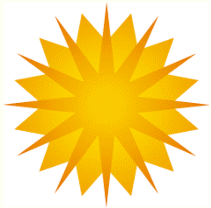


## Energy In Our Daily Lives

Our Energy Sources, Budgets, Expenditures



## Where Does Energy Come From

- Ultimately, from the Big Bang
  - Energy is, after all, conserved
- In our daily lives: 93% Sun, 7% nuclear
  - Food energy: sunlight, photosynthesis
  - Hydroelectric energy: sunlight-driven water cycle (7%)
  - Fossil Fuels: Stored deposits of plant energy (85%)
  - Wind Energy: solar-driven weather (< 1%)
  - Solar Energy: well…from the sun, of course (< 1%)
  - Our nuclear energy, in essence, derives from products of former stars (supernovae)





## World Energy Budget (annually)

| Source | $10^{18}$ Joules/yr | Percent of Total |
|---|---|---|
| Petroleum | 158 | 40.0 |
| Coal | 92 | 23.2 |
| Natural Gas | 89 | 22.5 |
| Hydroelectric | 28.7 | 7.2 |
| Nuclear Energy | 26 | 6.6 |
| Biomass (burning) | 1.6 | 0.4 |
| Geothermal | 0.5 | 0.13 |
| Wind | 0.13 | 0.03 |
| Solar Direct | 0.03 | 0.008 |
| Sun Abs. by Earth | 2,000,000 | then radiated away |

circa 2000

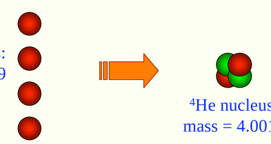




## Where does the sun get its energy?

- Thermonuclear fusion reactions in the sun's center
  - Sun is 16 million degrees Celsius in center
  - Enough energy to ram protons together (despite mutual repulsion) and make deuterium, then helium
  - Reaction per mole 20 million times more energetic than chemical reactions, in general

4 protons: mass = 4.029



$^4$He nucleus: mass = 4.0015

+ 2 neutrinos, photons (light)

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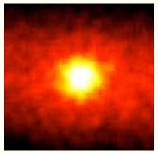
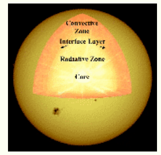


## $E = mc^2$ in Sun




- Helium nucleus is *lighter* than the four protons!
- Mass difference is 4.029 - 4.0015 = 0.0276 a.m.u.
  - 1 a.m.u. (atomic mass unit) is $1.6605\times10^{-27}$ kg
  - difference of $4.58\times10^{-29}$ kg
  - multiply by $c^2$ to get $4.12\times10^{-12}$ J
  - 1 mole ($6.022\times10^{23}$ particles) of protons → $2.5\times10^{12}$ J
  - typical chemical reactions are 100-200 kJ/mole
  - nuclear fusion is ~20 million times more potent stuff!

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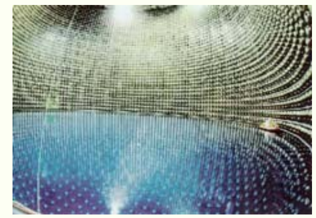
## Solar Energy Output Forms

- 2% in neutrinos: very light, non-interactive
  - more than ten billion per second course through your fingernail
  - fly through earth, as if it weren't even there
  - detected in rare interaction events in huge underground detectors



"Super-K" underground neutrino detector in Japan, half full of water

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## Solar Energy Output Forms, continued

- 98% in light: photons
  - Each photon takes about a million years to clear the annoying electrons in solar plasma
  - 8 minutes once free to reach earth
- 1370 Watts per square meter incident light power
  - Most makes it through atmosphere and reaches us here
  - That which is not reflected is re-radiated back to space
    - after warming us up
  - Hugely abundant: don't have to drill or mine for it

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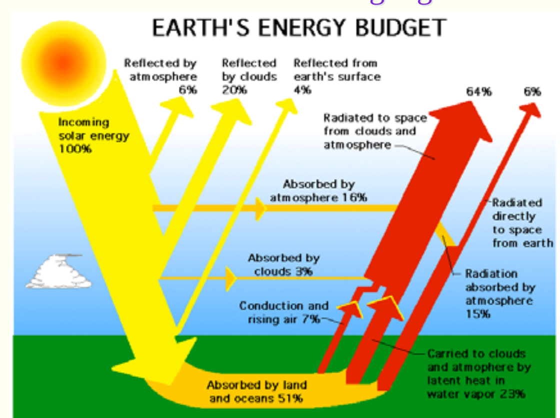
## Where does the sunlight go?

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## Human Energy Requirements

- 1,500 Calories per day just to be a couch-potato
  - 6,280,000 J
- Average human power consumption is then:
  - 6.28 MJ / 86,400 seconds ≈ 75 W
  - We're like light bulbs, constantly putting out heat
- Need more like 2,000 Cal for active lifestyle
  - 100 W of power

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## Energy from Food

**Nutrition Facts**
Serving Size 2/3 cup (52g)
Servings Per Container: 6

| Amount Per Serving | |
|---|---|
| **Calories** 180 Calories from Fat 60 | |
| | % Daily Value* |
| **Total Fat** 7g | 10% |
| Saturated Fat 1g | 4% |
| **Cholesterol** 0mg | 0% |
| **Sodium** 60mg | 3% |
| **Potassium** 230mg | 7% |
| **Total Carbohydrate** 28g | 9% |
| Dietary Fiber 7g | 27% |
| Sugars 12g | |
| **Protein** 10g (5g from soy) | |
| Vitamin A 0% • Vitamin C 2% | |
| Calcium 6% • Iron 15% | |

- Energy from fat, carbohydrates, protein
  - 9 Calories per gram for fat
  - 4 Calories per gram for carbohydrate
    - Fiber part doesn't count
  - 4 Calories per gram for protein
- Calculate 63 fat, 84 CH, 40 protein Cals
  - total is 187 Calories (180 is in the ballpark)
- 1 Calorie (kilo-calorie) is 4,184 J
  - 180 Cal = 753 kJ
  - set equal to $mgh$→ climb 1100 m vertically, assuming perfect efficiency

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## Not So Fast…

- Human body isn't 100% efficient: more like 25%
  - To put out 100 J of mechanical work, must eat 400 J
  - 180 Calorie candy bar only gets us 275 m, not 1100 m
- Maximum sustained power output (rowing, cycling) is about 150-200 W (for 70 kg person)
  - Consuming 600-800 W total, mostly as wasted heat
  - For 30 minutes → 800 J/s ×1800 s = 1.44 MJ = 343 Cal
- Can burst 700 W to 1000 W for < 30 sec
  - put out a full horsepower momentarily!

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## Most impressive display of human power

- The Gossamer Albatross crossed the English Channel in 1979, powered by Bryan Allen
  - Flight took 49 minutes, wiped Bryan out!
  - Sustained power out ~250 W


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## Aside: Human mass balance

- No nuclear power in our stomachs, so mass is conserved
  - mass in = mass out, assuming constant weight
  - burning Calories ≠ losing weight, not directly, anyway
- Breathing: an important element in mass balance
  - lose about a pound per day through nose/mouth!
  - breathe in $O_2$, breathe out $CO_2$: donating carbon to air
  - breathe in dry air, exhale moist air ($H_2O$ loss)
- Trees get their mass through inverse process

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## Human Energy Requirements Summarized

- We need chemical energy from food to run
  - Ultimate source is sun, long chain of events to twinkies
  - Constantly burn energy at rate of 75-100W
  - We spend energy at about 25% efficiency
  - Maximum sustained power is 150-200 W
    - actually burn 4 times this due to inefficiencies

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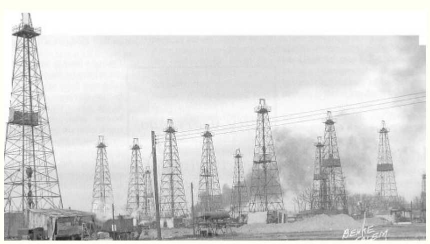
## Chemical Energy: Gasoline

- Gasoline and other combustibles are about as energy-rich as the fat we eat: 11 Calories/gram
  - Jet fuel, crude oil, kerosene, you name it



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## Fuel Efficiency

- Can calculate miles-per-gallon based on this info:
  - 30 m/s requires 50 kW to fight air drag (Lecture 8)
  - Go one mile in 54 seconds at this speed (67 m.p.h.)
  - 50 kW × 54 seconds = 2.68 MJ = 640 Calories
  - Assuming 30% engine efficiency (lots of heat), need 640 × 3.3 = 2100 Calories, or 192 grams of fuel
  - One gallon is 3.5 kg → ~20 miles-per-gallon!
- Improvement via aerodynamic drag reduction
  - also helps to go slower ($v^2$ dependence)

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## Energy Expenditure

- Per capita energy production in U.S. at > 10 kW
  - times 86,400 seconds per day is about 1 GJ per day!
    - 1,000,000,000 J per day per person
    - 250,000 Calories
  - Demands 23 kg (6 gallons) of gas per day per person
  - Or equivalently 38 kg (85 lb) of coal (at 6 Cal/gram)
- Most of this expenditure is industrial
  - Production of consumer goods
- Most residential/commercial energy used for heat

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## Solar Alternative

- Once fossil fuels are exhausted (coming soon!), need alternative production source
- Straight to solar may be smart
- 1370 $W/m^2$ incident on earth, 900 $W/m^2$ typically available to ground panel in full sun
  - take day/night and clouds into consideration: 200 $W/m^2$ average
  - silicon photovoltaics about 15% efficient → 30 $W/m^2$
- Each person would need 300 square meters of panels to cover *all* of our nation's energy needs
  - for just our electricity needs, would need square in desert 100 miles on a side→not impossible!

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## References and Assignments

- References
  - *Energy and the Environment*, Rinstinen & Kraushaar
  - *Energy*, by Gordon Aubrecht, Prentice Hall, 1995
  - *Energy: A Guidebook*, by Janet Ramage (British)
- Course on subject: Physics 12: Energy & Environ.
  - Spring Quarters (I'll teach Spring 2009)
- Midterm Reviews:
  - Wed. 4/30 6:30 PM to 8:20 PM; Pepper Canyon 122 (Tom)
  - Thu. 5/01 8:00 PM to 9:50 PM; Center 212 (Jim)
- Scantron form # 101864-PAR-L & No. 2 pencil
- Assignments:
  - HW for 5/09: Hewitt 7.E.42, 7.P.9, 6.R.16, 6.R.19, 6.R.22, 6.R.23, 6.E.8, 6.E.12, 6.E.43, 6.P.6, 6.P.12, 8.R.29, 8.E.47, 8.P.9

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