EcoDesign Strategies

San Jose State University
Environmental Studies 152

San José State University

Department of Environmental Studies

Agenda

- Selection of low impact materials
- Hazardous materials avoidance
- Cleaner production processes
- Maximization of energy & water efficiency
- Design for waste minimization

Selection of low impact materials

- Materials have impacts on all of the product lifecycle stages
  - "cradle-to-grave"
- Evaluation of the costs of materials
  - Total Environmental Cost = Real costs + Societal Costs
    - Real costs: e.g., landfill disposal fees
    - Societal costs: costs that will be paid to reduce the impacts; e.g., health impacts

Total Environmental costs of materials

MATERIALS		Cost ($/ton)	MATERIALS		Cost ($/ton)
Plastics			**Paper**		
	HDPE	$763		Bleaced kraft paperboard	$629
	LDPE	$824		Unbleached kraft paper	$554
	PET	$1,573		Unbleached coated folding boxboard	$542
	PP	$855		Folding boxboard from waste paper	$351
	PS	$880		Linerboard	$559
	PVC	$7,509		Linerboard from waste paper	$364
Glass				Corrugating medium	$290
	Virgin	$223		Corrugating medium from waste paper	$430
	Recycled	$180			
Aluminum			**Steel**		
	Virgin	$2,787		Virgin steel	$520
	Recycled	$486		Recycled steel	$508

note: 1993 costs corrected to 2007 dollars

from: Shapiro, K; *Life-cycle Evaluation of Packaging Materials* , Tellus Institute; 1993
http://ieeexplore.ieee.org/iel2/1034/7463/00302827.pdf?arnumber=302827

Material selection goals

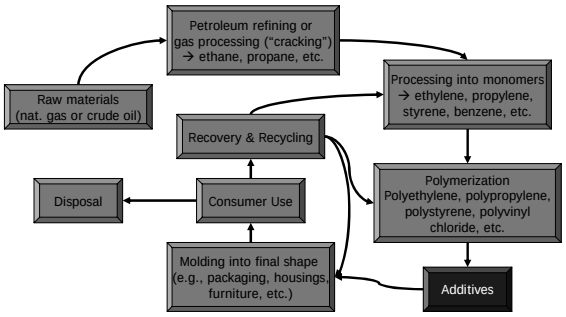
- Abundant, non-toxic, non-regulated materials
  - If toxic, generate them onsite rather than ship
- Choose natural materials rather than synthetic
- Design for minimal use of materials
  - Products, processes and services
- Get the most out of materials through recycling and reuse streams rather than from raw materials extraction.

Plastics

- Primarily from petrochemicals
  - Polymer
  - Some new materials from starches/sugars
- First plastic:
  - Celluloid...used to replace ivory in billiard balls
    - Pulped cotton + nitric acid → nitrocellulose
      - One problem...could explode! ☹
  - Also used for dentures, combs, knives, brushes, piano keys

- First mass produced artificial plastic: Bakelite (phenol-formaldehyde resin)
- Other early plastics: nylon, polyvinyl chloride, polystyrene, polyethylene

Plastics Manufacturing



Impacts of Plastics

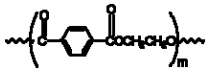
- Polystyrene
  - Benzene (PS); styrene is a carcinogen; highest energy consumption

- High density polyethylene (HDPE) & Low density polyethylene (LDPE)
  - Ethylene from nat gas or oil; CO2 & SO2 emitted

- Polypropylene (PP)
  - Propylene from oil refining, some solid wastes

Impacts of Plastics

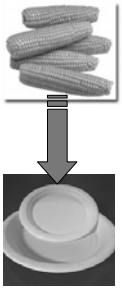
- Polyethylene terephthalate (PET)
  - Ethylene glycol + terephthalic acid from petroleum; steam & methanol (recycled)



- Polyvinyl Chloride (PVC)
  - Chlorine + ethylene from nat gas/oil; VC monomer is a carcinogen; chlorinated wastes link with dioxins; lowest energy consumption

Biodegradable Plastics

- Decompose from UV light, water, bacteria, enzymes, etc.
- Addition of starch powder a filler promotes breakdown, but plastic still remains
- Plastarch Material (PSM)
  - modified cornstarch + with several other biodegradable materials.
  - One of the only bioplastics capable of withstanding high temperatures
  - Broken down by bacteria
  - Stable in the atmosphere, but biodegradable in compost, wet soil, fresh water, seawater, and activated sludge where microorganisms exist.
  - Softens @ 125 C (257 F) and melts @ 156 C (313 F)
  - Packaging and utensils, personal care items, plastic bags, temporary construction tubing, industrial foam packaging, industrial and agricultural film, window insulation, construction stakes, and horticulture planters



Pros of Plastics

- Light weight
  - Same packaging in plastic weighs much less than many other materials
    - e.g., glass drink bottle vs. plastic drink bottle
    - Saves transport energy
  - Highly efficient
    - Often requires less material to achieve their function
      - e.g., cling wrap

Plastic Recycling

- PET: almost half of all bottles
  - Fiber, tote bags, new containers, clothing, shoes, luggage, upholstery, furniture, carpet, fiberfill, automotive parts
- HDPE: the other half of bottles
  - Pipe, liquid detergent bottles, oil bottles, pens, benches, doghouses, recycling containers, floor tile, picnic tables, fencing, lumber, and mailbox posts
- PVC
  - Binders, decking, paneling, mudflaps, roadway gutters, flooring, cables, speed bumps, and mats
- LDPE
  - Floor tile, garbage can liners, shipping envelopes, furniture, compost bins, paneling, trash cans, lumber, landscaping ties
- PP
  - Signal lights, battery cables, brooms, brushes, auto battery cases, ice scrapers, landscape borders, bicycle racks, rakes, bins, pallets, and trays
- PS
  - Thermal insulation, light switch plates, egg cartons, vents, rulers, foam packing, carry-out containers
- Other
  - Plastic lumber

Recycling Sources

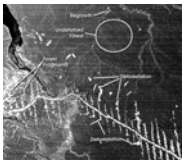
- Industrial waste
  - Manufacturing scraps...collected and reused on site
- Post-consumer industrial waste
  - Industrial products that have been used and discarded
    - e.g., plastic bags, crates
- Post-consumer domestic waste
  - Packaging from households; e.g., PET & HDPE bottles

Increasing difficulty to recycle

Design Strategy for Plastics

- Specify the use of plastics that have less impact on the environment, such as PE and PP
- Specify the use of recycled plastics whenever possible
- Use the minimum amount of material possible
  - "lightweighting"

Timber



- Natural material
- Harvesting has significant impacts
  - Old-growth harvesting: BAD
    - 53,000 mi^2 destroyed/yr in the 80's, almost half in the Amazon Basin; rate has decreased...Amazon deforestation has decreased to 4,800 mi^2/yr; total deforested = 230K mi^2 = Texas
  - Plantation harvesting: BETTER
    - Previously cleared land/farmland

Timber Product Issues

- Manufactured wood products
  - Medium density fiberboard (MDF)
  - Plywood
  - Resins & Glues: formaldehyde…probable human carcinogen
    - Risk primarily in manufacturing and construction from particles and off-gassing

- Possible solutions
  - Recycled plastic lumber
  - Steel studs
  - Surfacing from soybeans & recycled paper
  - Recycled wood + plastic composite
  - Formaldehyde-free sheathing

Design Strategies for Timber

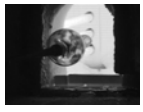
- Specify the use of plantation or recycled timber
- Avoid non-sustainably harvested rainforest timber
  - Labeling: e.g., Forest Stewardship Council
  - Timber certification information
    - www.panda.org/forests4life
    - www.certifiedwood.org
    - www.ra.org
    - www.fsc.org/en/
  - Specify fiberboard with reduced formaldehyde content or alternative binders

Rainforest Alliance

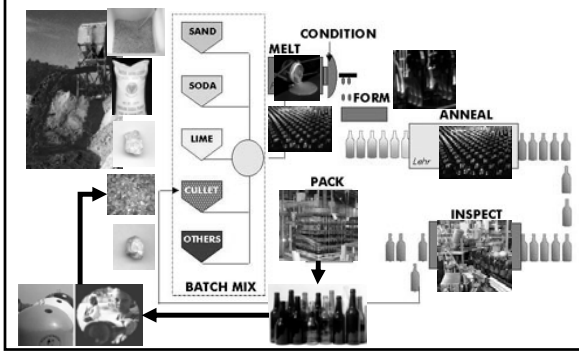
FOREST STEWARDSHIP COUNCIL
Because forests matter

Glass

- Glass: dates back 5,000 years…besides clay, the oldest packaging material
- Raw materials
  - Sand, soda ash, limestone, feldspar, recycled glass
- Process involves a lot of energy
  - Furnaces operate at 1,500°C



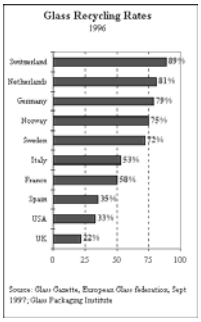
Glass Manufacturing



Impacts of Glass

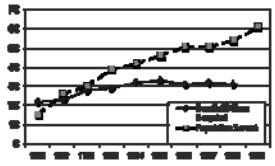
- Impacts
  - Mining
  - Energy use
    - Carbon dioxide emission
  - Emissions from processing
  - Impact on transportation due to weight
- Benefit: easiest to recycle
  - Amount of cullet has increased dramatically
    - Globally 35-90%
  - Segregate colors, remove contaminants (e.g., metals)

Glass Recycling



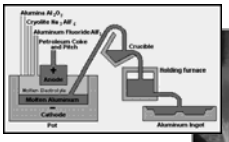
http://www.container-recycling.org/glassrate/GlassCurb.htm

- How are we doing? Could be better
  - Only UK & Turkey worse than US in %
    - Total mass is high though
  - >70% have producer responsibility legislation
- Design strategies...same as others:
  - Recycled materials and lightweighting



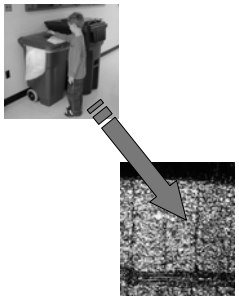
Aluminum

- Relatively new
  - manufactured only since mid-1800s
- Made from bauxite ore
- Transported to refineries and converted to alumina
- Smelting plant extracts aluminum and cast into large ingots
- Ingots transported to fabrication plants

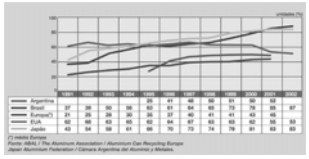


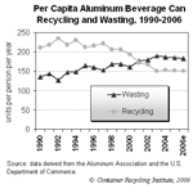
Aluminum recycling

- Aluminum processing requires tremendous energy…therefore a major contributor to greenhouse gas generation
- Easily recovered
- Strategies:
  - Recycled materials and lightweighting



Aluminum recycling





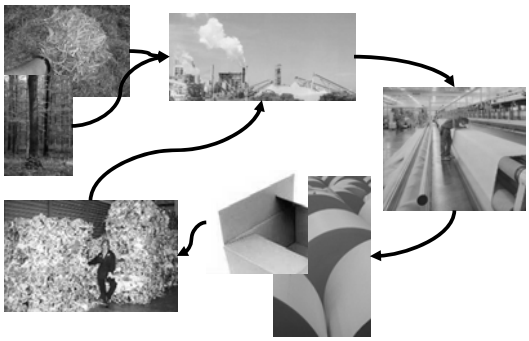
Steel

- Ancient...2000 years ago (swords), but only relatively recent for industrial applications: Fe + C + other metals (Co, Mn, Ni, Cr, etc.)
- Main steps
  - Mining & processing of iron ore
  - Limestone quarrying
  - Mining and processing of coal & coke formation from coal
    - "dirtiest" step...25% of the coal weight goes to atmosphere
  - Sintering
  - Steelmaking
  - Steel forming

Steel recycling

- Basic oxygen furnace uses 28% recycled steel...electric arc furnace can use 100% recycled steel
- Every ton of steel recycled saves:
  - 2,500 lb of iron ore, 1,400 lb of coal, and 120 lb. of limestone
  - Steel recycling in US ~67% → 70M tons
    - Automobiles: 100%
    - Structural steel: 95%
    - Rebar: 50%
    - Appliances: 85%
    - Cans: 58%
- Strategy:
  - Recycled steel, lightweighting, segregate from other materials

Paper

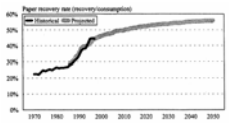


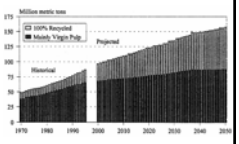
Paper impacts

- Deforestation
- Managed fiber sources
  - Pesticides
- Manufacturing
  - Solid waste and suspended solids (lignin)
    - Sulfides and mercaptans
  - Bleaching…chlorine…dioxin

Paper Strategy

- Good news…more than half of paper is now from regeneration forests…increasing
- Bad news: US paper & paperboard consumption is 100M metric tons
  - That's 790 lbs per person
- Choose elemental Cl-free, unbleached paper
- Use only brightness needed
- Investigate suitability of non-wood fiber paper (e.g., kenaf, hemp)
- Use Recycled paper





Avoid Hazardous Materials

- Avoid specifying use of materials that are hazardous or generate hazardous waste in the life-cycle
  - Materials toxic to humans or other organisms
  - Flammable, corrosive, reactive
  - Ozone depleting
  - Contribute to global warming

Toxic materials

- Heavy metals
  - Cd, Pb, Ni, Hg, As, Cr
- Formaldehyde
  - Resins in construction materials, Fiberglas, flooring, textiles
- Chlorinated organic solvents
  - Paints, paint strippers, glues
- Brominated flame retardants
  - Printed circuit boards & components, computer cabinets, appliances, TVs
- Restriction of Hazardous Substances (RoHS)
  - EU and China

Bad Atmospheric Materials

- Ozone depleting substances (ODSs)
  - Refrigerants (CFCs, HCFCs)
  - Dry cleaning agents (perchloroethylene)
  - Foam blowing agents (CFCs)
- Global Warming Gases (GWGs)
  - CO_2, methane, NOx, CFCs, HCFCs

Cleaner production processes

- Produce less waste
  - Environmental media: air, water, soil
- Waste reduction through
  - Working with R&D + manufacturing to select less wasteful products & processes
  - Working with purchasing staff to identify “green” suppliers...extended producer responsibility

Example: Nike

- Organic solvents in adhesives, primers, degreasers
  - MEK, toluene
- Began development of water based materials in 1992 and implementation in 1995
  - Since then have reduced solvent use by 88%, from 340 gms/pair of shoes to 40 gms/pair in 2001
  - Savings of $4.5M in material costs
- Solid waste reduction
  - In March 1999 all rubber waste in China was discarded
  - By Sept. 1999 90% of rubber wastes in 4 factories in Qingdao was recycled...in 17 plants over 50% is now recycled.

Maximization of energy efficiencies

- Design for energy efficiency
  - Energy efficient products
    - Appliances, consumer electronics
  - Eliminate waste
    - Leaks: heat leaks/insufficient insulation
    - Standby energy
      - MW oven...on high might use 1500W; cooking time = 5 min/day = 125W-hr/day x 300 days/yr x 12 yrs = 450kW-hr over life
      - 5W for digital displays x 24 hrs/day x 365 d/yr x 12 yr = 525kW-hr over life
    - Cycling loses
      - Hot water...pipes may hold a few gallons that must be re-heated...cost of original heating + cost of re-heating + waste of water

Maximization of energy efficiency

- Cleaner energy sources
  - Lowest environmental impact for the product location
    - Natural gas has lower impact that coal
  - Rechargeable batteries when batteries are required
    - Li-MH vs. NiCd vs. disposable alkaline
  - Use of clean and renewable energy sources
    - Solar, wind, hydro vs. others

Maximization for water efficiency

- Similar principles to energy efficiency
- Additionally:
  - Recover & reuse
    - May require filtration/purification
  - Eco-labeling
    - Australia has a water labeling system (e.g., low water usage toilets, showers, etc.

Design for waste minimization

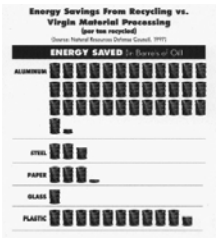
- Source reduction
  - Prevent raw material waste
    - Less mining, extraction, harvesting
    - Less energy needed for process and transport
    - Fewer emissions
  - Simplify the product…elimination of unnecessary components
  - Lightweighting
  - Less packaging

Design for waste minimization

- Extending product life
  - Identify and eliminate potential weak points in the design
    - Use of failure mode and effect analysis
  - Design product for regular use and likely misuse
  - Design for maintenance and reparability
  - Design for upgradeability
  - Determine design that will hold consumer interest the longest

Design for waste minimization

- Recycling



Design for waste minimization

- Product re-use
  - Will have lower impact, but must consider the life cycle impacts of cleaning/reprocessing
  - Design product for strength to withstand collection, handling, washing, refilling
  - Design for ability to clean
  - Design packaging for ways of re-use
    - Return to manufacturer
    - Return to retailer for refilling
    - Re-use in the home

Design for waste minimization

- Product remanufacture
  - Restore product characteristics to new; extends life and re-uses components
    - Example: automotive parts…rebuilt components are 30% less expensive
  - Applicable for products with a slow rate of design change
  - Must be able to easily disassemble
  - Must have a “core” component with sufficient value to retain and rebuild

Design for waste minimization

- Minimize consumption
  - Reduce the consumables used to operate the product
    - e.g., paper for copiers (duplex), detergent for washers, etc.
    - Eliminate consumables if possible
      - e.g., Dyson vacuum...cyclonic system instead of bags...saves on bags, reduces paper waste, increased vacuum efficiency, reduced energy consumption

  - Feedback mechanism to tell consumer when consumable really needs to be replaced
  - Design to use consumables that are re-usable
    - Print cartridges, toner cartridges, vacuum filters

Design for waste minimization

- Minimizing impact of disposal
  - Design for degradability
    - Works only if composted or biodegraded
    - Paper, cardboard, starch-based plastics
  - Cannot contain toxics
  - Need to provide instructions to the consumer

- *We have not inherited the Earth from our ancestors, we have borrowed it from our children.*
  - ancient proverb