

# What is Energy ?

- $\frac{1}{2} mv^2$
  - $mgh$
  - $P_{\text{ext}} \Delta V$
  - $C_v \Delta T$
  - $I^2R$
  - $h\nu$
  - $mc^2$
- 
- **a 2 trillion dollar per year global industry**



*How much energy do we use  
each year?*

---



# *How much energy do we use each year?*

---

**~ 400,000,000,000,000,000,000 Joules/year**

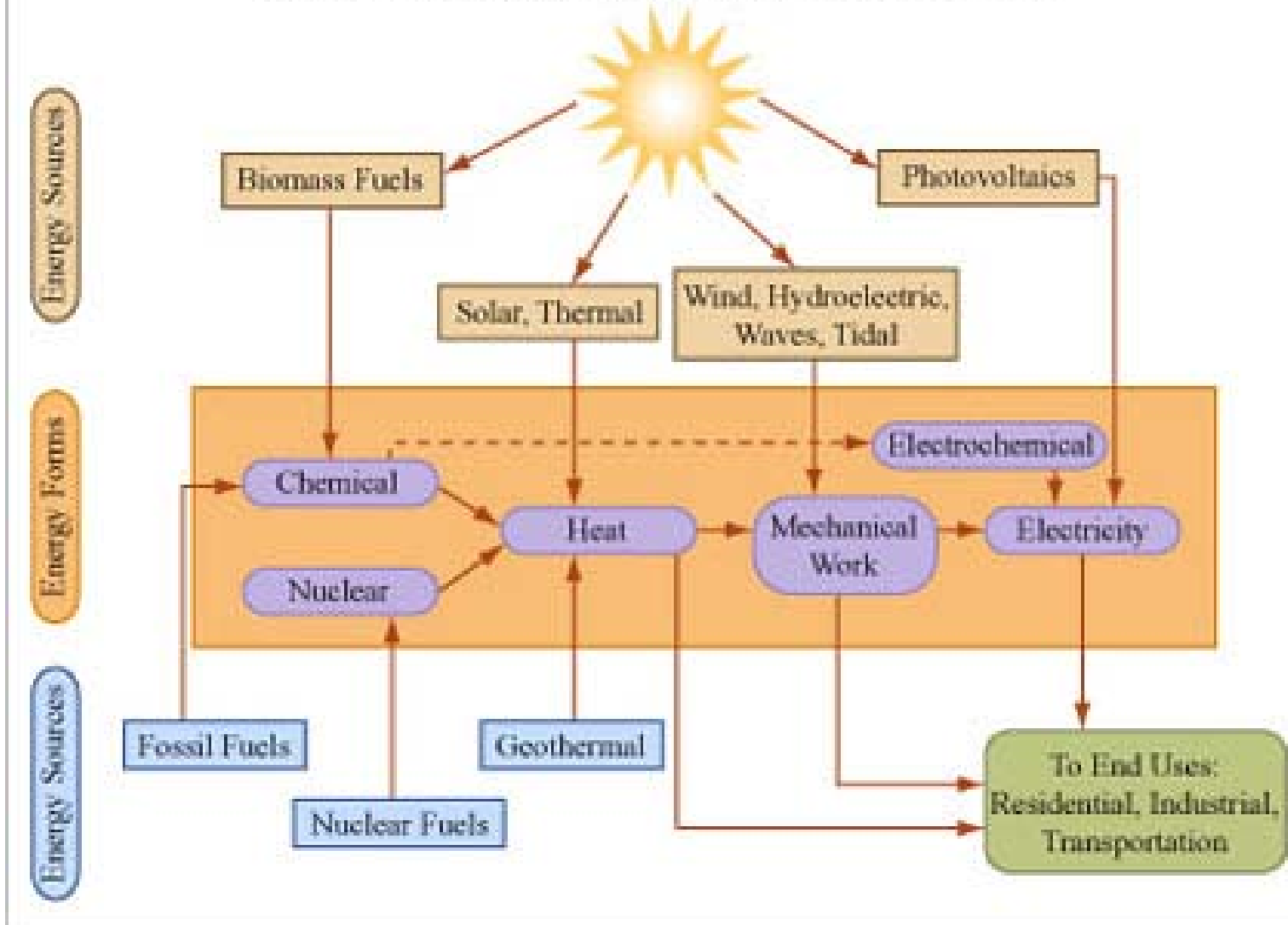
**(116,000,000,000,000 Kilowatt-hours / year)**

**1 Watt = 1 Joule used per second**

***12.8 TeraWatts***

**Global average = 2000 Watts per person  
(24 hrs/day, 365 days/year)**

# Energy Sources, Conversions and Use



(Image by MIT OCW)

# **The issues:**

- **Increasing energy demand by increasing population**
- **Associated CO<sub>2</sub> 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  $5.1 \text{ m sec}^{-1}$  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*

-- D. Nocera, *Dædalus*, Fall 2006, p. 112 – 115

**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.***