✓ Rubber materials present disposal and recycling challenges.

The major source of rubber scrap in the United States is discarded automobile tires, which are highly nonbiodegradable.

- ✓ **e-waste that needs to be disposed of (landfilled or incinerated) or recycled**

The rapid expansion of technology and ever-increasing appetite for new, better, and cheaper electronic gadgets has resulted in the generation of e-waste at a staggering rate.

Often, electronic waste sent to recyclers in the U.S., Canada, and Europe is exported to developing countries.





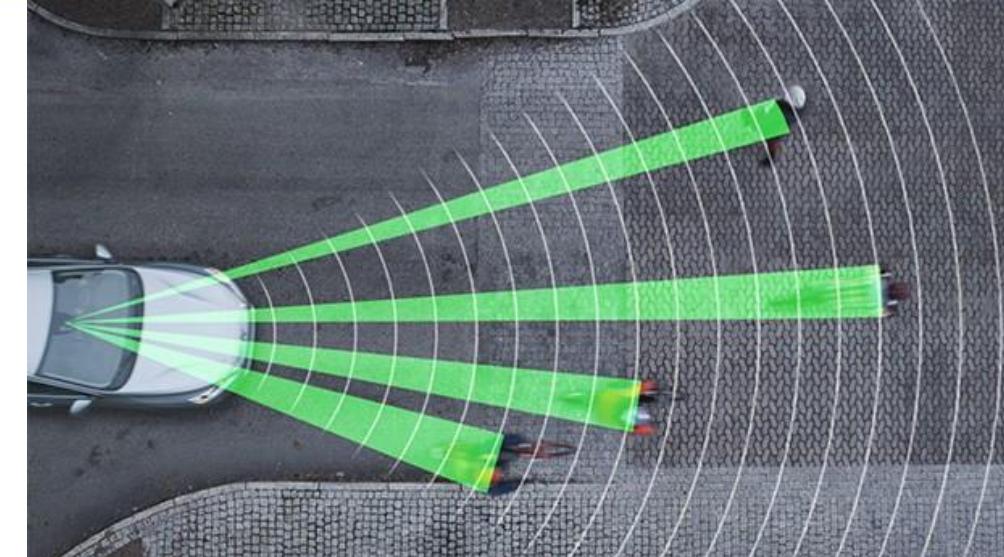
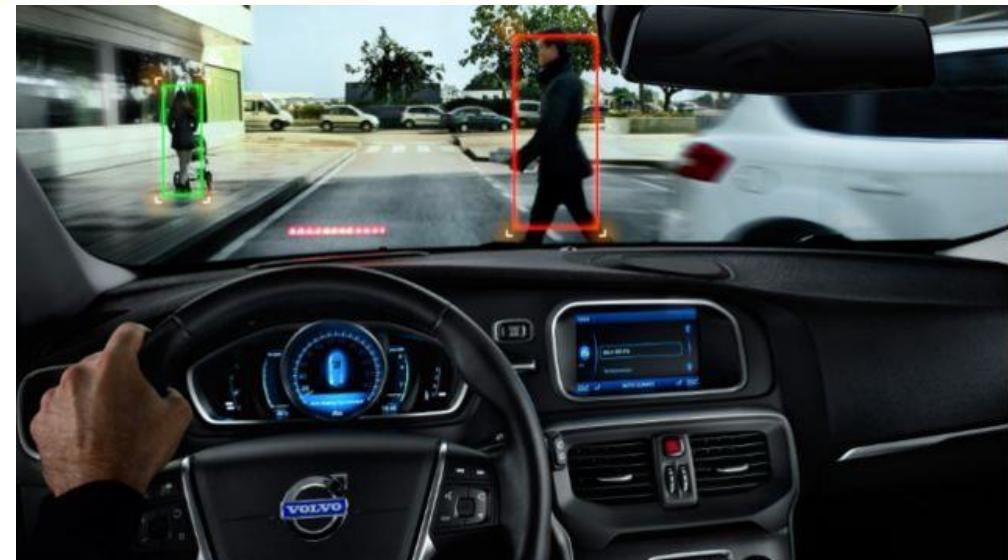
# Recycling Issues in Material Sciences

Recycle Codes,  
Uses of Virgin  
Material, and  
Recycled  
Products for  
Several  
Commercial  
Polymers

Recycle Code	Polymer Name	Uses of Virgin Material	Recycled Products
	Poly(ethylene terephthalate) (PET or PETE)	Plastic beverage containers; mouthwash jars; peanut butter and salad dressing bottles	Liquid-soap bottles, strapping, fiberfill for winter coats, surfboards, paint brushes, fuzz on tennis balls, soft-drink bottles, film, egg cartons, skis, carpets, boats
	High-density polyethylene (HDPE)	Milk, water, and juice containers; grocery bags; toys; liquid detergent bottles	Soft-drink bottle base caps, flower pots, drain pipes, signs, stadium seats, trash cans, recycling bins, traffic-barrier cones, golf-bag liners, detergent bottles, toys
	Poly(vinyl chloride) or vinyl (V)	Clear food packaging; shampoo bottles	Floor mats, pipes, hoses, mud flaps
	Low-density polyethylene (LDPE)	Bread bags; frozen-food bags; grocery bags	Garbage can liners, grocery bags, multipurpose bags
	Polypropylene (PP)	Ketchup bottles; yogurt containers; margarine tubs, medicine bottles, carpet fibers	Manhole steps, paint buckets, ice scrapers, fast-food trays, lawnmower wheels, automobile battery parts
	Polystyrene (PS)	Compact disc jackets; coffee cups; knives, spoons, and forks; cafeteria trays; grocery store meat trays; fast-food sandwich containers	License-plate holders, golf-course and septic-tank drainage systems, desktop accessories, hanging files, food-service trays, flowerpots, trash cans



# Technology Saving Lives





## Economy

(Financial & Built Capital)



*industrial demand  
for ecological  
goods and services  
places stress on  
natural capital*

*economic value  
is created for  
society*

## Society

(Human & Social Capital)



*community use of  
ecological goods and  
services places stress  
on natural capital*

*labor is utilized in industry*

*some waste  
is recovered  
and recycled*

*emissions may  
harm humans*

*waste and emissions may  
degrade the environment*

**Environment**  
(Natural Capital)



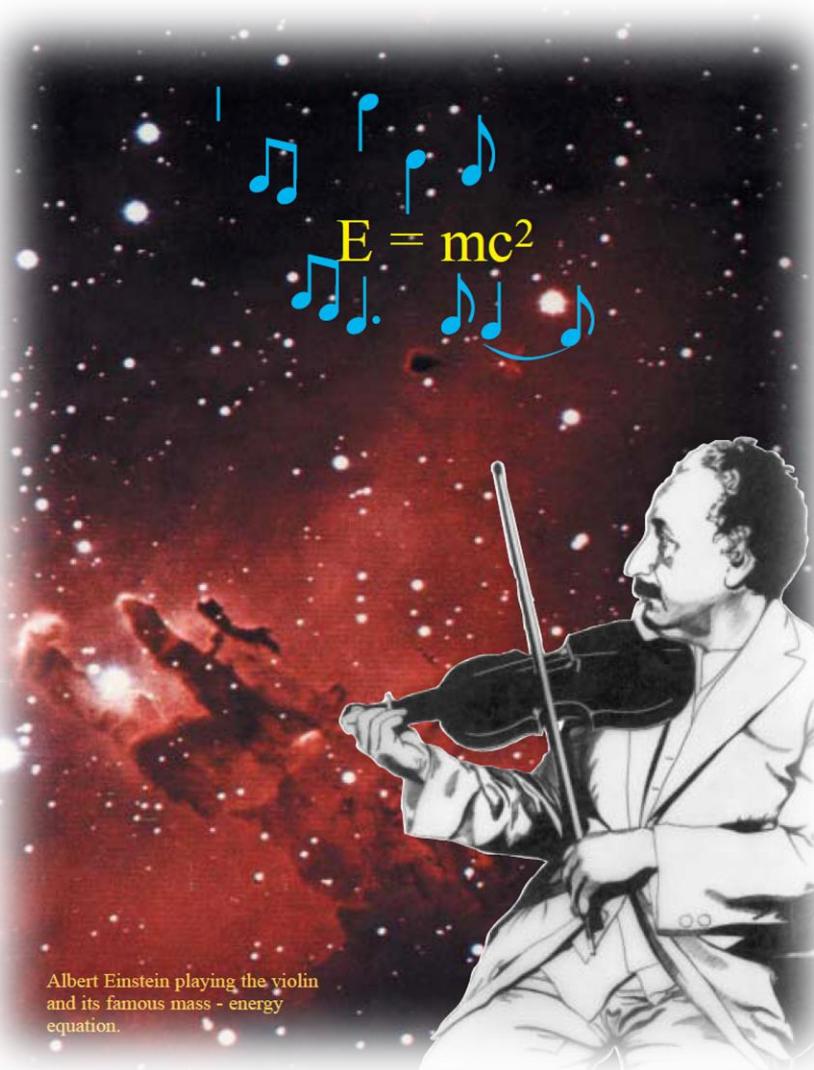
## *Biodegradable and Biorenewable Polymers/Plastics*



Biodegradable plastic mulch films that have been laid out on farmland being cultivated.



Examples of applications for biodegradable/biorenewable poly(lactic acid): films, packaging, and fabrics



Albert Einstein playing the violin  
and its famous mass - energy  
equation.

... Think about our Green Planet... ...

# Materials and sustainability of life in our planet





We welcome

**Highly motivated students**

to do part of their undergraduate project in the field of

**2D Materials, Optoelectronics, Nano-electronics  
and Sensors**

**Group: Quantum Materials & Device  
Research Group (QMDrL)**

[prasana@matsc.iitkgp.ac.in](mailto:prasana@matsc.iitkgp.ac.in)



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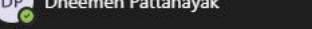
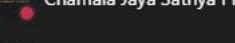
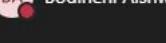
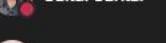
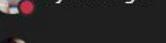
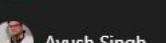
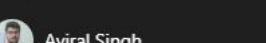
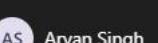
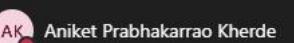
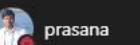
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