

# Energy and Environmental Considerations in Recycling

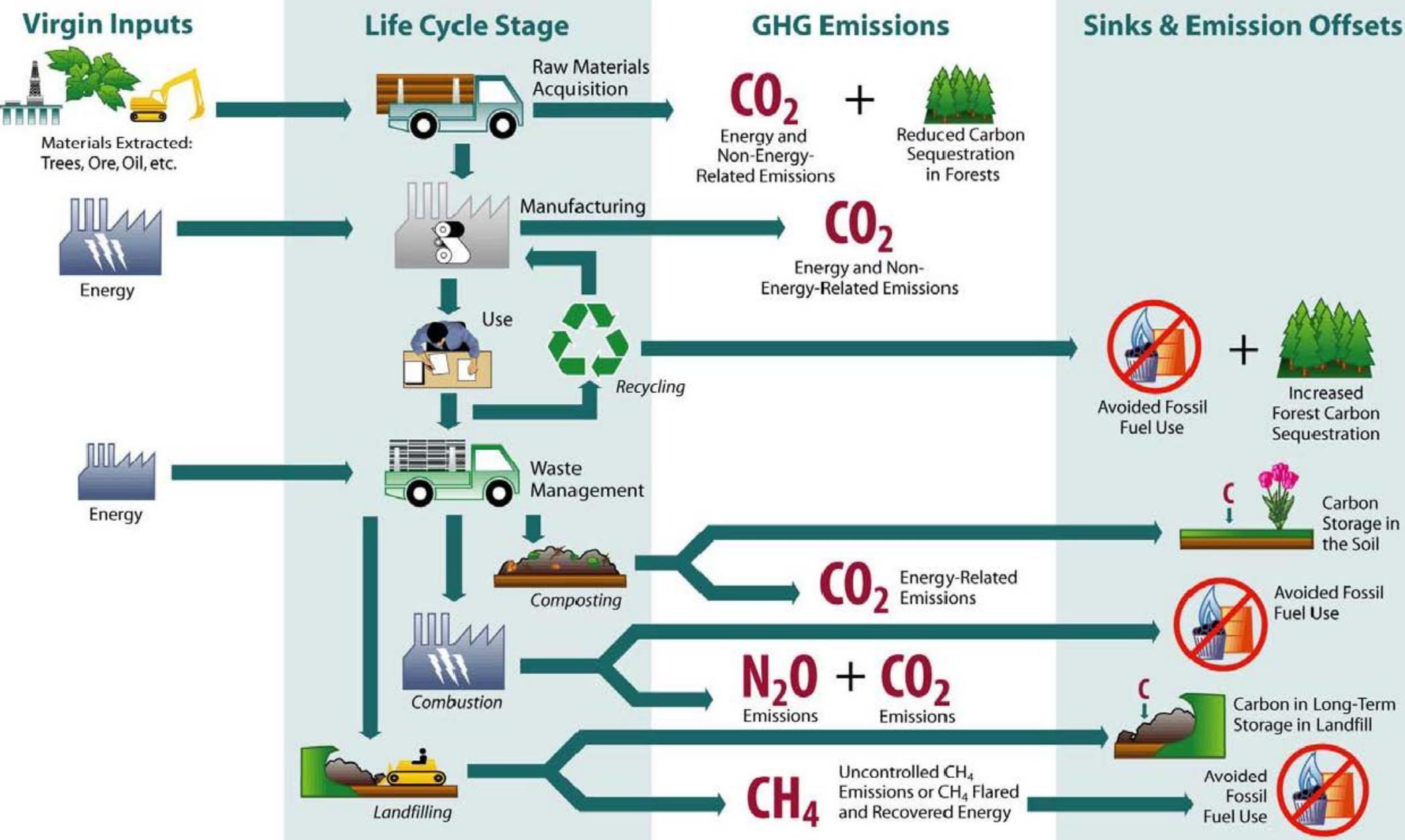
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11 April 2012

Physics H190

# Environmental Variables

- Energy required to produce virgin materials vs. reclaim raw materials from recyclables
- Carbon emissions & water pollution from production of virgin materials vs. recycling
- Methane from decomposing materials in landfill
- Depletion of natural resources (trees, minerals, oil)
- Energy use & carbon emissions from separate collection of recyclables
- Carbon sequestration in forests or landfills



EPA. (2006). *Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks*. Retrieved from: <http://epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf>.

# How Recycling Works: Collection

- Factors to consider:
  - Infrastructure
  - Convenience for consumers (waste producers)
  - Quality of recyclables
- Collection methods:
  - Drop-off centers
  - Buy-back centers (e.g. CRV)
  - Curbside collection
    - Mixed waste
    - Single-stream/commingled recyclables
    - Source separation

# How Recycling Works: Processing

(example from San Francisco's NorCal Waste Systems)

- Large cardboard & plastic bags removed by hand
- Spinning disk screens separate paper from containers
  - Cardboard & paper separated
- Plastic removed by hand
  - Separated into PET, HDPE, and other
- Tin-plated & steel cans removed by magnet
- Eddy current separators remove aluminum cans
- Glass separated by color (clear, brown, amber, green)
- Recyclables cleaned & baled, shredded, or crushed

“The truth about recycling.” *The Economist*. 7 June 2007. Retrieved from:  
<http://www.economist.com/node/9249262>.

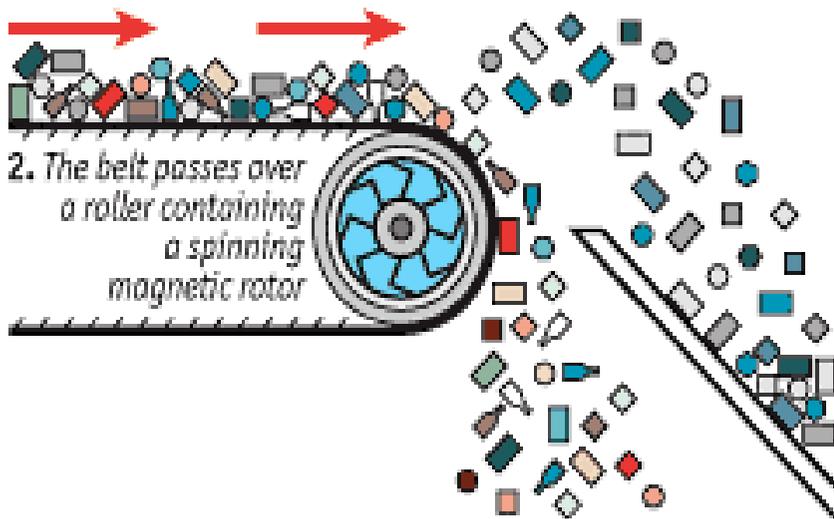
## Green flingers

### Eddy-current separator

1. A stream of waste material travels along a conveyor belt

2. The belt passes over a roller containing a spinning magnetic rotor

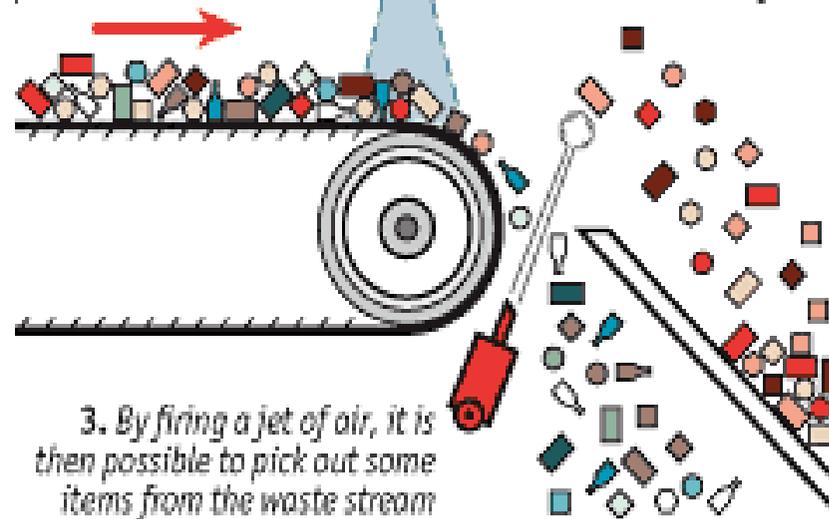
3. A secondary magnetic field is induced in metallic items, and magnetic repulsion pushes them clear of the waste stream



### Spectroscopic sorter

1. A stream of waste material travels along a conveyor belt and passes under a camera

2. Each type of material reflects a unique combination of wavelengths in the infra-red spectrum and can thus be identified



Sources: TiTech, *The Economist*

# TiTECH Sorting Equipment

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<http://www.economist.com/node/9249262>.

# Aluminum

- Metals can be recycled indefinitely
- Virgin aluminum production is very energy intensive
  - Alumina (aluminum oxide) extracted from bauxite
  - Dissolved in molten salt
  - Electric current reduces oxide into pure aluminum
- Recycling aluminum uses only 5% of this energy & releases 5% of the CO<sub>2</sub>
- 1 kg of recycled aluminum represents:
  - 6 kg bauxite saved
  - 4 kg byproducts prevented
  - 14 kWh electricity saved
- Note: aluminum foil & cans are different alloys

# Steel

- "Tin cans" are tin-plated steel
- Recycling steel:
  - Uses 60% less water and 25% less energy than producing virgin steel
  - Reduces air pollution by 86%, water pollution by 76%, and CO<sub>2</sub> emissions by 80%
- 1 ton of recycled steel represents:
  - 1.5 tons iron ore saved
  - 0.5 tons coal saved
  - 1.3 tons solid waste prevented

# Glass

- Glass can also be recycled indefinitely
- Producing glass from cullet (crushed recycled glass) uses slightly less energy (5-30% less) than producing glass from silica
- 1 ton of recycled glass represents:
  - 1.2 tons raw materials saved (silica & additives)
  - 315 kg CO<sub>2</sub> prevented
  - landfill space saved (glass doesn't degrade)
- Color matching problems in some economies

# Paper

- A batch of paper can be recycled ~6 times
- Recycling paper doesn't "save trees," but does have ecological benefits
- Most of the energy used to make virgin paper goes into pulping wood
  - Producing recycled paper uses 28-70% less energy and releases 95% less air pollution
- Recycled paper is usually not rebleached (or uses  $H_2O_2$ )
- Paper in landfills rots & releases  $CH_4$  (greenhouse gas)
- 1 ton of recycled paper represents:
  - 30,000 L water saved
  - 3,000 - 4,000 kWh electricity saved

# Types of Plastic

1. PET = polyethylene terephthalate  
○ 2-liter soda bottles, water bottles



2. HDPE = high-density polyethylene  
○ milk jugs, detergent bottles



3. PVC = polyvinyl chloride

○ piping, shampoo bottles

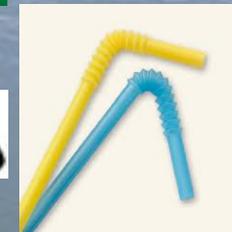


4. LDPE = low-density polyethylene  
○ dry cleaning bags, produce bags



5. PP = polypropylene

○ bottle caps, straws, frozen dinner dishes



6. PS = polystyrene

○ cups, to-go boxes, meat trays, packing peanuts



7. other: Tupperware, Nalgene, bioplastics, etc.



# Plastics

- 8% of world oil consumption goes into plastic
- All plastics are recyclable, but most programs only collect PET and HDPE (1 & 2)
  - Plastic industry rarely incorporates recycled plastic into its manufacturing process
- Plastic degrades during recycling, so virgin stock is always needed
- Production of plastic bags using recycled plastic reduces:
  - Energy usage by 67%
  - SO<sub>2</sub> production by 67%
  - NO<sub>x</sub> production by 50%
  - H<sub>2</sub>O usage by 90%
- 1 ton of recycled plastic saves 1.8 tons of oil



Berkeley Ecology Center. "Plastics Recycling: Q&A." Retrieved from:  
[http://www.ecologycenter.org/recycling/recycledcontent\\_fall2000/plastics\\_qa.html](http://www.ecologycenter.org/recycling/recycledcontent_fall2000/plastics_qa.html)

# Open- vs. Closed-Loop Recycling

Closed-loop:

Materials are recycled into the same product.

Open-loop, a.k.a. "Downcycling":

Materials that cannot be recycled economically can sometimes be reused in a less pure, lower valued form.

- Aluminum foil goes into automotive parts
- Glass cullet is used as aggregate in "glasphalt"
- Short paper fibers go into toilet paper
- Plastics go into "plastic lumber," carpet fiber, etc.

# Things to Consider

- Economic feasibility
  - Infrastructure & maintenance
  - Government subsidies
  - Recycled materials market
- Environmental impact
  - Landfill space
  - Greenhouse gas emissions
  - Ecosystem/landscape destruction
  - Air/water pollution
- Energy efficiency
  - Transportation of recyclables
  - Sorting & processing
  - Production vs. recycling of materials

# Questions?

## Works Cited

"The truth about recycling." The Economist. 7 June 2007.

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"Plastics Recycling: Q&A." Berkeley Ecology Center.

[http://www.ecologycenter.org/recycling/  
recycledcontent\\_fall2000/plastics\\_qa.html](http://www.ecologycenter.org/recycling/recycledcontent_fall2000/plastics_qa.html)

Waste Online: Information Sheets

<http://www.wasteonline.org.uk/searchresults?>

Type=Information%20Sheet

Solid Waste Management and Greenhouse Gases: A Life-Cycle Assessment of Emissions and Sinks. EPA. 2006.

<http://epa.gov/climatechange/wycd/waste/downloads/fullreport.pdf>