ENGS-171 – INDUSTRIAL ECOLOGY- DARTMOUTH COLLEGE

SOME USEFUL NUMBERS

Compiled by Benoit Cushman-Roisin

ENERGY PRODUCTION

1 **barrel of oil** weighs 106 kg.
1 **barrel of oil** holds 42 US gallons = 0.159 m^3 = 5.8 x 10^6 Btu = 6.12 x 10^9 J
10^6 ft^3 (28300 m^3) of **natural gas** is equivalent to 172 barrels of **crude oil**

Combustion – Incineration:

1 kg of **wood** → 17.6 MJ
1 cord of seasoned **firewood** (8'x 4'x 4') → 20 million BTUs = 21,100 MJ
(*Note*: A typical woodstove is only 60-70% efficient;
the rest of the heat goes out the chimney)
1 kg of **wood pellets** → 19.1 MJ
1 kg of **paper** → 20 MJ
Domestic **compost** → 9,000 to 10,000 BTUs/lb = 22 MJ/kg in form of heat
1 kg of **municipal garbage** → 12 MJ
1 kg of **polystyrene** → 40 MJ
1 kg of **dung** → 15 MJ
1 kg of **coal** → 23 to 42 MJ
1 kg of **bitumous coal** → 30 MJ
1kg of **charcoal** → 28.8 MJ
1 kg of **crude oil** → 43 MJ (or 117.2 MJ/gallon)
1 kg of **diesel** → 50 MJ
1 L of **diesel** or **heating oil** → 38.8 MJ
1 kg of **gasoline** → 47 to 49 MJ, or 31 MJ/L on volume basis
1 kg of **natural gas** → 43 MJ
1 gallon of **liquified propane** → 91,500 BTUs = 96.5 MJ, or 25.5 MJ/L
1 kg of **liquified natural gas** → 35 MJ
1 kg of **ethanol** → 29.8 MJ
1 kg of **methanol** → 20 MJ
1kg of **hydrogen** → 142.5 MJ
1 L of **liquified hydrogen** → 8.4 MJ
1 ton of **Uranium-235** (^{235}U) = 70 x 10^{12} BTUs = 7.4 x 10^{16} J

Wood to ethanol conversion: 1 kg of **wood** yields 0.33 kg of **ethanol**.

WATER, OIL & ENERGY CONSUMPTION

Average **fuel efficiency**:
personal vehicles in the USA: 24 mpg (9.8 L/100 km)
diesel freight trucks in the USA: 8.5 mpg (L/100 km)

Automobile at 55 mph (90 km/h) consumes 28 kW of power

Energy used in **transportation of freight**:

Airplanes	31,600 BTUs/ton-mile	= 20.7 MJ/ton-km
Trucks	4,400 BTUs/ton-mile	= 2.9 MJ/ton-km
Trains	371 BTUs/ton-mile	= 0.24 MJ/ton-km
Trains	1 gallon of diesel to move 2000 lbs over 420 miles	
Ships	411 BTUs/ton-mile	= 0.27 MJ/ton-km

Energy used in **transportation of people**:

Private airplane	9,600 BTUs/passenger-mile	= 6.3 MJ/passenger-km
Air carrier	3,600 BTUs/passenger-mile	= 2.4 MJ/passenger-km
SUV, light truck	5,900 BTUs/passenger-mile	= 3.9 MJ/passenger-km
Automobile	3,600 BTUs/passenger-mile	= 2.4 MJ/passenger-km
Motorcycle	1,900 BTUs/passenger-mile	= 1.2 MJ/passenger-km
Motor coach (long-distance bus)		0.191 MJ/passenger-km
Mass transit	3,000 BTUs/passenger-mile	= 2.0 MJ/passenger-km

To produce 1 kg of **plastics** takes 2 kg of petroleum.

To produce a 2-gram **computer chip**
takes 32 kg of water, 1.6 kg of fossil fuel, 700 g of elemental gases (mainly N_2), and 72 g of chemicals
takes 41.2 MJ
A 2-gram computer chip consumes 15.0 MJ during its lifetime.

1 Liter of **gasoline** → 2 kg of CO_2
1 kg of **gasoline** → 3.343 kg of CO_2, 0.100 kg of CO and 0.3 g of particulate matter
1 kg of **diesel** → 3.460 kg of CO_2, 0.022 kg of CO and 0.34 g of particulate matter
1 gallon of **diesel** → 22.38 lbs of CO_2
1 kWh of **electricity** from a typical fossil-fuel power plant → 0.689 kg of CO_2
1 ton of **cement** → 1 ton of CO_2

Humans & Food:

Human person, sitting = 60 watts = 860 calories/minute = 0.86 Calorie/minute
Human person, running = 1000 watts = 14,340 calories/minute = 14.34 Calorie/minute

A **human** person requires a daily food intake of

2000 Calories = 2000 kcal = 2 x 10^6 calories = 7,940 BTUs = 8370 kJ

This is equivalent to a power consumption of about 100 watts/person

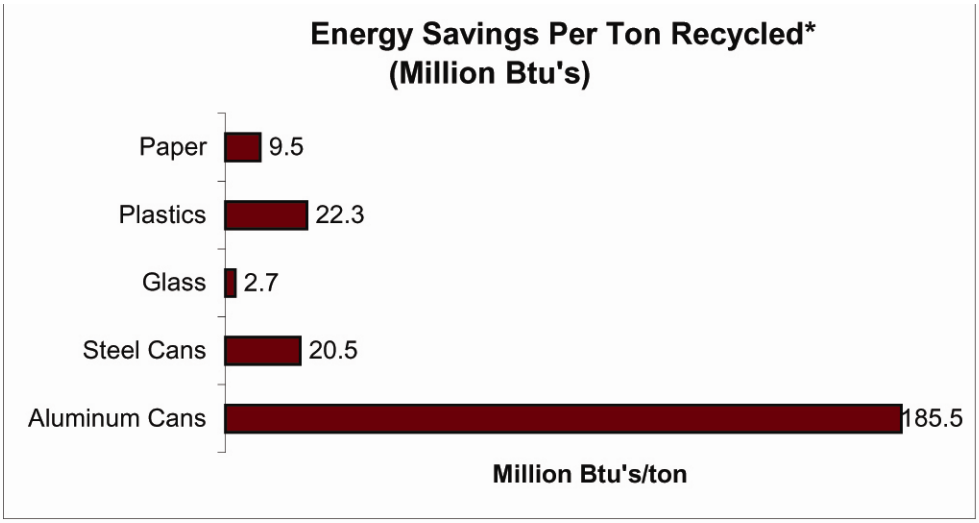
There are 3,500 kcal in 1 lb (0.454 kg) of fat.

It has been estimated that it takes 10 times as much energy to produce, process, transport and refrigerate food as there is energy in the food (Nathan Lewis, Cal Tech).

Paper: 600 trees on an acre (1500 trees on 1 hectare)
each tree requires 130 gallons (490 L) of water for growth
50 gallons (189 L) of water for processing into paper
A cord of wood is 8ft x 4 ft x 4ft and, if air dried and consisting of hardwoods weighs about 2 short tons, about 15-20% of which is water
A cord of wood makes 1000 to 2000 lbs of paper (depending on process)
1 metric ton of paper contains 440 reams
1 ream of paper contains 500 sheets and weighs 5 lbs = 2.27 kg.
production of 1 metric ton of paper requires 17 trees
12,770 MJ of energy
25 m^3 of water
680 gallons (2.57 m^3) of oil
and generates 6.93 tons of CO_2.
In the USA, 36% of the fibers used to make new paper come from recycled sources (paperrecycles.org).

Reuse
Hard-plastic **trays** and **crates** can be reused 300 times before being worn out or broken.

Recycling
Recycling 1 kg of **steel** saves: 1.25 kg of iron ore
0.50 kg of coal
0.02 kg of limestone



*Assumes recycled materials would otherwise have been disposed in a landfill.

Source: http://www.epa.gov/climatechange/wycd/waste/downloads/energy.pdf

Energy Consumed/Avoided from MSW Management Options (Million Btu's/Ton)				
Material	Source Reduction for Current Mix of Inputs*	Recycling	Combustion	Landfilling
Aluminum Cans	-103.25	-184.99	0.12	0.53
Steel Cans	-26.45	-19.97	-17.04	0.53
Glass	-6.49	-2.13	0.08	0.53
HDPE	-24.07	-18.99	-6.66	0.53
LDPE	-35.26	-24.10	-6.66	0.53
PET	-26.86	-22.20	-3.46	0.53
Corrugated Cardboard	-18.26	-13.00	-2.51	0.51
Magazines/third class mail	-32.83	-0.69	-1.87	0.52
Newspaper	-31.41	-16.49	-2.83	0.52
Office Paper	-31.90	-10.08	-2.42	0.49
Phonebooks	-37.83	-11.93	-2.83	0.52
Textbooks	-34.89	-1.03	-2.42	0.49
Dimensional Lumber	-3.41	0.59	-2.96	0.52
Medium Density Fiberboard	-11.19	0.86	-2.96	0.52
Food Scraps	NA	NA	-0.85	0.52
Yard Trimmings	NA	NA	-1.00	0.52
Mixed Paper	0.00	0.00	0.00	0.00
Broad Definition	NA	-6.65	-2.52	0.51
Residential Definition	NA	-6.65	-2.10	0.51
Office Paper Definition	NA	-13.95	-1.98	0.51
Mixed Plastics	NA	-20.53	-4.92	0.53
Mixed Recyclables	NA	-16.78	-2.65	0.51
Mixed Organics	NA	NA	-0.93	0.52
Mixed MSW	NA	NA	-1.78	0.52

* “Current mix” refers to the current mix of virgin and recycled inputs. Most new materials are produced using some percentage of recycled inputs. These calculations account for this percentage, rather than assuming new products are produced from 100 percent virgin inputs.

Source: http://www.epa.gov/climatechange/wycd/waste/downloads/energy.pdf

BUILDING ENERGY CONSUMPTION

Private (small) house:
(2,415 ft^2 in average, with 2.5 people in average → 966 ft^2/person)

Space heating:	30%
Appliances:	27% (incl. washer, dryer, TV)
Water heating:	15%
Space cooling:	9%
Refrigeration:	9%
Lighting:	6%
Cooking:	4%
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Total:	100%

Retail & Warehousing: (from U.S. Dept. of Energy)

Typical store in a shopping mall: 9.7 kWh/ft^2 per year
Warehouse storage (> 10,000 ft^2): 5.0 kWh/ft^2 per year

To make 1 kg of	Energy required (in kJ) if from primary source	Energy required (in kJ) if from recycled source
Acrylonitrile	111,000	51,400
Aluminum - wrought	196,000	26,700
Aluminum - cast	189,000	26,000
Aluminum - sheet	279,720	40,320
Automotive fluids, (transmission, brake and steering fluids)	52,000	---
Automotive anti-freeze	76,000	---
Automotive engine oil	60,200	---
Alpha alumina	26,100	---
Beta alumina	267,000	---
Brass	100,000	45,000
Butadiene	111,000	51,400
Copper	60,000	45,000
Fiberglass	66,500	40,000
Glass	30,000	13,000
Glass - sintered	48,000	---
Iron	34,000	24,000
Lead	41,100	8,000
Magnesium - cast	284,000	27,200
Nylon	119,000	32,100
Polycarbonate	158,000	48,100
Polyester	95,800	50,000
Polyethylene terephthalate (PETE)	106,000	???
Polyethylene (PE)	98,000	56,000
Polypropylene (PP)	74,300	42,300
Polystyrene		
Polyurethane	72,100	44,600
PVC (polyvinylchloride)	65,400	29,300
Rubber	67,600	---
Sand	1,000	---
Sodium	107,000	---
Steel	40,000	18,100
Styrene	102,000	43,500
Sulfur	2,300	---
Zinc	53,000	15,900

Source: Life-cycle analysis: Getting the total picture on vehicle engineering alternatives", Automotive Engineering, March 1996, pages 49-52.