Speaking of Energy...

Professor David Kirkby
Physics & Astronomy
Experimental particle physics:

- What are the fundamental building blocks of nature?
- What holds them together?
- "high energy" physics
CERN, Geneva
SLAC, Stanford
Observational cosmology:

- What is the Universe made of?
- How was it different in the past?
- What is its ultimate fate?
- “dark energy”
Sloan Digital Sky Survey (NM)
Big & Small:

- Cosmology
- Particle physics
- Energy is the universal currency
The space in between:

- Human, terrestrial scales
- Near-term applications of science
- Energy still plays a central role
- Will focus on electrical energy
An Energy Primer:

- Energy takes many forms
- Energy is (usually) conserved
- Not all forms of energy are equally useful
Measuring Energy

- Kilowatt hour (kWh)
- British Thermal Units (BTU)
- Calories
- Joules
- ...

• 1 kWh = 385 AA batteries

• 1 kWh = 860 food calories

• 1 kWh = 1/2 cup of gasoline
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1 kWh = 1/2 cup of gasoline

electricity: 10¢ per kWh
Energy Efficiency:

- electric vehicle ~ 60%
- car engine ~ 20%
- human muscle ~ 20%
- solar cell ~ 15%
Energy and Power

- power measures the rate of energy consumption (or generation)

- 100 Watt lightbulb = 0.1 kW power

- x 10 hours (h)

- = 1 kiloWatt-hours (kWh) of energy
Figuring Power

- V8 car engine ~ 200 kW (kW ~ hp)
- USA consumes ~ 10 kW / person
- household plug max ~ 2 kW
- square meter of sunlight ~ 1 kW
- human at rest consumes ~ 0.1 kW
Star Power

- All of our terrestrial energy originates from the Sun (almost)
- Most of the atoms in your body originated in other stars
Solar
Wind
Oil & Gas
Nuclear
A Global Perspective

- Richer nations use more energy
- Access to energy enables growth
- Developing nations need to use more energy to improve their standard of living
Total Energy Consumption
(tonnes of oil equiv.)

GDP (US$, inflation adj.)

Energy Consumption per Person
(tonnes of oil equiv.)

- **Petroleum**: 37%
- **Natural Gas**: 25%
- **Coal**: 21%
- **Renewable**: 8%
- **Nuclear**: 9%

2009 total U.S. energy use = 94.6 quadrillion Btu

Richard Newell, December 16, 2010
Renewables grow rapidly, but under current policies fossil fuels still provide 78% of U.S. energy use in 2035.


U.S. primary energy consumption quadrillion Btu per year

History

2009

Shares of total U.S. energy

Projections

Renewables (excluding liquid biofuels)

Source: EIA, Annual Energy Outlook 2011
Are we running out of energy?

- coal is abundant and cheap
- renewable energy is... renewable
Is there an energy problem?

- a healthy economy needs energy
- the cheapest forms of energy today are the most expensive for our health and environment
- energy independence ~ national security
Possible solutions:

- better batteries
- cheaper solar cells
- safer nuclear power
- use less energy: conservation
Electricity as Energy

- not readily available from nature
- an invisible form of energy
- good medium for transporting and using energy
- difficult to store in large quantities
US Energy Consumption (2009)

D. Kirkby / data from DOE 2009 Annual Energy Review

kW per capita

Residential | Commercial | Industrial | Transportation

D. Kirkby / 10 Nov 2010
US Energy Consumption (2009)

D. Kirkby / data from DOE 2009 Annual Energy Review

kW per capita

Residential
Commercial
Industrial
Transportation

D. Kirkby / 10 Nov 2010
US Energy Consumption (2009)

uci@home

15%
Average US home uses 35 kWh/day of electricity (2005)

D. Kirkby / data from DOE 2005 Residential Energy Consumption Survey
Californians use less energy in different ways.

D. Kirkby / data from DOE 2005 Residential Energy Consumption Survey
Plug-Load Consumption is Rising

Data from DOE Residential Energy Consumption Surveys 1978-2005

- appliances & lighting
- AC
- water heating
- space heating
Plug-Load Consumption is Rising

Data from DOE Residential Energy Consumption Surveys 1978-2005

Data from DOE 2010 Annual Energy Outlook
Plug-Load Consumption is Rising


"white goods"

37% in 2035
People Consume Energy

- People, not appliances
- We chose what to buy and how we use it
- Performance and convenience usually trumps energy efficiency
The uci@home Project

- interdisciplinary research team
- physical and social scientists
- based at UCI
“...consider groceries in a hypothetical store totally without price markings, billed via a monthly statement... how could grocery shoppers economize under such a billing regime?”

KEMPTON & LAYNE 1994

We consume our energy in an information vacuum
Conservation Challenges:

- Electricity is an intangible resource
- Cannot look at a plug and know how much energy it is using
Research Questions

- How do we actually use electricity at home today?
- How might we use less electricity without giving up performance or convenience?
Research Questions

- Can we design “smart plugs” that make your energy use more tangible and intuitive?
- Would such “smart plugs” lead to reduced electricity use at home?
Smart Plug

- sensors:
  - power, lighting, temperature
- feedback:
  - LEDs, speaker

web displays

Hub
- archives data from all plugs every 3 seconds
University Hills Pilot Study

- 6 randomly selected homes
- installed 7 smart strips
- collected 14 weeks of data (Jun-Sep 2010)
University Hills Pilot Study

- participants could view their energy use in real-time from any web browser at home

- we also experimented with different types of “ambient” feedback (omni-present, unobtrusive)
**uci@home**

**Wednesday 22 September**

<table>
<thead>
<tr>
<th>Location</th>
<th>Temp</th>
<th>Light</th>
<th>Power</th>
<th>Projected</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kitchen Counter</td>
<td>76.6°F</td>
<td>0.08W</td>
<td>&lt;1¢/day</td>
<td>&lt;1¢/day</td>
<td></td>
</tr>
<tr>
<td>Media PC &amp; TV Control</td>
<td>79.6°F</td>
<td>68W</td>
<td>16¢/day</td>
<td>12¢/day</td>
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<tr>
<td>Living Room Lights</td>
<td>79.1°F</td>
<td>0W</td>
<td>&lt;1¢/day</td>
<td>21¢/day</td>
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<tr>
<td>Fish Tank</td>
<td>79.2°F</td>
<td>19W</td>
<td>5¢/day</td>
<td>3¢/day</td>
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<tr>
<td>Bedroom Electronics</td>
<td>75.8°F</td>
<td>9W</td>
<td>2¢/day</td>
<td>9¢/day</td>
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<tr>
<td>Living Room Laptop Plug</td>
<td>76.7°F</td>
<td>43W</td>
<td>10¢/day</td>
<td>4¢/day</td>
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<tr>
<td>Living Room Satellite Plug</td>
<td>76.8°F</td>
<td>44W</td>
<td>11¢/day</td>
<td>10¢/day</td>
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Click to enter a new note...

![Power vs Time of Day Graph](chart.png)
Research Findings:

- detailed real-time data does not dramatically change consumption habits

- actual savings are even less than expected (10-15%), based on studies from the 1970s
Possible causes:

- consumers need actionable prompts instead of engineering data

“Unplugging your printer at night would save $5 a month.”
Possible causes:

- we are surrounded by much more data today
- any one piece of data gets lets attention and has less influence
Research Findings

- “ambient” feedback shows potential for making energy use more tangible and intuitive

- use LEDs and speaker to unobtrusively signal energy use
Ambient Feedback Examples

- Glows green when you have used < 10¢ over past 24 hours
- Green vs Red (positive / negative)
- Musical consumption:
Energy Research at UCI

- Advanced Power & Energy Program
  - Fuel cells, improved combustion engines, demonstration projects.
- Campus is living lab for “green” buildings.
- Calit2 Plug-Load Research Center
help yourself!
dkirkby@uci.edu

http://positron.ps.uci.edu/~dkirkby/

http://athome.ps.uci.edu

“Physics for Future Presidents”, Richard A. Muller