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

- Many of you wanted to know about: Alternative energy sources
There are quite a few ideas out there, some old and some new. Here are some possibilities:

- **Hydropower:** use turbines to harness the energy released by transferring water stored behind dams.
  - Environmental Impact:
    - altered water quality and flow downstream of dam
    - dams act as barriers to fish spawning
    - altered movement of sediment

According to the American Rivers organization: 925 dams have been removed in the US over the past 100 years.

Four hydroelectric dams were scheduled for removal from the Klamath river in 2010 to restore salmon runs.

**Itapu:** world’s 2nd largest hydroelectric plant

Brazil & Paraguay
Wind energy

- use windmills or wind turbines to capture wind energy that originates in response to temperature gradients
  - Environmental Impact
    » extensive land use
    » visual impact
    » bird strikes
    » possible noise pollution

Latest idea: put turbines on floating platforms 100 mi. out to sea.
More on wind energy

- Wind farm off of Nantucket Island has been approved despite great public resistance.
- Long Island’s Power Authority wants to construct an up to 700-MW wind farm off shore by 2015.
- Los Angeles is installing a 3-GW plant in the Mojave desert.

U.S. Primary Energy Consumption by Energy Source, 2010

- Total: 98 quadrillion Btu
- Petroleum 37%
- Natural Gas 25%
- Coal 21%
- Renewable Energy 8%
- Nuclear Electric Power 9%
- Total: 8 quadrillion Btu
- Solar 1%
- Geothermal 3%
- Wind 11%
- Biomass waste 6%
- Biofuels 23%
- Wood 25%
- Hydropower 31%

Note: Sum of biomass components does not equal 53% due to independent rounding.
Potential for Wind Energy Projects

Wind Resources and Transmission Lines

The remaining states use data from the 1987 "Wind Energy Atlas of the United States".

Wind Power Classification

<table>
<thead>
<tr>
<th>Wind Power Class</th>
<th>Resource Potential</th>
<th>Wind Power Density at 50 m W/m²</th>
<th>Wind Speed at 50 m m/s</th>
<th>Wind Speed at 50 m mph</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Marginal</td>
<td>200 - 300</td>
<td>5.6 - 6.4</td>
<td>12.5 - 14.3</td>
<td></td>
</tr>
<tr>
<td>3 Fair</td>
<td>300 - 400</td>
<td>6.4 - 7.0</td>
<td>14.3 - 15.7</td>
<td></td>
</tr>
<tr>
<td>4 Good</td>
<td>400 - 500</td>
<td>7.0 - 7.5</td>
<td>15.7 - 16.8</td>
<td></td>
</tr>
<tr>
<td>5 Excellent</td>
<td>500 - 600</td>
<td>7.5 - 8.0</td>
<td>16.8 - 17.9</td>
<td></td>
</tr>
<tr>
<td>6 Outstanding</td>
<td>600 - 800</td>
<td>8.0 - 8.8</td>
<td>17.9 - 19.7</td>
<td></td>
</tr>
<tr>
<td>7 Superb</td>
<td>800 - 1600</td>
<td>8.8 - 11.1</td>
<td>19.7 - 24.8</td>
<td></td>
</tr>
</tbody>
</table>

Wind speeds are based on a Weibull k value of 2.0

Source: U.S. Department of Energy National Renewable Energy Laboratory

Transmission Lines

- Voltage (kV)
  - 345 - 499
  - 500 - 699
  - 700 - 799
  - 1000 (DC)

Inset map of Alaska.
Wind Energy Projects
Throughout the United States of America

Current Installed Wind Power Capacity (MW)

Total: 43,635 MW
(As of 09/30/2011)

Wind Power Capacity
Megawatts (MW)

- Green: 1,000 - 10,200
- Dark Green: 100 - 1,000
- Light Green: 20 - 100
- Lightest Green: 1 - 20


NREL
National Renewable Energy Laboratory
Solar-Thermal technology

Sunlight is focused to create a high temperature for heating or power generation

- **Parabolic trough**
  - trough collector focuses sun on an oil-filled pipe. Oil is circulated to heat water or to drive a heat engine.

- **Central receiver system**
  - sun-tracking mirrors or parabolic dishes reflect sunlight to a heat exchanger located on top of a tower.

- **Solar ponds**
  - Hot water from the bottom surface layers is used to drive a Rankine-cycle engine.

Energy, in the form of hot water, is extracted by circulating water in pipes laid on the bottom of the pond.

Salinity and temperature differences with change in depth.
Still other ideas

- **Photovoltaic Energy** - photo cells can produce energy directly from sunlight
  - Environmental Impact
    » Cadmium and other heavy metals can enter environment from disposal of used cells.

- **Geothermal Energy** - makes use of regions with temperatures above the ambient mean in the subsurface
  - Geothermal reservoirs are tapped by drilling wells and available steam or superheated fluid is used to generate electricity.
Despite abundant geothermal recourses, most of New Zealand’s power comes from hydroelectric.
850 MW Manapouri HydroPower Station

- Located 200 m below the surface.

- Project took 1,800 workers 8 years to cut the underground cavern for the generators, a 2 km long spiral access tunnel, and two 10 km tailrace tunnels out of hard rock.
Generators in the power plant

- For the geotechs in the audience: a 1,500 ton tunnel boring machine was used. A total of 4,084 cutters on the face of the borer had to be replaced. The best advance rate achieved for the borer was 65 ft, the daily average was 32 ft.
Still more alternatives

- **Solar Hydrogen**
  - photovoltaic energy is used to generate a DC current that is used for electrolysis of water into \( \text{H}_2 \) and \( \text{O}_2 \) gas. \( \text{H}_2 \) can be stored and transferred by gas lines and cleanly burned as a fuel.

- **Fuel cells**
  - Typically use the reaction between hydrogen and oxygen to generate energy. In a hydrogen fuel cell (a) hydrogen is stripped of its electrons \( (\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-) \). The electrons create an electric current that is used for power. (b) The resulting \( \text{H}^+ \) ions migrate through the cell to the negative electrode, where they regain their electrons to form \( \text{H}_2 \); (c) the \( \text{H}_2 \) then reacts with \( \text{O}_2 \) to produce water. The hydrogen for fuel cells is obtained from natural gas resulting in production of \( \text{CO}_2 \).
Catalysts are biological material: enzymes or bacteria
Ocean Energy

Tidal energy

- makes use of a dam across an estuary equipped with sluice gates to permit entry of water on rising tides.
  - low-head axial turbines are used to capture energy of water raised by tidal forces.
- Or, flow velocity caused by tides used to move hydrofoils or propellers
- may have an impact on estuarine ecosystems.

The largest tidal turbine in the world was installed near Scotland in 2010 for testing

- Could produce enough energy for 1,000 homes

Water is almost 1000x denser than air, so you can get the same ocean energy from a machine much smaller than a wind turbine.
Cornell’s new Roosevelt Island campus is adjacent to a tidal energy system.


- Goal: 1 MW pilot project with up to 30 turbines in the East Channel of the East River.
Ocean Energy

- **Wave energy**
  - an oscillating water column that acts like a piston to pump air or a fluid is driven by high and low water levels.

- **Thermal energy**
  - similar to a solar pond. Makes use of natural oceanic (or deep lake) temperature differences. Warm surface water evaporates a low-boiling point liquid that drives a turbine and the vapor is then condensed by cold bottom water.

![Image of Pelamis wave converter](image)

750 W “Pelamis” wave converter trial off the coast of Scotland. As ocean waves jerk the sections to and fro, hydraulic rams within the joints pump oil through turbines, driving generators and producing electricity, which is fed to the grid onshore.

Lake source cooling!
Biomass energy: from plant derived materials

- **Anaerobic digestion**
  - in the absence of oxygen bacteria will degrade organic materials to make methane, a fuel gas.

- **Alcohol fuel (ethanol)**
  - fermentation of crops such as sugar cane and corn can be used to produce ethanol, that can, in turn, be used as a fuel source for automotive engines.
the Ethanol debate

- Prof. Pimentel (Cornell) calculates that production of ethanol from corn requires 29% more fossil fuel energy than the energy value of the ethanol. Others say there is a 34% energy gain.

- Use of corn for ethanol increases the cost of corn and reduces its economic advantage (and increase the cost of food to the developing world).

- The amount of corn used to produce 9 billion gal. of ethanol would require about ¼ of total U.S. corn acreage.

- Ethanol has 2/3 the energy value of gas, so 9 billion gal. of ethanol = 6 billion gal. of gas = 4.3% of the 140 billion gal. of gas used per year in the U.S.
Ethanol from lignocellulosics?

Switch grass has been touted by none other than former President Bush as a potential source for ethanol.

- The sugars in cellulose are locked in complex carbohydrates (polysaccharides). Separating these complex polymeric structures and turning them into sugars that bacteria can ferment is what limits our ability to get fuel from cellulose.

Novozymes and Genecor are firms working to reduce the cost of making cellulase, the enzyme used to covert the cellulose in biomass such as corn stover into glucose for fermentation to fuel ethanol.
Cellulosic biofuel progress has been slow.

**Making Cellulosic Biofuels**

<table>
<thead>
<tr>
<th>Renewable Fuel Standard goal for 2012 production(^a):</th>
<th>Estimated 2012 actual production:</th>
<th>U.S. capacity on-line in 2013:</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 million gal</td>
<td>25 thousand gal</td>
<td>75 million gal</td>
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</tbody>
</table>

To make 25 million gal ethanol requires\(^b\):

- 285,000 tons of corn stover collected from 445 square miles of cropland
- 250,000 tons of corn harvested from 96 square miles of cropland

One acre of cropland can produce:

- 80 gal of cellulosic ethanol
- 400 gal of corn ethanol

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\(^a\) As required by the Energy Independence & Security Act of 2007

\(^b\) Assumes 1 dry ton of stover collected per acre.

SOURCES: Energy Information Administration, company information
Cornell’s Geneva Experiment Station has a $950,000 grant to breed **shrub willow** for fuel and to install a boiler to heat two buildings on campus.

- Shrub willow can grow on marginal poorly drained land without herbicide or pesticide application, and with only a small need for fertilizer.
- Willow wood chips are used as fuel for the boilers, and willow is being bred to improve its use in ethanol production.
Local developments

The town of Fenner (east of Cazenovia) has a large wind-power turbine generation system. Produces enough electricity to supply > 7,000 homes (30 MW)

- Other projects have been proposed in Otsego, Ontario and Erie counties but residents have objected to the visual impact of the turbines.
- A single home unit was built in Lansing in 2004.
- The Ithaca Science Center has announced plans to obtain 100% of its power from wind power.

Cornell

- a 1,900-kilowatt hydroelectric plant in Fall Creek, supplies about 2% of Cornell's energy
- the Lake Source Cooling Project reduces campus electricity purchases by 10%.
- solar panels generating a peak 15 kilowatts (kw), were installed on Day Hall in 2006
- Cornell's new Plantations' Welcome Center has LEED Gold certification.
- The goal for the NYC campus is a “net zero energy” status (i.e., electricity generation = electricity consumption)

LEED: Leadership in Energy and Environmental Design
More local developments

Cornell plans to be carbon neutral by 2050 and has realized a 25 percent cut in greenhouse gas emissions in the last two years, due in part to the new Combined Heat and Power Plant and doing away with all coal combustion.