The energy challenge ... and your stake in it!

UNIVERSITY OF SOUTH CAROLINA

Andrew B. Greytak

You can make a difference

- Energy production & use
- Environmental impacts (including of energy)
- Water purification
- Management of chronic health issues & disease

The energy challenge

- Energy production & use

1 Btu = 1055 J

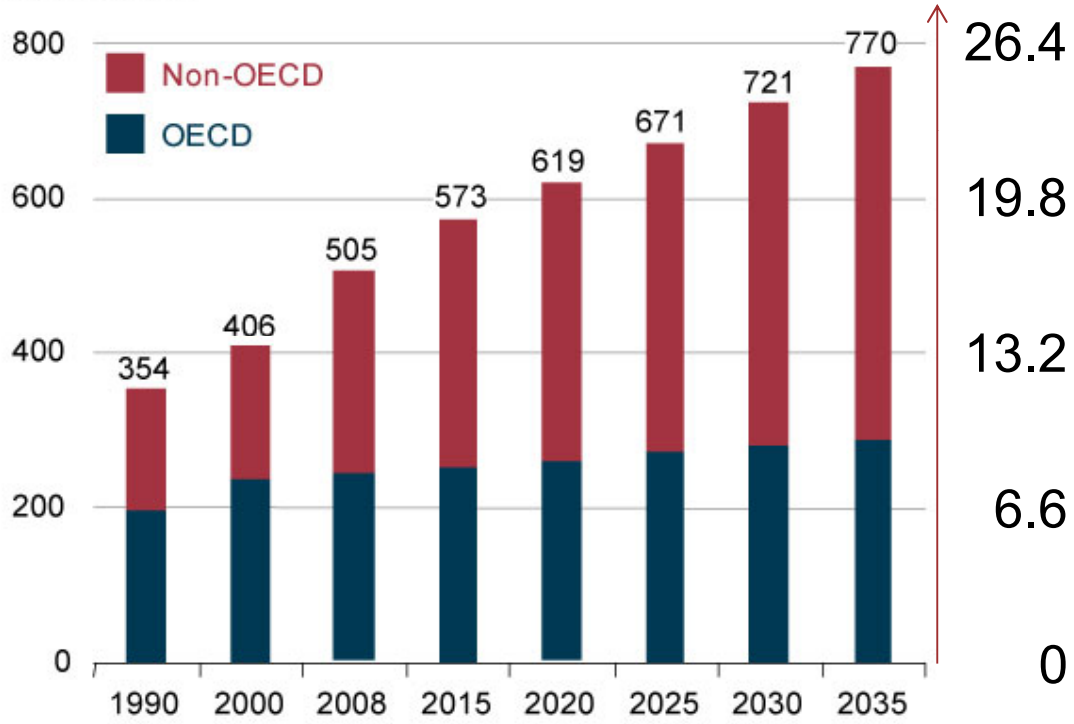
1 quadrillion = 10^{15} Btu = 1.055×10^{18} J

60×60×24×365 = 31,536,000 sec/year

100×10^{15} Btu /year = 3.3×10^{12} W

= 3.3 TW

Figure 1. World energy consumption, 1990-2035
(quadrillion Btu)



26.4 TW

19.8

13.2

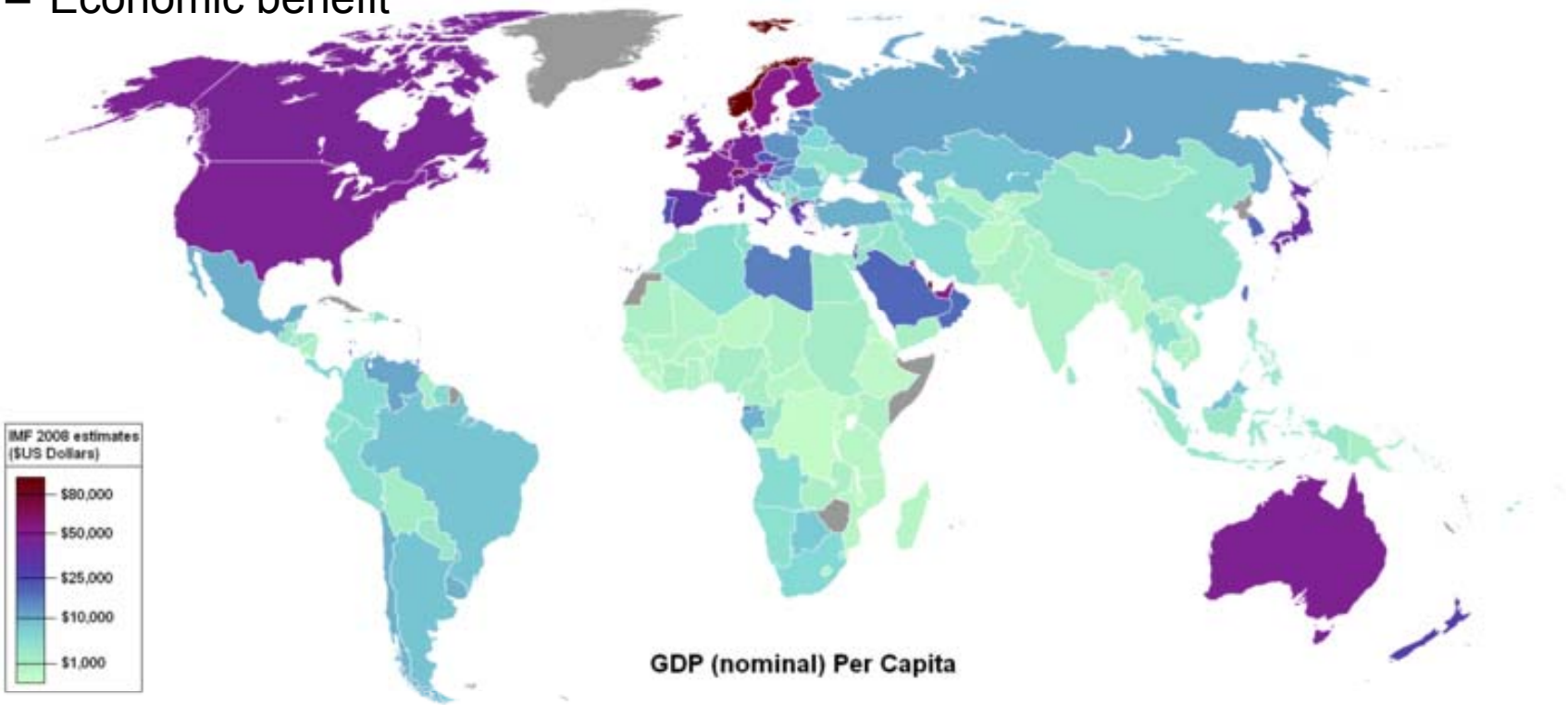
6.6

0

Source: US Energy Information Administration: www.eia.gov

The energy challenge

- Energy production & use
  - Economic benefit



Source: IMF, via Wikipedia

1 barrel of oil ≈ 6 GJ (ΔH_c)

Work equivalent: 3 GJ (50% efficiency)

Manual labor: ~75 W = 0.5 GJ / year

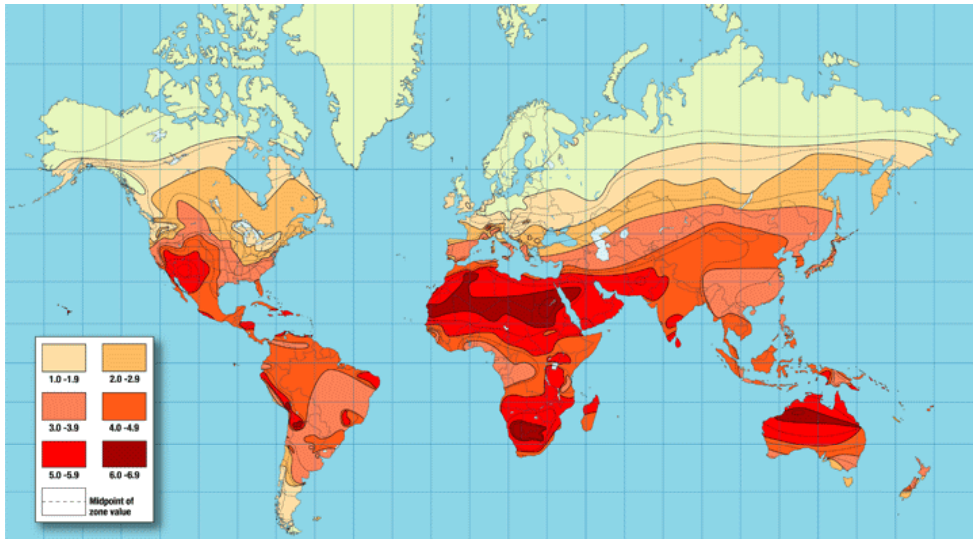
6 years of manual labor!

All that stuff

- Energy production & use
- Environmental impacts (including of energy)

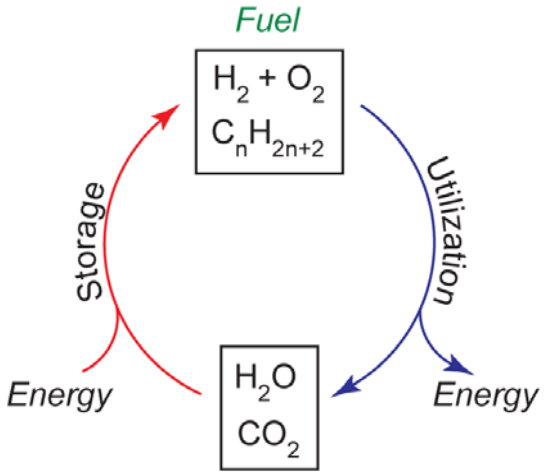
12 gigatons C = 44 gigatons CO_2 **per year**

The solar energy challenge



Solar energy is plentiful, but diffuse and intermittent

- Insolation: 9000x energy demand
- 200 W / m^2
  - 1 barrel of oil = 6 GJ
  - 1 acre = 4000 m^2
  - 1 b.o.e./day/acre at 10% eff.



$2H_2O \rightarrow 2H_2 + O_2$ Water splitting

$H_2 + CO_2 \rightarrow H_2O + CO$ Reverse Water-gas shift

$H_2 + CO \rightarrow C_nH_{2n+2}$ Fischer-Tropsch

Energy: Why you care

- Personal interest and environmental stewardship
- Scientific opportunities
  - Solar and nuclear energy materials
  - Energy storage chemistry: mobile and stationary
  - Efficient energy use
  - Reductive synthetic chemistry
  - Earth-abundant materials and catalysts
- Business opportunities
  - Changes in energy use
  - Export market
  - Demographic, thermodynamic constraints
  - Political and regulatory environment
- Educational opportunities
  - Educate: basic chemistry knowledge, scientific method … (as well as tomorrow's innovators)
  - Educate: to create an environment receptive to changes in practice

What you can do NOW

In the chemistry classroom

- Energy transactions in chemistry
  1. Thermal power vs. electrical power: 1 MW wind turbine replaces several MW of thermal (fossil or nuclear) energy

     $\eta < 1 - T_c/T_h$

  2. ΔG = work required *at* constant temperature
     ΔH = energy required to *maintain* constant temperature

$$\begin{array}{rcll} 2H_2O & \leftrightarrow & O_2 + 4H^+ + 4e^- & E_{ox} = 1.23 - 0.059\times pH \text{ (V vs. NHE)} \\ 4H^+ + 4\,e^- & \leftrightarrow & 2H_2 & E_{red} = 0 - 0.059\times pH \\ \hline 2H_2O & \leftrightarrow & 2H_2 + O_2 & E_{rxn} = -1.23\ V = -\Delta G°/nF \end{array}$$

- Catalysis
- Challenge yourself

What you can do NOW

In the lab

- Become an expert in your field … and in some techniques
- You are not looking to be "just" a set of hands

What you can do NOW

More broadly

- Science … Check the hotsheets!
  - C & E News
  - NYT Science … Tuesdays … also business
  - Nature – Wednesday afternoons
  - Science – Thursday nights

What you can do NOW

More broadly

- Business
  - Forums on campus?
  - Apply your chemical common sense – no H_2 economy without H_2
- Where to get info
  - Energy Information Administration
  - Google energy use model
  - World Bank database of economic information
  - International initiatives: www.cleanenergyministerial.org
  - NIST Chemistry WebBook