We didn't plan to talk about it, but since you asked . . .

Here’s some info re recycle of plastics vs. landfills

• Are the benefits of recycling plastics outweighed by the pollution that results from recycling plastic?

• How much energy is conserved through recycling?

• Besides plastics what else goes into landfills and what comes out?
How well do you know your plastics?

• **PET** (polyethylene terephthalate) — commonly used in soft drink bottles.

• **HDPE** (high-density polyethylene) — used in milk and water jugs, detergent bottles and the base cups of soft drink containers.

• **PVC** (polyvinyl chloride) — commonly used in durable construction products such as pipes and siding.

• **LPDE** (low-density polyethylene) — used in plastic film items such as grocery bags.

• **PP** (polypropylene) — common in durable items, fibers and diaper liners.

• **PS** (polystyrene) — familiar in foamed form ("Styrofoam" is a particular brand name) as fast-food packaging, hot cups and meat trays; also used in rigid and semi-rigid containers.
### Plastic container code system.

<table>
<thead>
<tr>
<th>CODE</th>
<th>MATERIAL</th>
<th>PERCENT OF TOTAL VOLUME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Polyethylene Terephthalate (PET)</td>
<td>20-30 percent</td>
</tr>
<tr>
<td>2</td>
<td>High Density Polyethylene</td>
<td>50-60 percent</td>
</tr>
<tr>
<td>3</td>
<td>Vinyl/Polyvinyl Chloride (PVC)</td>
<td>5-10 percent</td>
</tr>
<tr>
<td>4</td>
<td>Low Density Polyethylene</td>
<td>5-10 percent</td>
</tr>
<tr>
<td>5</td>
<td>Polypropylene</td>
<td>5-10 percent</td>
</tr>
<tr>
<td>6</td>
<td>Polystyrene</td>
<td>5-10 percent</td>
</tr>
<tr>
<td>7</td>
<td>All other resins</td>
<td>5-10 percent</td>
</tr>
</tbody>
</table>

Polyethylene (high density and low density) accounts for the largest volume, with 10.4 billion pounds of U.S. sales. Polypropylene contributed another 8 billion and polyvinyl chloride (including copolymers) 7.7 billion pounds. Polyester (thermoplastic and unsaturated, no textiles) accounted for 2.9 billion pounds (6 percent) of U.S. sales. These billions of pounds of thermoplastics offer the opportunity to recycle. The nature of a thermoplastic is such that it can be re-melted or extruded into remanufactured products.
We found a comprehensive study by the **Tellus Institute** in Boston.

- The study assessed the impacts of production and disposal of packaging (including plastics). It was prepared for the Council of State Governments and the N.J. Dept. of Environmental Protection and Energy.
How much will recycling of plastics reduce landfills?

As of 2009, 12.3% of solid waste (by weight) in a landfill is plastic.

More importantly, by volume about 20% of solid waste is plastic.

Almost 14% of plastic containers and packaging is recycled.

Over 2.1 billion pounds of post-consumer plastic bottles were recycled during 2005, accounting for 24 percent (by weight) of all plastic bottles produced in the United States.
Which produces more pollution; production of plastics from raw materials or recycling?

• The next slide gives statistics for 4 sizes of polyethylene terephthalate (PET) soft drink bottles (one of the major current plastic products).
  – values are given as lbs of EPA pollutants / 1000 gallons
<table>
<thead>
<tr>
<th>Size</th>
<th>air emissions (lb./1000 gal.)</th>
<th>water emissions (lb./1000 gal.)</th>
<th>solid wastes (lb./1000 gal.)</th>
<th>solid wastes (cubic feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16 oz</td>
<td>98.7</td>
<td>16.6</td>
<td>940</td>
<td>56.2</td>
</tr>
<tr>
<td>1 L</td>
<td>78.9</td>
<td>13.6</td>
<td>688</td>
<td>42.9</td>
</tr>
<tr>
<td>2 L</td>
<td>59.0</td>
<td>10.3</td>
<td>479</td>
<td>29.</td>
</tr>
<tr>
<td>3 L</td>
<td>57.4</td>
<td>10.4</td>
<td>464</td>
<td>28.1</td>
</tr>
<tr>
<td></td>
<td>from Virgin material</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 oz</td>
<td>92.3</td>
<td>15.9</td>
<td>815</td>
<td>46.1</td>
</tr>
<tr>
<td>1 L</td>
<td>74.1</td>
<td>13.1</td>
<td>592</td>
<td>35.1</td>
</tr>
<tr>
<td>2 L</td>
<td>55.8</td>
<td>10.0</td>
<td>415</td>
<td>23.9</td>
</tr>
<tr>
<td>3 L</td>
<td>55.2</td>
<td>10.1</td>
<td>403</td>
<td>23.0</td>
</tr>
<tr>
<td></td>
<td>from Recycled material</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For PET, gross pollution is slightly lower with recycling than with land-filling. The main reason that the values are so close is that a lot of the pollution for recycling comes from trucks that collect and transport the plastic.
The energy used in the production of plastics from raw materials is much higher than required to melt plastic for recycling.

<table>
<thead>
<tr>
<th>Plastic</th>
<th>Production energy (from raw materials) (BTU / lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>38,500</td>
</tr>
<tr>
<td>HDPE</td>
<td>36,500</td>
</tr>
<tr>
<td>PS</td>
<td>34,300</td>
</tr>
<tr>
<td>PET</td>
<td>48,700</td>
</tr>
<tr>
<td>PVC</td>
<td>25,600</td>
</tr>
</tbody>
</table>

To compare: it takes 1000 to 2000 BTU / lb. to melt plastics for recycling.

(In addition there would be energy costs for granulation, drying, pelletizing, separation, resin extrusion, etc.)
The main alternative to recycle of plastics is disposal into landfills.

So let’s take a quick look at how we make use of landfills for waste disposal.
Let’s start by thinking about what goes into landfills* . . .

✓ food wastes [9%]  rubber (tires) [0.5%]  
✓ paper [34%]  plastics [12%]  ORGANIC
✓ textiles [2%]  yard wastes [18.5%]
✓ wood [2%]  cardboard [6%]
✓ leather [0.5%]

✓ aluminum [0.5]  glass [8.0]  INORGANIC
✓ tin cans [6.0]  dirt, ash [3.0]

* % by weight of residential solid waste, excluding recycled components
An interesting new option is to compost food plus yard wastes (about 27% of total mass) to reduce landfill input.

- The city of Houston started doing this in 2010.
- They saved $1.5 million/year in “tipping fees”.
- Instead they collect $5/ton from their composting contractor.
- They use compostable clear plastic bags for collection of the food and yard waste.

Source: Chemical and Engr. News; Mar. 19, 2012
Municipal solid waste also has hazardous components such as:

**HOUSEHOLD CLEANERS**
- aerosols (flammable)
- chlorine bleach (corrosive)
- drain openers
- toilet bowl cleaner
- oven cleaner

**AUTOMOTIVE PRODUCTS**
- antifreeze
- brake fluid
- car batteries
- gasoline
- waste oil

**OUTDATED MEDICINES**

**PESTICIDES, AND HERBICIDES**
Basically what ever goes into a landfill can come out (transformed?) as a leachate component.

- **Physical components**
  - Taste, color and odor causing compounds
  - Dissolved and suspended solids (turbidity source)

- **Biological components**
  - bacterial, viral, and protozoan

- **Chemical components**
  - inorganic
    - toxic metals such as Cd, Pb and Hg
    - algal nutrients [P and N (including NO₃⁻)]
  - organic
    - source of oxygen demand (BOD)
Trace organic components of leachate can include:

- **Toxins**
  - pesticides, herbicides, etc.

- **Carcinogens**
  - benzene, vinyl chloride, PCBs, etc.

- **Volatile**
  - solvents (including trichloroethylene), and fuel components (ex., toluene)

- **Organic acids**
  - phenols, tanins, lignins
Leachate constituents can be modified by physical, chemical and biological processes

- filtration (removal of small particles)
- precipitation
- oxidation/reduction [ex. Fe (III) $\rightarrow$ Fe(II)]
- sorption and ion exchange (removal onto surfaces of the porous media)
- biodegradation
The sanitary landfill:
Engineered management of municipal solid wastes.

- containment of leachate by liners (both clay and synthetic)
  - collection by gravity drainage into pipes or trenches
  - storage in collection tanks
  - management by:
    - leachate recycling (accelerates degradation of land filled wastes)
    - evaporation in lined ponds (for volume reduction)
    - treatment
      - on site systems
      - transport to wastewater treatment plant
Want to know more?

- Here's a good reference text:

**INTEGRATED SOLID WASTE MANAGEMENT**

by: Tchobanoglous, Theisen and Vigil

McGraw-Hill, Inc. 1993

OR

Take Professor Haith's course:
**BEE 4760; Solid Waste Engineering**