Energy Flow and Conversion

PHYS 4400, Principles and Varieties of Solar Energy

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January 29, 2013

Comments on Quiz #1

The quiz will cover topics covered up through Jan. 29, including reading assignments, lectures, discussion, and homework. Expect ~ 15-20 True/false or multiple choice questions, and ~4-5 short answer problems.

Bring a calculator, pencil, and eraser for the quiz.

The quiz is closed book and closed notes.

Comments on Quiz #1 (cont.)

Jan. 8, 10	Introduction; energy vs. power; overview of Earth's energy: forms of energy, sources and use, stored energy, average and peak power.
	Reading (complete before class). January 8. http://en.wikipedia.org/wiki/Energy (Parts 1-5); http://en.wikipedia.org/wiki/Power_(physics) (Parts 1-2, 5, 6). January 10: http://en.wikipedia.org/wiki/Light (Parts 1-5; for Units and Measures, familiarize yourself with and be prepared to explain Radiant Energy, Radiant Flux, Irradiance, Spectral Irradiance).
Jan. 15, 17	Light and photons: generation and destruction of light, interactions between light and matter, photon flux. Blackbody radiation. Jan. 17 – guest lecture on the physics of the Sun (J.D. Smith, UT Astronomy).
	January 15: http://en.wikipedia.org/wiki/Photon (Parts 1, 2 (not 2.1), 11, and 12). January 17: http://en.wikipedia.org/wiki/Sun (Parts 1, 2, and 6). Blackbody radiation: http://en.wikipedia.org/wiki/Black-body_radiation (Parts 1-4)
Jan. 22, 24	Insolation, solar spectra, extraterrestrial and terrestrial spectra, air mass, atmospheric effects, direct vs. indirect insolation, integrating the solar spectrum.
	January 22: The solar constant: http://en.wikipedia.org/wiki/Solar_constant . http://en.wikipedia.org/wiki/Sunlight (Parts 1- 4, 6, 9); Textbook sections 2.1, 2.2.
Jan. 29, 31	Introduction to energy conversion. Value of and need for energy conversion and energy efficiency; environmental impacts, and challenges. Fossil energy, the greenhouse effect, global climate change, weather vs. climate. January 31: In-class quiz.
	January 29: Textbook Chapter 1, and section 2.3; http://en.wikipedia.org/wiki/Energy_conversion January 31: http://en.wikipedia.org/wiki/Greenhouse_effect .

Some near-term topics

Energy conversion
Need for energy conversion
Value of energy efficiency
Environmental impacts and challenges
Fossil energy
Greenhouse effect
Global climate change
Weather vs. climate

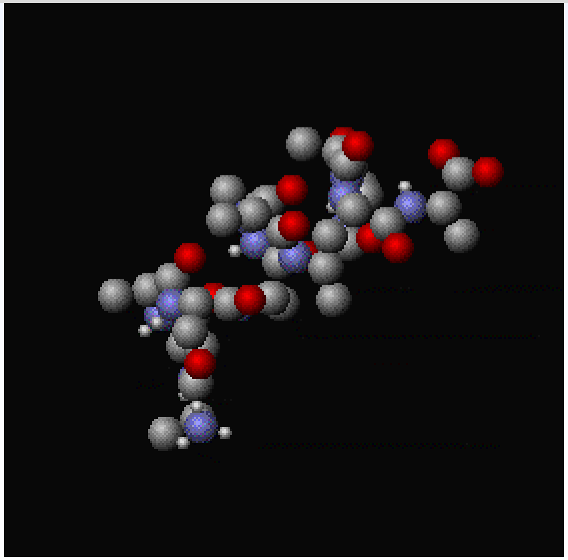
Forms of energy

- Thermal energy
- Chemical energy
- Electric energy
- Radiant energy
- Nuclear energy
- Magnetic energy
- Elastic energy
- Sound energy
- Mechanical energy
- Luminous energy
- Mass ($E=mc^2$)

Thermal energy

- Temperature, determined by the average kinetic energy of a material's constituent atoms and/or molecules.
- Vibrational energy in solids (phonons).
- Total thermal energy of a body depends upon the **specific heat capacity** of the material, which indicates how much thermal energy is stored as heat for a given quantity (typically mass), of a material at a certain temperature. Units are J/(kg K).
- Many energy forms convert naturally to thermal energy.

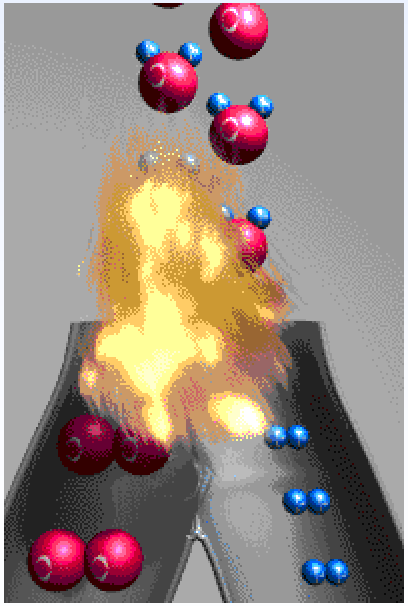
Thermal motion of a segment of protein alpha helix.



http://en.wikipedia.org/wiki/File:Thermally_Agitated_Molecule.gif

Chemical energy

- Refers to the chemical potential energy (or just "chemical potential") stored as a result of the possibility of a chemical reaction.
- Reactants undergo change in a reaction, due to changing order and/or bonding configurations -- which can either absorb or release thermal or radiant energy.
- Exothermic vs. endothermic…



$O_2 + 2H_2 \rightarrow 2H_2O$ + Energy

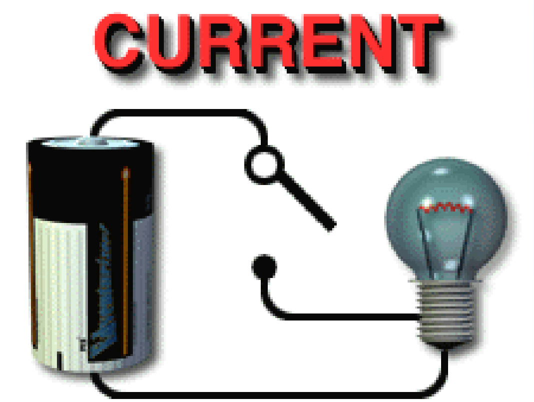
Energy = 286 kJ/mol

Electric energy

- Electrostatic potential energy, associated with the configuration of fixed charges under the Coulomb force, where k_e is Coulomb's constant:

$$\vec{F} = k_e \frac{q_1 q_2 \hat{r}_{21}}{r_{21}^2}$$

- Refers to electric *potential* energy, in the form of an electric current and an electric potential (voltage).
- Drawing power from the electric potential energy involves the conversion of the potential to another form of energy.



Radiant energy

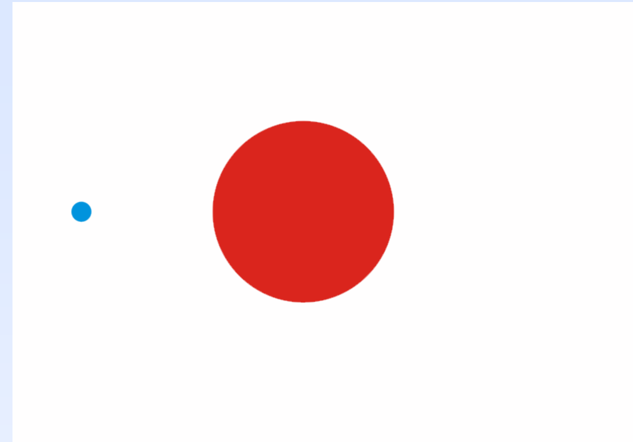
Location of Gemasolar

Country	Spain
Location	Fuentes de Andalucía, Sevilla
Coordinates	37°33′29.11″N 5°19′44.6″W
Status	Operational
Commission date	May 2011
Owner(s)	Torresol Energy
Solar farm information	
Type	CSP
CSP technology	Solar power tower
Heliostats	2,650
Power generation information	
Installed capacity	19.9 MW
Annual generation	110 GW·h

http://en.wikipedia.org/wiki/File:Gemasolar.jpg

Nuclear energy

- Practical: the thermal energy released in fission, which drives turbines in a nuclear power plant.
- In 2011 worldwide nuclear output fell by 4.3%, the largest decline on record, on the back of sharp declines in Japan (-44.3%) and Germany (-23.2%).

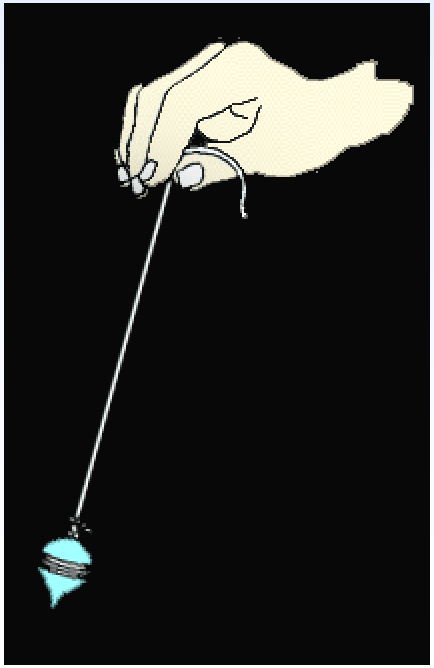


http://www.cigionline.org/sites/default/files/Nuclear%20Energy%20Futures%20Overview.pdf

http://upload.wikimedia.org/wikipedia/commons/thumb/9/9b/Nuclear_power_percentage.svg/1000px-Nuclear_power_percentage.svg.png

Mechanical energy

- Energy of motion and position: the sum of kinetic energy and potential energy.
- The equivalence between lost mechanical energy and an increase in temperature was discovered by James Prescott Joule. As an example, any inelastic collision results in conversion of mechanical energy to thermal energy [http://en.wikipedia.org/wiki/Mechanical_energy]



http://www.occultopedia.com/r/radiesthesia.htm

Energy flow (Earth vs. the Universe)

<u>The Universe</u> -- a richly complex landscape of energy flow:

Following the Big Bang, hydrogen was formed, and serves as the building block for other elements through fusion in stars (fusion releases thermal energy, manifested as radiant energy);

Heavy isotopes were formed in nucleosynthesis, reliant on the conversion of gravitational potential energy following supernovae collapse;

Heat from radioactive decay fuels some of the heat within planets' cores; the rest comes primarily from the heat of formation, i.e. the conversion of gravitational potential energy to kinetic energy (heat).

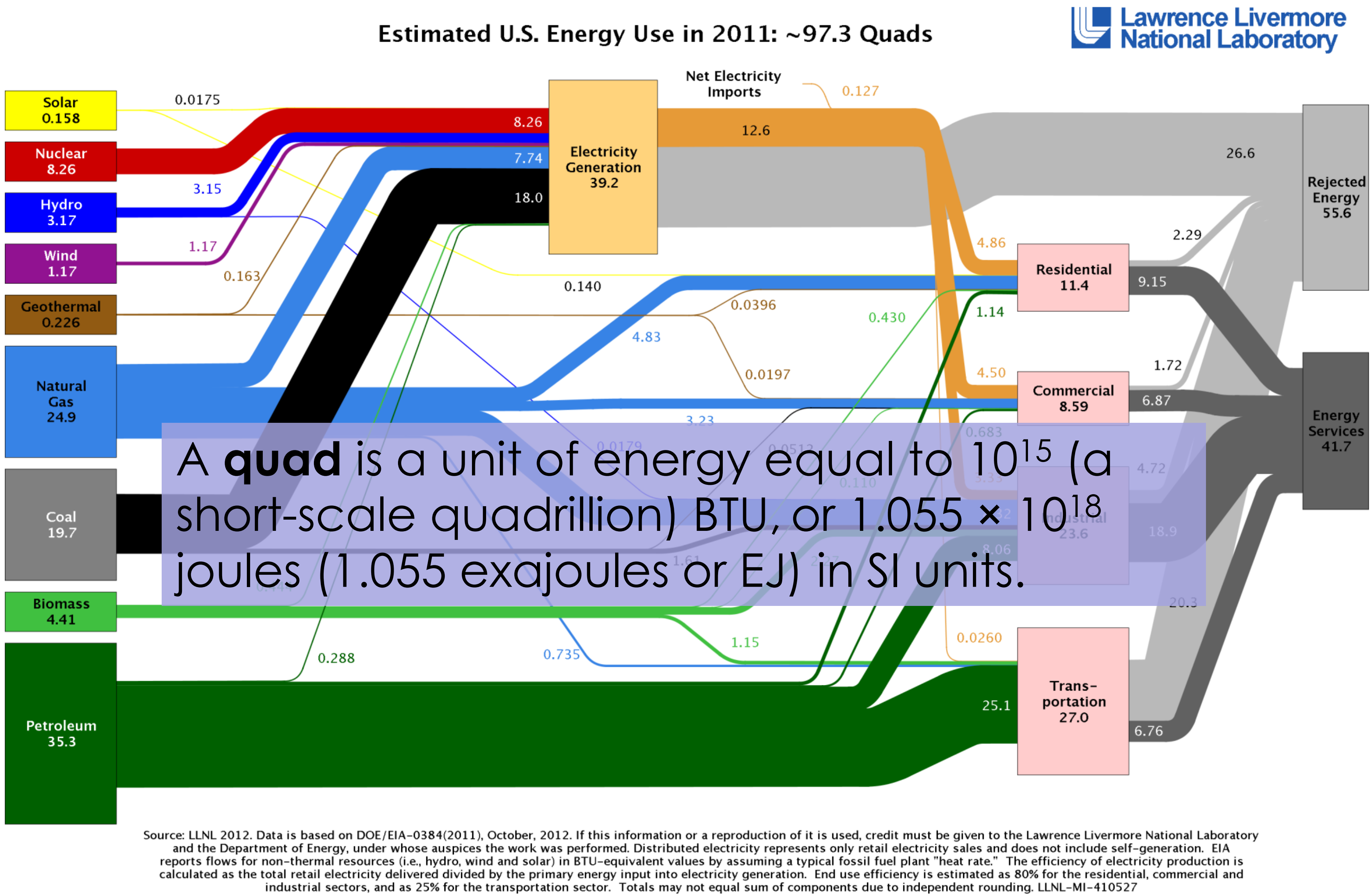
<u>Earth</u> -- equally complex, and at present quite different due primarily to life and human activity:

Earth maintains many of the same energy fluxes, including the effects of heat of formation, radioisotope decay, gravitational potential energy, and the reception of radiant energy from our own star;

Photosynthesis operates as a huge photochemical conversion energy system, and served as a primary basis for the gradual formation of fossil fuels beginning ~5 to 650 million years ago.

Human activity transforms energy between numerous forms (liquid and gas fuels, solid fuels, electricity, bioenergy, thermal energy, gravitational energy, kinetic energy).

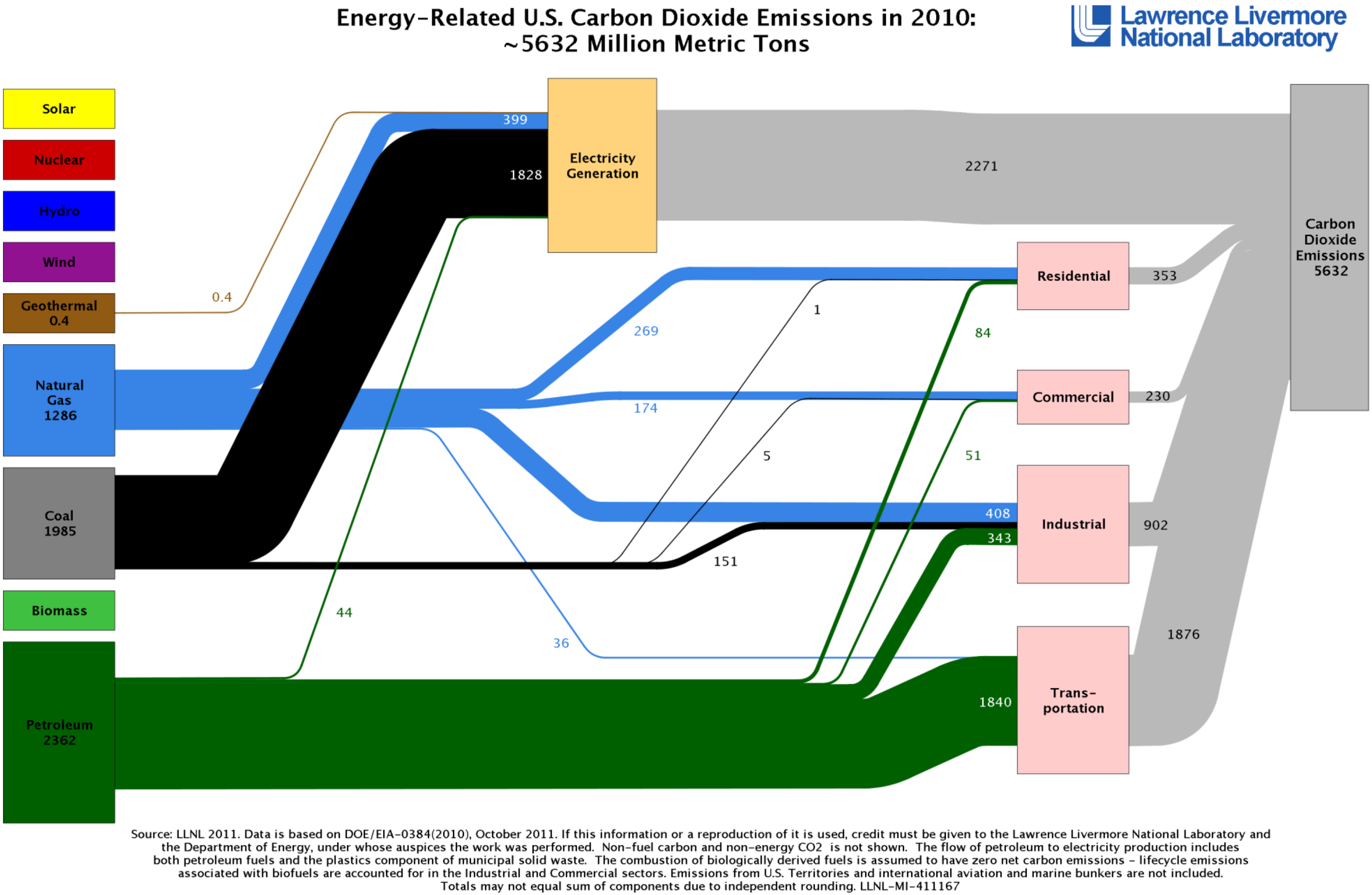
2011 US Energy Flow



A **quad** is a unit of energy equal to 10^{15} (a short-scale quadrillion) BTU, or 1.055×10^{18} joules (1.055 exajoules or EJ) in SI units.

https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2011/LLNLUSEnergy2011.png

2011 energy-related CO_2 emissions



https://flowcharts.llnl.gov/content/carbon/carbon_emissions_2010/LLNL_US_Carbon_2010.png

Energy efficiency

Cost-effective? Example: "*California began implementing energy-efficiency measures in the mid-1970s, including building code and appliance standards with strict efficiency requirements. During the following years, California's energy consumption has remained approximately flat on a per capita basis while national U.S. consumption doubled. As part of its strategy, California implemented a "loading order" for new energy resources that puts energy efficiency first, renewable electricity supplies second, and new fossil-fired power plants last.*"

Appliances

Building design

Industry

Vehicles

Alternative fuels

Energy conservation

Sustainable energy

Rebound effect

Organizations and programs

Energy efficiency example:

# of households in US = 132×10^6

Assume two 23 W CFLs replace 100 W incandescents, in each home.

Assume 3 hours/day on time.

Cost of CFL is ~6x higher, but lifetime is ~6x longer.

Real savings in electricity consumption:

$(132 \times 10^6)(77\ W)(2)(3\ hrs/day)(365\ days/yr) = 2.2 \times 10^{13}\ W\ hr/yr = 2.2 \times 10^{10}\ kW\ hr/yr = 2.2 \times 10^4\ GW\ hr/yr$

Davis-Besse puts out 7.7×10^3 GW hr/yr

http://en.wikipedia.org/wiki/Efficient_energy_use

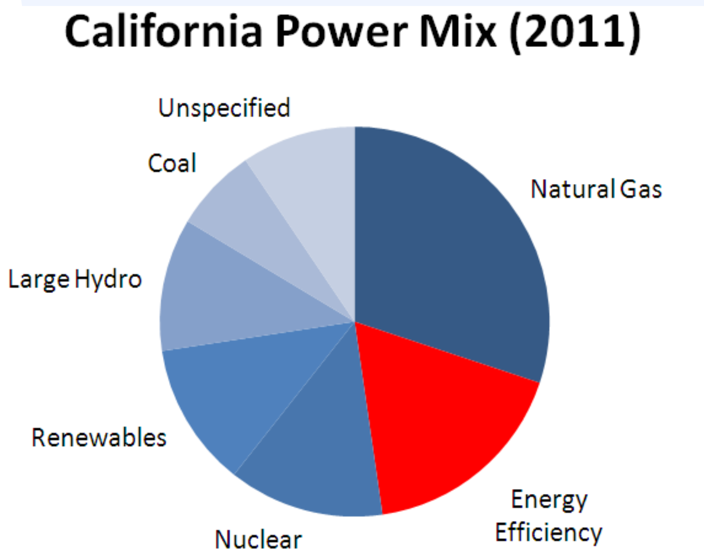
Energy efficiency

Energy efficiency allows us to avoid building new electric power plants.

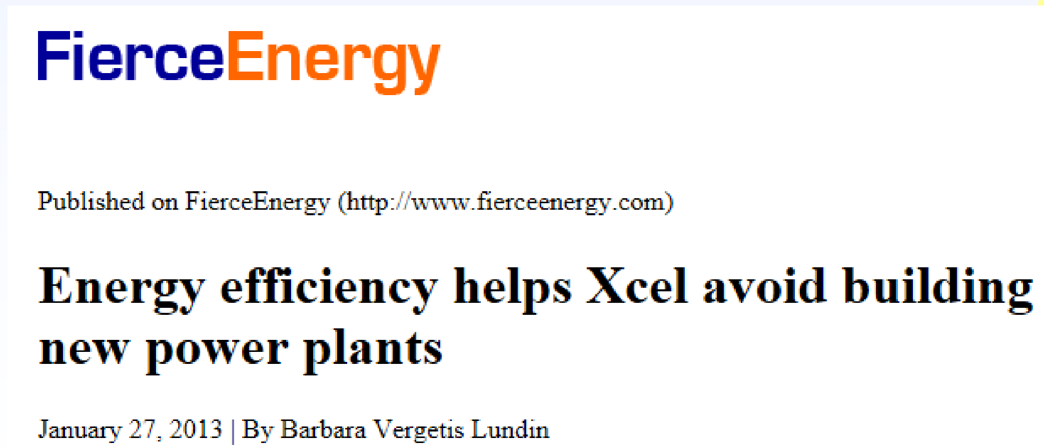
"The cleanest energy is the energy you never use."

"Energy efficiency costs 3 cents per kWh. By comparison, new natural gas power costs 6 cents per kWh or more, traditional coal equals about 11.1 cents per kWh, nuclear power is 12.25 cents per kWh, and biomass resources, geothermal, and wind have average prices of 8.9, 7.55 and 8.5 cents per kWh, respectively."

http://www.theoec.org/campaign/energy-efficiency



Sources: CEC, NRDC analysis


FierceEnergy

Published on FierceEnergy (http://www.fierceenergy.com)

Energy efficiency helps Xcel avoid building new power plants

January 27, 2013 | By Barbara Vergetis Lundin

Greenhouse Gas Equivalencies Calculator

http://www.epa.gov/cleanenergy/energy-resources/calculator.html

Environmental effects of energy

Every energy source presents environmental or health implications. Let's consider them now, from more traditional to more recent.

Wood

Coal

Oil

Natural gas

Hydroelectric

Nuclear

Wind

Solar

Modern bioenergy