Discussion Topics

During the Friday class I will assign a discussion topic taken from the textbook chapter that will be discussed during the Wed. class of the follow week. A student discussion leader will be assigned to lead the discussion.

Topic for Ch. 2: (from the textbook)

"If you go to a high altitude, the temperature of the air is usually lower. What do you think that does to the sound velocity?"

Provisionally, students will be assigned in alphabetical order of last name. This order and topic can be negotiated. However, all Students must lead 1 Wed. discussion section during the semester.

Multiple Choice Questions

The quizzes on Fridays of each week will be based on the multiple choice questions at the end of each chapter

Essay Assignment
Due 01-14-11

Number 2, at the end of chapter 1

2. Describe in a page what aspects of this chapter you think are most important. What would you tell your friends, parents, or children are the key points? Which points are important for future Presidents or just good citizens.

Enrollment in HONR 29900 as 01/10/2011

1 Gilfix, Jake M.
2 Grace, John S.
3 Mc Iver, Kara B.
4 McClung, Elizabeth B.
5 Miller, Jakob A.
6 Oliver, Scott A.
7 Petrie, Angela M.
8 Shaxted, Andrew P.
9 Smith, Patrick J.
10 Todd, Aaron J.

Elementary Dimensional Analysis and Units

Length (distance): l, e.g. inches, feet, meter, miles, nanometers, light-years

Time: t, e.g. seconds, minutes, hours, years, nanoseconds

Mass: m, e.g. grams, pounds, kilograms, tons

Velocity (speed): s = l/t, e.g. feet/second miles/hour, kilometers/hour

Acceleration: a or g = s/t = $l/(t^2)$, e.g. feet per second squared

Force: (m)(a) or (m)(g), e.g. newtons, pounds, dynes

Work: = Energy = Heat: (m)(a)(l) = (m)(g)(l) = $(m)(s^2)/2$, e.g. joules, ergs, BTU, watt-hours, electron volts, Calories

Charge: = C, e.g. coulombs; electronic charge, $q = 1.6 \times 10^{-19}$ C

Electric current: q/t, e.g. amperes

Power: Heat/t, Work/t, Energy/t, e.g. watts, horsepower, Calories/second

Energy is the ability to do work. (Work is defined numerically as the magnitude of a force multiplied by the amount the force moves in the direction of the force.)

Alternative definition for Energy: anything that can be turned into heat.[2]

Heat is something that raises the temperature of a material, as measured by a thermometer. (It will turn out that heat is actually the microscopic energy of motion of vibrating molecules.)

Kinetic energy

The kinetic energy equation:

$$E = \frac{1}{2} m v^2$$

To use this equation, v must be in meters per second, and m in kilograms, and the energy will be in joules. To convert energy to Calories, divide by 4000. Here are useful (approximate) conversions:[10]

Energy is "conserved"

Calorie

The unit you might feel most familiar with is the Calorie. That's the famous "food calorie" used in dieting. It is the one that appears on the labels of food packages. A chocolate chip (just the chip, not the whole cookie) contains about 3 Calories. A 12-ounce can of Coca Cola™ has about 150 Calories.

Beware: if you studied chemistry or physics, you may have learned the unit called the calorie. That is different from the Calorie! A food Calorie (usually capitalized) is 1000 little physics calories. That is a terrible convention, but it is not my fault. Physicists like to refer to food Calories as kilocalories. Food labels in Europe and Asia frequently say "kilocalories", but not in the U.S. So 1 Cal = 1000 cal = 1 kilocalorie.[3]

Kilowatt-hour

Another famous unit of energy is the "kilowatt-hour", abbreviated kWh. (The W is capitalized, some say, because it stands for the last name of James Watt, but that doesn't explain why we don't capitalize it in the middle of the word kilowatt.) What makes this unit famous is that we buy electricity from the power company in kWh. That's what the meter outside the house measures. One kWh costs between 5 and 25 cents, depending on where you live. (Electric prices vary much more than gasoline prices.) We'll assume the average price of 10 cents per kWh in this text.

Wh = 1 Calorie (approximately)
1kWh = 1000 Calories

Joule. Physicists like to the use energy unit called the joule (named after James Joule) because it makes their equations look simpler. There are about 4000 joules in a Calorie, 3600 in a Wh, 3.6 million in a kWh.

The energy table below shows the approximate energies in various substances. I think you'll find that this table is one of the most interesting ones in this entire textbook. It is full of surprises. The most interesting column is the last one.

Table of Common Energy Units

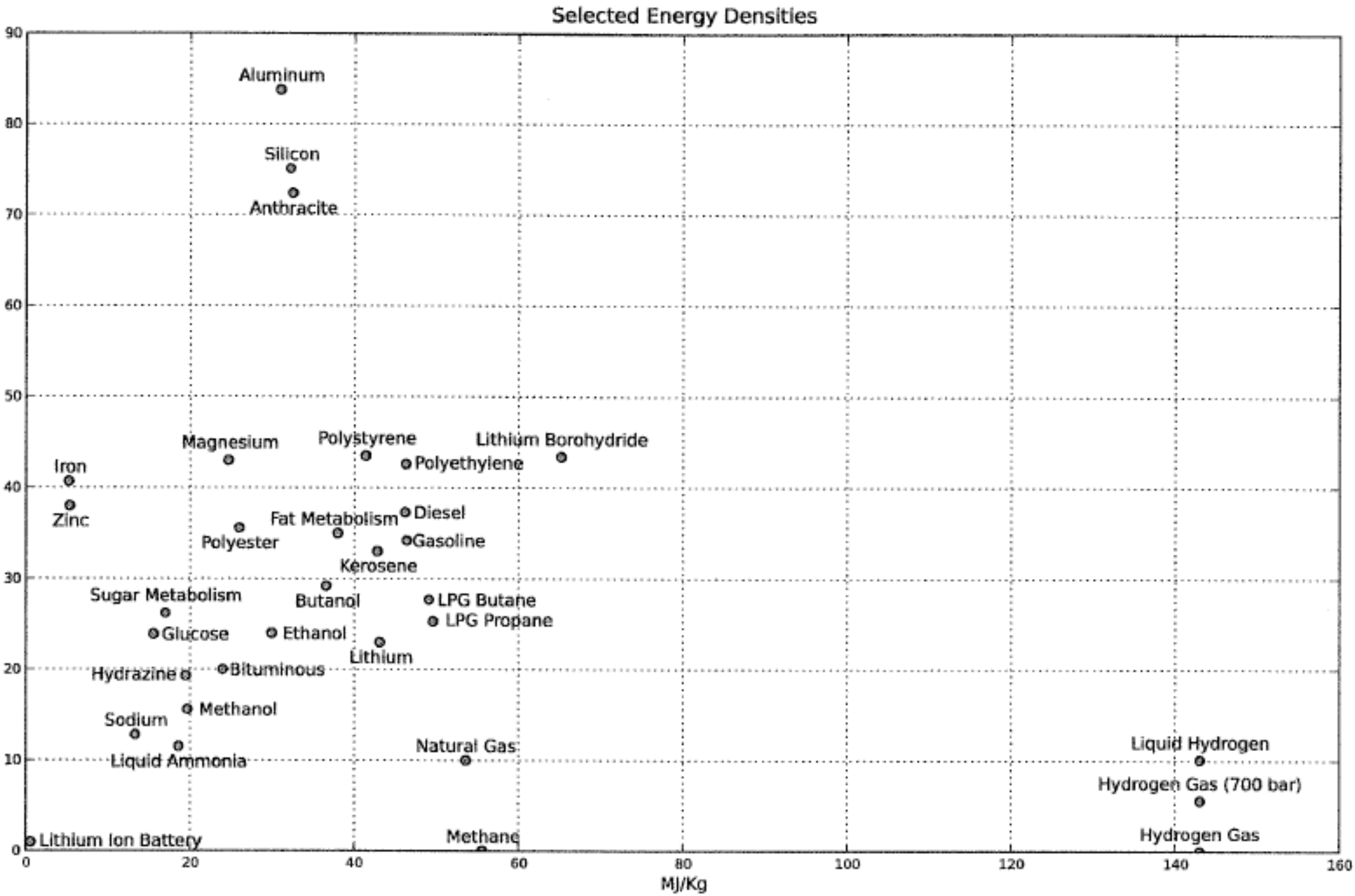
Note: the symbol "≈" means "approximately equal to"

energy unit	definition and equivalent
calorie (lowercase)	heats 1 gram of water by 1 C
Calorie (capitalized), the food calorie, also called kilocalorie	heats 1 kg of water by 1 C 1 Calorie = 4182 joules ≈ 4 kJ
joule	1/4182 Calories ≈ Energy to lift 1 kg by 10 cm ≈ Energy to lift 1 lb by 9 in
kilojoule	1000 joules = ¼ Calorie
megajoule	1000 kilojoules = 10^6 joules costs about 5 cents from electric utility
kWh (kilowatt-hour)	861 Calories ≈ 1000 Calories = 3.6 megajoules costs 10 cents from electric utility
BTU	British Thermal Unit 1 BTU = 1055 joules ≈ 1 kJ = ¼ Calorie
Quad	A quadrillion BTUs = 10^{15} BTU ≈ 10^{18} J Total US energy use ≈ 100 quads per year; total world use is ≈ 400 quads per year

Energy per gram

object	Calories (or Watt-hours)	joules	compared to TNT
bullet (at sound speed, 1000 ft per sec)	0.01	40	0.015
battery (auto)	.03	125	0.05
battery (rechargeable computer)	0.1	400	0.15
battery (alkaline flashlight)	0.15	600	0.23
TNT (the explosive trinitrotoluene)	0.65	2,723	1
modern High Explosive (PETN)	1	4200	1.6
chocolate chip cookies	5	21,000	8
coal	6	27,000	10
butter	7	29,000	11
alcohol (ethanol)	6	27,000	10
gasoline	10	42,000	15
natural gas (methane, CH_4)	13	54,000	20
hydrogen gas or liquid (H_2)	26	110,000	40
asteroid or meteor (30 km/sec)	100	450,000	165
uranium-235	20 million	82 billion	30 million

Note: many numbers in this table have been rounded off.


Selected Energy Densities
Aluminum
Silicon
Anthracite
Magnesium
Polystyrene
Lithium Borohydride
Iron
Polyethylene
Zinc
Fat Metabolism
Diesel
Polyester
Gasoline
Kerosene
Sugar Metabolism
Butanol
LPG Butane
LPG Propane
Glucose
Ethanol
Lithium
Hydrazine
Bituminous
Methanol
Sodium
Liquid Ammonia
Natural Gas
Liquid Hydrogen
Hydrogen Gas (700 bar)
Lithium Ion Battery
Methane
Hydrogen Gas
0
10
20
30
40
50
60
70
80
90
100
120
140
160
MJ/Kg

fuel	market cost	cost per kWh (1000 Cal)	cost if converted to electricity
coal	$40 per ton	0.4¢	1.2¢
natural gas	$10 per million cubic feet	3¢	9¢
gasoline	$3 per gallon	9¢	27¢
electricity	$0.10 per kWh	10¢	10¢
car battery	$50 to buy battery	21¢	21¢
computer battery	$100 to buy battery	$4.00	$4.00
AAA battery	$1.50 per battery	$1000.00	$1000.00

Discussion topics for Fri class

How does the author get the number of $4.00/kWh as the cost of energy For a computer battery?

Computer battery: energy-60 Wh; maximum number of recharges – 400

Power

power = energy/time

1 Watt = 1 W = 1 watt = 1 joule per second
1 kW = 1 kilowatt = 1000 joules per second

1 horsepower ≈ 1 kilowatt

Table of Power Examples

value	equivalent	example of that much power use
1 watt	1 joule per second	flashlight
100 watts		bright light bulb; heat from a sitting human
1 horsepower (1 hp)	≈ 1 kilowatt[A]	typical horse (for extended time) human running fast up flight of stairs
1 kilowatt (1 kW)	≈ 1 hp[B]	small house (not including heat); power in 1 square meter of sunlight
100 horsepower	≈ 100 kW[C]	small automobile
1 megawatt (MW)	1 million (10^6) watts	electric power for a small town
45 megawatts		747 airplane; small power plant
1 gigawatt = 1 GW	1 billion (10^9 watts	large coal, gas, or nuclear power plant
400 gigawatt = 0.4 terawatts		average electric power use US
2 terawatts	= 2 x10^{12} watts	average electric power for World

[A]more precise value: 1 hp = 746 watts
[B]more precise value: 1 kW = 1.3 hp
[C]more precise value: 100 hp = 74.6 kW

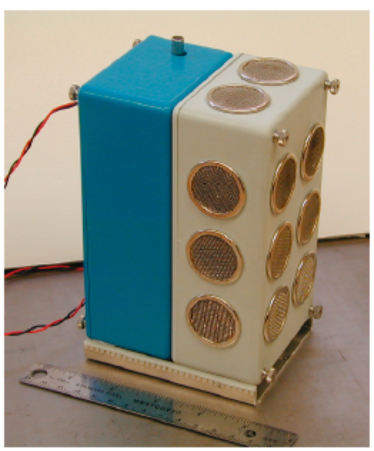
Hydrogen vs. gasoline -- and the fuel cell

Remember this: Compared to gasoline, **liquid hydrogen** has

3 x *more* energy per gram (or per lb)
3 x *less* energy per gallon (or per liter)

1 kilogram of hydrogen ≈ 1 gallon of gasoline

Compared to gasoline, compressed gas hydrogen has **6 x *less* energy per gallon (or per liter)**



Fuel cell developed by NASA. Hydrogen gas enters through the inlet on the top. Air enters though some of the circular openings, and carbon dioxide leaves through the others. The electric power comes from the wires in the back.

Here is a summary of the important numbers for solar power:

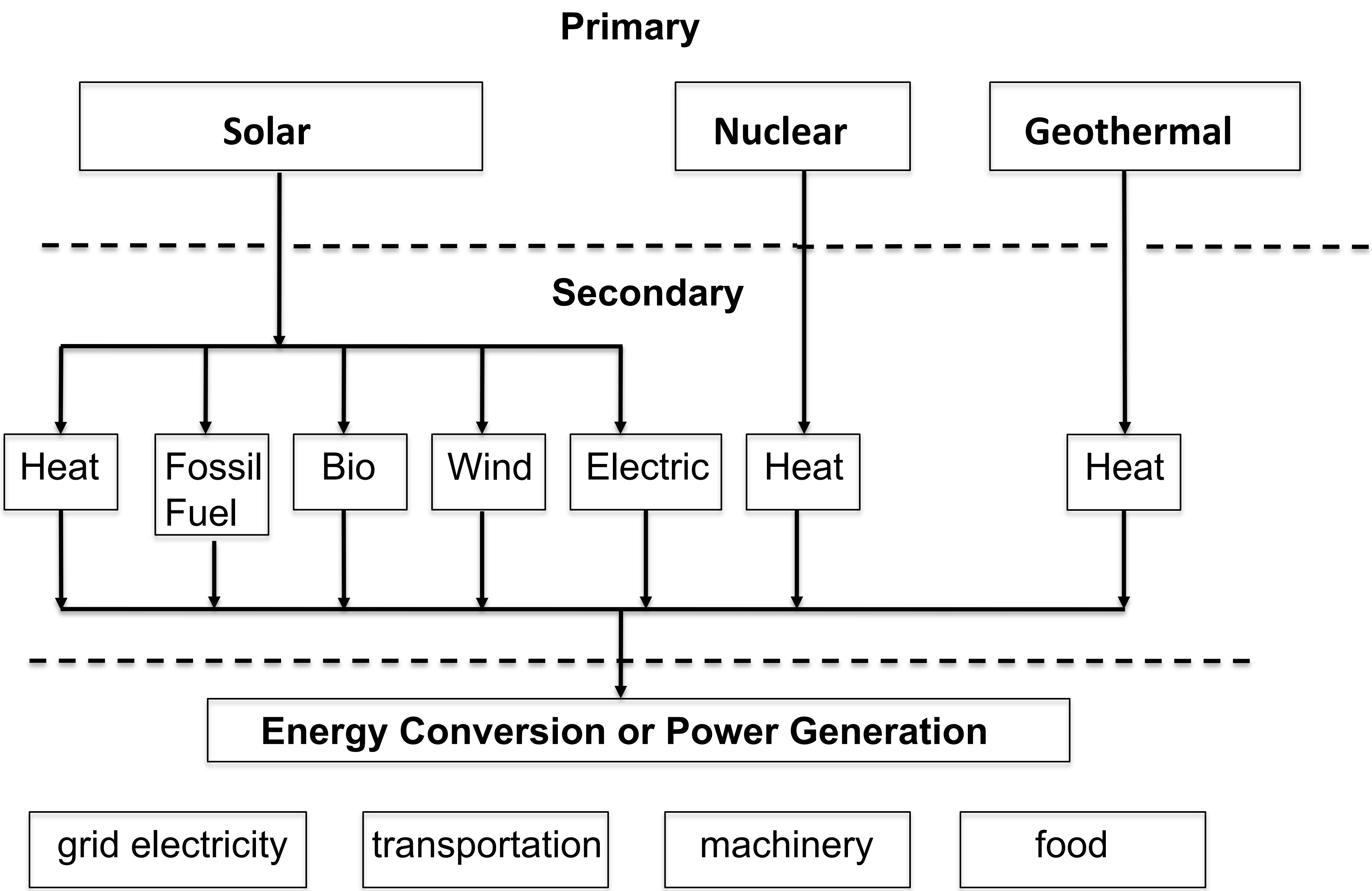
1 square meter	1 kilowatt of sunlight
	150 – 400 watts electric using solar cells
1 square kilometer	1 Gigawatt of sunlight
	150 – 400 Megawatts electric

So why isn't Arizona covered with solar cells? Because these 15% cells cost \$10/watt!! A 1 km^2 solar farm would produce an average daily power of only 100 million watts and not 150 million watts (the cell power at noon on a clear day). The *total cell cost only* would be \$10/watt x 100 million watts = \$1 billion

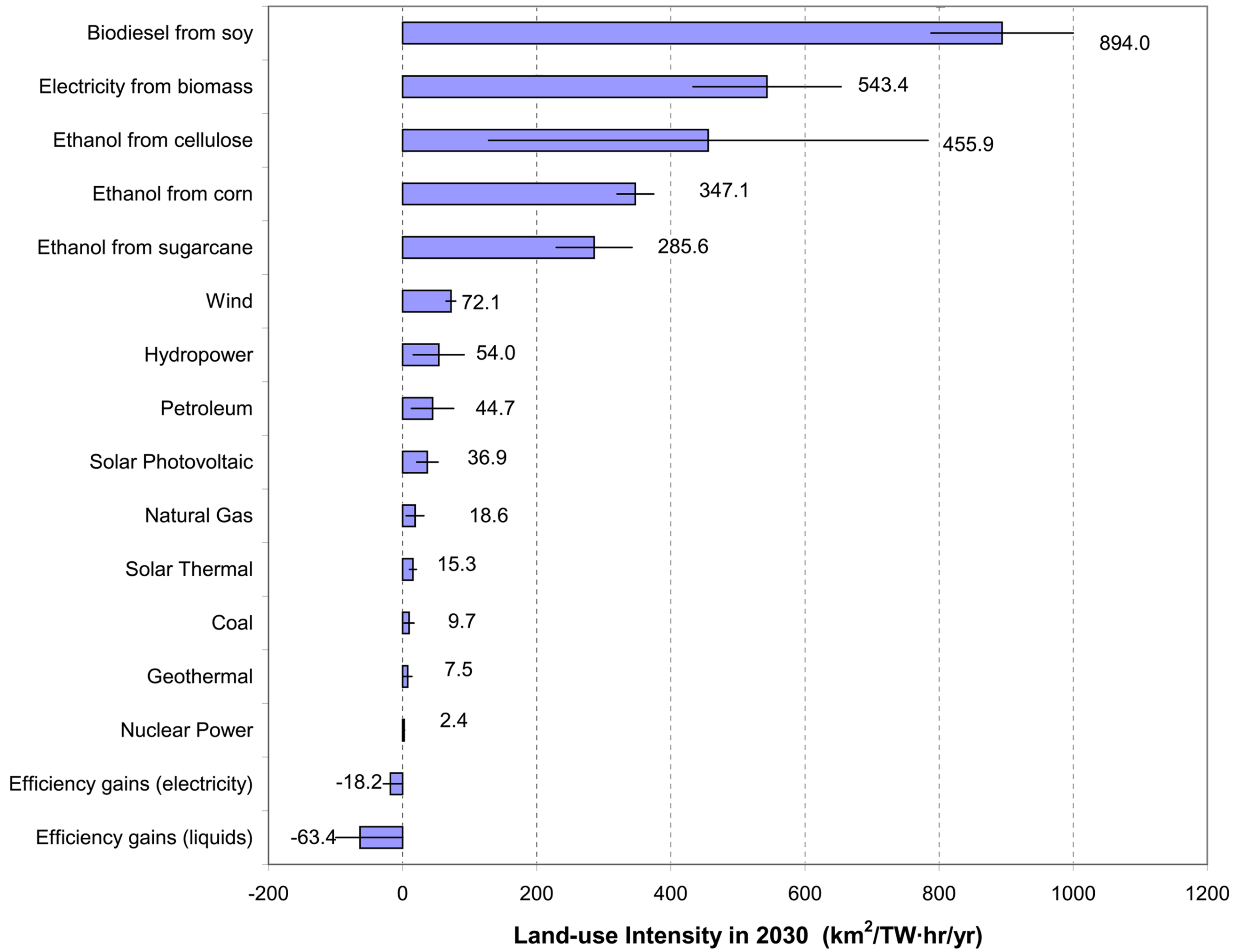
Okay, so we run it for "free" for 20 years. Assuming six hours of useful solar power per day, there are 43,800 hours of sun power in 20 years with an average daily power production of 100 megawatts/km^2. This produces 4.36 trillion Wh of energy = 4.36 billion kWh. This energy cost \$1 billion to make or \$0.23/kWh. To get a real number you must add to this cost: power conditioning, storage, maintenance, etc. etc. Guess? \$0.60/kWh.

The capital cost of coal fired electric utilities is about \$1/watt. The cost of coal to deliver electricity to the wall plug = \$0.012/kWh. Electricity cost = \$0.10/kWh

Sources/Forms of Energy/Power



1TW-h = 3 TBTU = 0.00003 US annual energy consumption; US land area = 10^7 km^2; at 500 km^2/TW-h/yr, we need ½ US land area to get 30% US energy consumption



http://www.plosone.org/article/info:doi/10.1371/journal.pone.0006802

Interesting Tidbits

Solar-powered automobiles and airplanes

Gee whiz, but not very practical, since areal power density is small, 1kW/m^2; and how do you store solar power?

Wind power

Getting better but how do you store wind power?

Human power

Our bodies “burn” about 100 watts at rest, if we bike, we burn about 200 watts

Smart rocks and brilliant pebbles

Kinetic energy, $E = mv^2/2$; therefore high v and modest mass has lots of E
Since power = E/t, and power produces explosions, if t is small power is big

The demise of the dinosaurs

If m is huge and v is very large great damage is done to a planet

The 2009 Tesla Roadster EV

Why E.Vs currently suck: the strange case of the Tesla

The Tesla Roadster, which currently costs $134,000 to make, uses enough computer batteries to store 153 kWh of electrical energy. Assume that to drive a 245 mi. trip you will need 125 kWhr of battery energy. If these batteries cost $4.00/kWh (retail) each trip would cost $500 or about $2/mile! Plus after about 400 fully depleted recharges the battery no longer functions (hence the $4.00/kWh number, i.e. initial cost divided by the capacity, kWh, times the number of recharges available)

You can get a high performance ICE powered Porsche for this kind of money. It gets 20 miles per gallon of gasoline. Let's assume that in the near future gasoline cost $4.00 per gallon. We now compare owning a Porsche to the Tesla. We divide $4.00/gallon by 20 miles/gallon (using our dimensional analysis tool) and we get $0.2/mile!

So, why would anyone buy this car?

What if we could use batteries that cost only $1.00/kWh to use, i.e. raise the energy density and increase the number of recharges. Let's make a car that only uses 100kWh of electricity per 200 mile trip. This works out to only $100/200 mile trip or about $0.50/mi. Elon Musk thinks he can make a sedan Tesla that can do this and sell it for $50K! What do you think?

1. “Smart Rocks” are considered for
   ( ) geologic dating
   ( ) ballistic missile defense
   ( ) nuclear power
   ( ) solar power

2. One watt is equivalent to:
   ( ) one joule/sec
   ( ) one coulomb/sec
   ( ) one calorie/sec
   ( ) one horsepower

3. The asteroid that killed the dinosaurs exploded because
   ( ) it was made of explosive material
   ( ) it was made out of U-235
   ( ) it got very hot from the impact
   ( ) it didn’t explode. It knocked the Earth out of its normal orbit.

4. Kinetic energy can be measured in:
   ( ) watts
   ( ) calories
   ( ) grams
   ( ) amperes

5. Which of the following statements is true?
   ( ) energy is measured in joules and power is measured in calories
   ( ) power is energy divided by time
   ( ) batteries release energy but TNT releases power
   ( ) power signifies a very large value of energy
   ( ) all of the above

6. Next to each of these mark whether it is a unit of energy (E) or power (P)

horsepower	_____
kilowatt-hour	_____
watt	_____
calorie	_____

7. Hybrid vehicles run on:
   ( ) electric and solar power
   ( ) solar power and gasoline
   ( ) electric power and gasoline
   ( ) nuclear power and gasoline

8. What is the main reason that hydrogen-driven automobiles have not replaced gasoline ones?
   ( ) Hydrogen is too expensive
   ( ) Hydrogen is too difficult to store in an automobile
   ( ) Hydrogen is radioactive, and the public fears it
   ( ) Hydrogen mixed with air is explosive

9. Which is not a unit of energy?
   ( ) kWh
   ( ) Calorie
   ( ) joule
   ( ) watt

10. Compared to an equal weight of gasoline, uranium-235 can deliver energy that is greater by a factor of (pick the closest)
   ( ) 2200
   ( ) 25,000
   ( ) one million
   ( ) one billion

11. Which of the following contains the most energ per gram?
   ( ) TNT
   ( ) chocolate chip cookies
   ( ) battery
   ( ) uranium

12. Compare the energy in a kilogram of gasoline t that in a kilogram of flashlight batteries:
   ( ) the gasoline has about 400 times as much energy
   ( ) the gasoline has about 10 times as much energy
   ( ) the gasoline has about 70 times less energy
   ( ) they cannot be honestly compared, since on stores power and the other stores energy

13. The kinetic energy of a bullet, per gram, is (within a factor of 2)
   ( ) about the same as the energy released from one gram of TNT
   ( ) about the same as the kinetic energy in a typical one gram meteor
   ( ) about the same as the energy released by one gram of chocolate chip cookies
   ( ) none of the above