SEBS Honors Seminar: State of the Earth
A Brief Tour of the Global Energy System – Reference Sheet
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<u>Questions addressed in class</u>

- What is energy?
- What do we (as individuals, as a nation, as a planetary civilization) use energy for?
- What are the proximate sources of the energy we use?
- What are the ultimate sources of the energy we use? How does the human energy system fit into the natural energy system?
- How has human energy use changed over history?
- Is the present energy system sustainable? What are the major risks associated with it?
- What alternatives are there to the present energy system? What are the barriers to energy system transformation?
- What sorts of policies can overcome these barriers?

<u>SI Energy and Power Units</u>

Energy: 1 Joule (J) = 1 kg m/s^2 *(the amount of energy in a 2 kg mass moving 1 m/s)*
Power: 1 Watt (W) = 1 J/s
Energy: 1 Watt•hour (Wh) = 1 W × 1 hour = 1 W × 3600 s = 3600 J
1 W•year = 8,766 Wh

<u>SI Electrical Units</u>

Current: 1 Ampere (A) – *a fundamental unit; practically defined as 1 coulomb/second*
Electrical potential: 1 Volt (V) = 1 W/A = 1 J/C
so 1 A flowing down a 1 V potential gradient will acquire 1 J of energy per second
Resistance: 1 Ohm (Ω) = 1 V/A
Power dissipated into heat is given by voltage x current or by $current^2$ x resistance

So: on a 120 V circuit (as in the U.S.), a 1,000 W device (e.g., a microwave) will draw a current of 8.3 A.

<u>SI Prefixes</u>

milli (m) = 10^{-3}
kilo (k) = 10^{3}
mega (M) = 10^{6}
giga (G) = 10^{9}
tera (T) = 10^{12}
peta (P) = 10^{15}
exa (E) = 10^{18}
zetta (Z) = 10^{21}

<u>Non-SI Units that appear</u>

1 **calorie** = 4.184 J, *energy required to heat 1 g of water by 1°C*
[note that 1 food Calorie = 1 kcal]
1 **British Thermal Unit (BTU)** = 252 cal = 1.055 kJ
energy required to heat 1 lb (454 g) of water by 1°F (0.56°C)
1 **Quad** = 1 quadrillion BTU = 1.055 EJ (~293 TWh)
1 **tonne oil equivalent (toe)** = 41.9 GJ = 11.6 MWh

Handy Reference Numbers

World annual primary exergy consumption = 474 EJ = 132,000 TWh

Of which, ~35% oil, ~29% coal, ~22% natural gas, ~12% biomass, ~7% nuclear, ~3% renewable

World annual final exergy demand = 325 EJ =91,000 TWh

Civilizational primary power supply = 474 EJ/year = 15 TW

Civilization final power demand = 325 EJ/year = 10 TW

Annual CO_2 emissions = 32 Gt CO_2 = 32 Pg CO_2

Solar cross-sectional energy flux at 1 AU = 1,360 W/m^2

Solar flux distributed over the surface area of the Earth = 340 W/m^2 = 174,000 TW

Solar flux making it to the surface = 184 W/m^2 = 94,000 TW

Geothermal heat flux = 86 mW/m^2 = 44 TW

Per Field et al. (1998)

Net primary productivity (terrestrial + marine) = 105 Pg C/yr

Terrestrial net primary productivity = 56 Pg C/yr

Biomass energy density ~ 2 kWh/kg C

Burial of net primary productivity ~ 0.1%

Transformation of buried organic matter into fossil fuels ~ 0.05%

Human appropriation of net primary productivity ~ 20% (14-26%)

Per Swart & Weaver (2012)

Total conventional oil resource base ~ 23 Gt C

Total unconventional oil resource base ~ 35 Gt C

Total conventional gas resource base ~ 22 Gt C

Total unconventional gas resource bas ~ 190 Gt C

Total coal resource base ~ 980 Gt C

Total fossil fuel resource base ~ 1,250 Gt C

Requried Readings

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Useful web sites

Energy Information Administration: http://www.eia.gov/
International Energy Agency: http://www.iea.gov/
New Jersey State Energy Master Plan: http://nj.gov/emp/
Bloomberg New Energy Finance: http://bnef.com/
Stanford Exergy Flow Charts: http://gcep.stanford.edu/research/exergycharts.html

Other References

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Zhu, Xin-Guang, Stephen P Long, and Donald R Ort. "What Is the Maximum Efficiency with Which Photosynthesis Can Convert Solar Energy into Biomass?" *Current Opinion in Biotechnology* 19, no. 2 (April 2008): 153–159.