What percentage of the energy used in the U.S. is supplied by wind and solar?

1. Less than 1%
2. 5%
3. 10%
4. 25%
What percentage of the energy used in the U.S. is supplied by fossil fuels (oil, coal, natural gas)?

1. 25%
2. 50%
3. 75%
4. 85%

The correct answer is 4. 85%.
Biomass Energy:

Energy from the sun that is stored in plants and other living organisms.
What percentage of the energy used in the U.S. is supplied by biomass?

1. 3%
2. 10%
3. 25%
4. 50%
CO2 from Biomass Energy does not contribute to global warming.

Why not?
CO2 lets in sunlight (yellow) but blocks heat escape (red) acting like a blanket on the earth.
CO2 from Biomass does not increase CO2 in the air.

Why not?
Answer:

Carbon in Biomass came from the air.

Energy in biomass came from the sun.
The miracle of photosynthesis

Green plants turn sunlight and CO2 into chemical energy
How much carbon was stored in fossil fuels? (billions of metric tons)

- Atmosphere: ~800 billion metric tons
- Vegetation: ~600 billion metric tons
- Soil: ~1,500 billion metric tons
- Ocean: ~40,000 billion metric tons
- Rock and sediment: ~75,000,000 billion metric tons
- Fossil Fuel: ~4,000 billion metric tons
Let's try a demonstration!

Atmosphere

CO2 in atmosphere
1. Carbon in biomass comes from the air, so emissions do not increase CO2 average.
2. Carbon in fossil fuels comes from the ground, so emissions increase CO2 in air.
Sources of U.S. Energy

- Biomass – 3%
- Wind and Solar - <1%
- Fossil Fuels (oil, gas, coal) – >85%

Source – Energy Information Agency
http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea_sum.html
How much energy is available in new biomass each year – compared to all the energy used in the world?

1. One quarter
2. One half
3. About the same
4. Two times
5. Four times

![Bar chart showing 25% for each option]
Biomass challenge:

There is 4x the energy in new biomass than all the energy used in the world. How can we harness biomass energy to replace fossil fuels?
What is biomass energy? (the miracle of photosynthesis)

Green plants turn sunlight into chemical energy
How do plants store their chemical energy?

1. Sugar
2. Starch
3. Oil
4. Cellulose
5. 1-3 above
6. 1-4 above
Biomass energy storage

- Sugar (eg. sugar cane)
- Starch (eg. corn)
- Oil (eg. Soybean oil)
- Cellulose (stalks, wood, leaves, etc.)
Biomass fuels

- Sugar (eg. sugar cane)
- Starch (eg. corn)
- Oil (eg. Soybean oil)
- Cellulose (stalks, wood, leaves, etc.)

Ethanol
(at a price competitive with gasoline)
Biomass fuels

- Sugar (eg. sugar cane)
- Starch (eg. corn)
- Oil (eg. Soybean oil)
- Cellulose (stalks, wood, leaves, etc.)

What can we do with it?
Soybean oil

Can we run an engine on it?
Yes!

A diesel engine runs great on vegetable oil!

There’s just one problem... Viscosity.

It clogs fuel lines, filters, and injectors.
Can we use a little science to solve the viscosity problem?

Vegetable oil molecule

Carbon chains
Make Biodiesel fuel

Vegetable Oil

Catalyst and methanol

Glycerin

Biodiesel

Carbon chains
Used fryer oil

Once we have fried food in vegetable oil, is it still any good?
Waste fryer oil — how much of its original “solar energy” does it still contain?

1. Less than 5%
2. 25%
3. 50%
4. 75%
5. 100%
A Class Activity

Can we make biodiesel fuel from waste fryer oil?

Let’s try it!
Let’s Start

Waste Vegetable Oil (WVO) + Catalyst and methanol + Heat = ?
Making Biodiesel fuel

Vegetable Oil

Carbon chains

Catalyst and methanol

Biodiesel

Glycerin
Viscosity
another class activity while we’re waiting…

Does biodiesel flow well enough?

How could we test it?
Viscosity given these objects...

How could we test the viscosity of biodiesel? How would we know if it flows well enough?
Viscosity results...

<table>
<thead>
<tr>
<th></th>
<th>Time to empty 10 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Fuel</td>
<td></td>
</tr>
<tr>
<td>Canola oil</td>
<td></td>
</tr>
<tr>
<td>Waste oil</td>
<td></td>
</tr>
<tr>
<td>Biodiesel</td>
<td></td>
</tr>
</tbody>
</table>
Back to our biodiesel production

Waste Vegetable Oil (WVO) + Catalyst and methanol + Heat = ?
Is it a good fuel?

How could we test it?
What should we look for?

- Stays lit
- Size of flame
- Color of flame
- Smoke
Back to our biodiesel production

Waste Vegetable Oil (WVO) + Catalyst and methanol + Heat = ?
What have we made?

- Biodiesel (with unreacted oil)
- Glycerin (waste “backbone”)
Making Biodiesel fuel

Vegetable Oil

Carbon chains

Catalyst and methanol

Glycerin

Biodiesel
How can we tell if we made biodiesel?

Biodiesel
(with unreacted oil)

Glycerin
(waste “backbone”)
What plants produce vegetable oil?

- Soybean ~50 gpa
- Canola ~100 gpa
- Sunflower ~130 gpa
- Jatropha ~200 gpa
- Palm ~500 gpa
- Algae 1000+ gpa
Ideas discovered…

Biomass stores 4x the energy we use each year.
Ideas discovered...

Sugar, starch, and oil is easily converted to motor fuel at competitive costs.

But... this is part of the plant we use for food!
Solutions...

Use waste oil

Oil from algae

Find a way to use the cellulose (all the parts of the plant we DON'T eat)
Cellulosic Ethanol

Many companies are researching how to turn cellulose into ethanol.

It would let us use waste vegetation - instead of food - to make fuel.