What is Energy?

- $\frac{1}{2} mv^2$
- $mgh$
- $P_{ext} \Delta V$
- $C_v \Delta T$
- $I^2R$
- $h\nu$
- $mc^2$

- a 2 trillion dollar per year global industry
How much energy do we use each year?
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\[ \approx 400,000,000,000,000,000,000,000 \text{ Joules/year} \]

\[ (116,000,000,000,000 \text{ Kilowatt-hours / year}) \]

1 Watt = 1 Joule used per second

**12.8 TeraWatts**

Global average = 2000 Watts per person

(24 hrs/day, 365 days/year)
The issues:
- Increasing energy demand by increasing population
- Associated CO$_2$ emissions and accumulation
- Depletion of petroleum and other resource reserves
- 1.6 billion people without access to electricity or other forms of “clean” energy
- Energy-related security challenges, including
  -- uneven distribution of resources (the Tenth Commandment does not apply!)
  -- vulnerability to threats and natural disasters
  -- geopolitical instability and tensions
  -- nuclear weapons proliferation
What are our options for meeting the world’s energy needs and reducing GHG emissions?

Hydropower: 0.7 ~ 2.0 TW … if we dam all remaining rivers on earth

Nuclear: ~ 8 TW … if we build and commission one new nuclear power plant every two days for the next 45 years

Wind: 2.1 TW … if we place windmills everywhere that the mean wind speed exceeds 5.1 m sec⁻¹ at 10 m above the ground

Biomass: 7 ~ 10 TW … if the entire arable land mass is used to grow crops for energy, not for food

Solar: 120,000 TW of radiant energy is intercepted by the Earth … this is 10,000 times the energy we actually use but it is dispersed and intermittent

Geothermal: 15 million exaJ stored energy in US alone (J. Tester) corresponds to 500,000 Terawatt-years … if technologically and economically feasible

Energy efficiency and conservation are essential — but improvements in efficiency are usually overwhelmed by increases in consumption (bigger cars, bigger homes, more computers, etc.)

Fusion? Solar collectors in space? And what about hydrogen???
The nature of “the energy problem”
(J.P. Holdren, AAAS Past President; Director, Woods Hole Research Center)

• Few people, other than energy specialists, are interested in Exajoules, or terawatts, or quads …

• We are interested in energy services:
  – comfortable rooms, cold beer soda, warm food, convenient transportation, web access 24/7, …

• But all of us are interested in
  – the state of the economy and our piece of it;
  – the state of the environment and our piece of it;
  – our personal and national security.

This translates into concern about energy choices if those put any of these values at risk.