ENGR290: Renewable Energy

Homework 3: Energy Density and Efficiency

Assigned: Jun 3, 2014
Due: Jun 10, 2014

Notes:

Energy Density of Fuels

Energy density is the amount of energy a particular fuel contains per unit of mass or volume. The class handout (or a quick internet search) shows the energy density of several common fuels such as Gasoline = 46MJ/kg. This means that if you completely burn 1 kg of gas, it will release 46MJ of energy. Higher energy densities means you can carry more energy with less weight, but you must also look at the energy density per unit volume. Hydrogen has a 3 times the energy density of gasoline in mass, but it is a gas so it has a much lower energy density per unit volume which means it requires a very large tank.

Efficiency

Efficiency is generically $\frac{Output}{Input}$. Efficiencies multiply, so if there are 3 devices in series you must multiply their efficiencies to find the overall efficiency. For our purposes it is essential to include in all calculations because everything runs at $<$ 100% efficiency.

- For example, a good quality gasoline engine may reach 30% efficiency. A rotary electric generator may be 90% efficient. So of the 46MJ of energy stored in one kg of gasoline, you will only get $46MJ * 0.3 * 0.9 = 12.4MJ$ of electricity from a gas powered generator.
- Another example: we know that solar radiation delivers $1kW/m^2$ to the earth's surface. But a typical PV panel is around 18% efficient and the power inverter is probably about 90% efficient, so of the 1kW you should get out of a $1m^2$ panel, you will only see $1000W * 0.18 * 0.9 = 162W$ out if it.

Fuel	Energy density	Energy density
	(MJkg^{-1})	(MJlitre^{-1})
Nuclear fusion of hydrogen	300,000,000	425,000,000
Nuclear fission of uranium 235	77,000,000	1,500,000,000
Liquid hydrogen	143	10
Natural gas (compressed to 200×10^5 Pa)	54	10
Petrol	46	34
Diesel fuel	45	38
Aviation fuel	43	33
Residential heating oil	43	33
Vegetable oil	42	31
Crude oil	42	37
Liquified natural gas	37	24
Coal (anthracite)	33	72
Charcoal	29	
Coal (bituminous)	24	20
Wood	6–18	2–3
Liquid hydrogen and liquid oxygen	13	6
Household waste	8-10	
TNT	4.2	7

Figure 1: Fuel energy density

Battery Type	Cost $ per Wh	Wh/kg	Joules/kg	Wh/liter
Lead-acid	$0.17	41	146,000	100
Alkaline long-life	$0.19	110	400,000	320
Carbon-zinc	$0.31	36	130,000	92
NiMH	$0.99	95	340,000	300
NiCad	$1.50	39	140,000	140
Lithium-ion	$0.47	128	460,000	230

Figure 2: Battery energy density

Problem 1

I have a cabin with the power load profile shown in Figure 3. I installed a PV system on the roof with the power production shown in Figure 4.

1. How much energy does my house consume each day? (kWh/day)

2. How much energy does the PV system produce each day? (kWh/day)

3. Clearly you will need some storage for this arrangement. For the following calculate just what you need for each day (don't add margin for cloudy days).

   (a) How much battery storage do you need to make this arrangement work? (Ah)

   (b) How much weight of Lead-Acid batteries would this be? (kg)

   (c) How much weight of LiPo batteries would this be? (kg)

4. If I replace the PV system with a 30% efficient diesel generator, how much fuel will I use each day?

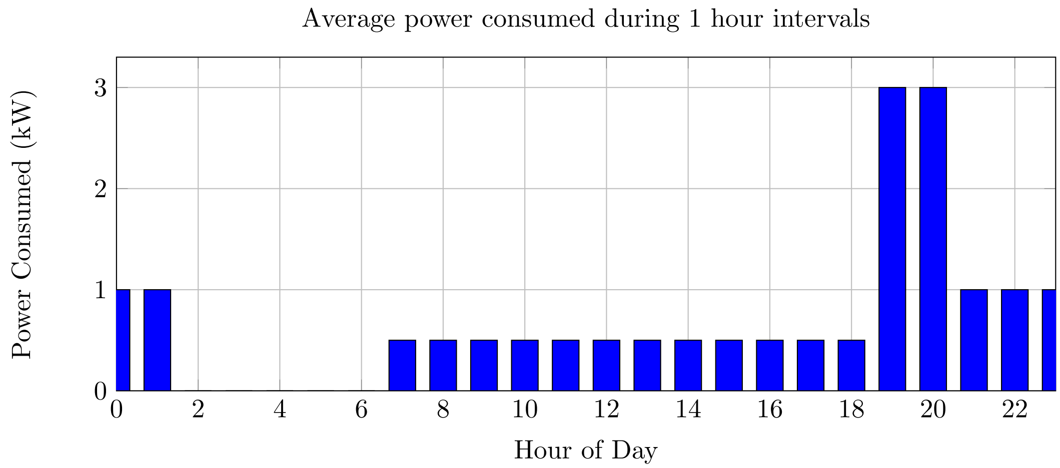

Figure 3: My (very simplified) household power consumption

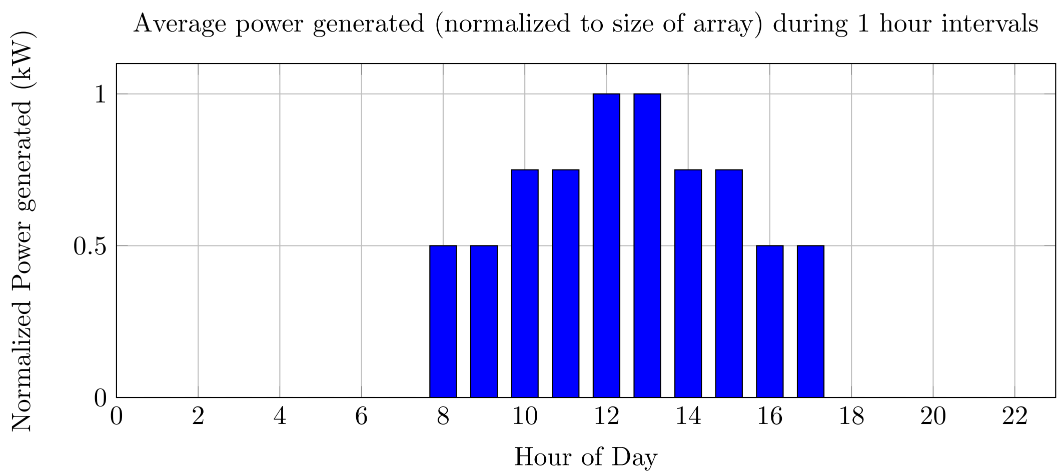

Figure 4: PV power generation curve