DIY Green Energy-math

For PDF copy go to: www.joyfulcatholics.com/DIY-Green-Energy-math

For overview of how these numbers are applied
go to: www.joyfulcatholics.com/DIY-Green-Energy-overview

PLEASE CHECK MY RESEARCH AND MY MATH

COW MANURE
"Generally speaking, a 1000 pound cow will produce about 82 lbs of manure daily. Most cows are bigger than this."
https://farmandanimals.com/how-much-manure-does-a-cow-produce/
82 lbs/day manure / 2.2 lbs/kg = 37.2 kg/day manure.
I USE 20 kg/day cow manure to allow for leaving manure in the fields.
Table 1 "Beef Manure (Outdoor Pen) 10 Wet Mass Methane Potential (m3 CH4/1000 kg)"   standard (1 atmosphere pressure and 20 C)
https://extension.okstate.edu/fact-sheets/anaerobic-digestion-of-animal-manures-methane-production-potential-of-waste-materials.html   Table 1
10 m3 CH4/1000 kg Wet Mass = 10 liters methane/kg manure
I USE 10 liters of methane/kg of cow manure.
I include cow manure mostly to get lots of the microbes that do the digesting. The four chamber stomachs of cows take the time to produce plenty of the microbes that do the digesting, but leave relatively little of the stuff to be digested.

1 cow * 20 kg/day manure * 7 days = 140 kg manure
140 kg manure * 10 liters of methane/kg of manure = 1,400 liters methane
1,400 liters methane * 0.044 mol/liter = 61 mol methane
61 mol methane * 0.247 kWh/mol methane = 15 kWh methane/cow/week

HORSE MANURE
"One horse (defined here as a 454 kg (1000 lb) animal) produces roughly 17 kg (37lb) feces and 9 L (2.4 gal) of urine per day"
https://rucore.libraries.rutgers.edu/rutgers-lib/26434/PDF/1/play/
"A 1,000-pound horse produces about 31 lbs of feces and 2.4 gallons of urine daily..."
https://extension.psu.edu/horse-stable-manure-management
Interesting to see the sources not match.
31 lbs horse manure/day / 2.2 kg/pound = 14 kg horse manure/day
I USE 7 kg/day horse manure to allow for leaving manure in the fields.

“methane production potential of horse manure averaged over all batch experiments was 139 ± 65 mL methane per g horse manure VS”
https://rucore.libraries.rutgers.edu/rutgers-lib/26434/PDF/1/play/
VS is basically the methane producing part of the stuff to be digested. VS varies widely so I have taken the minimum methane production from the experiments.
139-65 mL methane/g horse manure = 74 liters methane/kg horse manure
I USE 75 liters methane/kg horse manure.
The single chamber stomachs of horses process food more quickly than cows so they provide much less of the microbes, but have not removed as much of the stuff to be digested.

1 horse * 7 kg/day manure * 7 days = 49 kg manure
49 kg manure * 75 liters methane/kg manure = 3,675 liters methane
3,675 liters methane * 0.044 mol/liter = 161 mol methane
161 mol methane * 0.247 kWh/mol methane = 39 kWh methane

HUMAN FECES
“While the wet mass of feces excreted daily ranges between 70 and 520 g per person per day (g p− 1 d− 1), an amount of 350–400 g p− 1 d− 1 is generally considered as a reasonable average.”
https://www.sciencedirect.com/science/article/pii/S0973082615000939
0.128 kg of feces/day can be collected.
https://en.wikipedia.org/wiki/Human_feces
Interesting to note how the two sources do not agree.
I USE 0.3 kg/day human feces based on the 350-400 g/day feces average

https://reader.elsevier.com/reader/sd/pii/S1876610215005561?token=CDEE5C5118B54FF69E42A22C843480632D55BEFEAAAA4AD51DCF4C5C843F60C4868121262E4C8E7F2FBF9675B8ACDD77&originRegion=us-east-1&originCreation=20220820043926

“there is a possibility of potential biogas per kg human faeces becomes equal or higher than the manure, and the levels of methane in the biogas can reach 70%
search for this PDF file: a-review-of-recycling-of-human-excreta-to-energy-through-biogas-generation-indonesia-case.pdf
I USE the same 10 liters of methane/kg of human feces that I use for cow manure.

Human feces provide little, but not zero, of both the microbes and the stuff to be digested. Human feces are included primarily as a way to properly dispose of human feces.

1 human * 0.3 kg feces/day * 7 days = 2 kg feces/week
2 kg feces * 10 liters methane /kg feces = 20 liters methane
20 liters methane * 0.044 mol/liter = 0.88 mol methane
0.88 mol methane * 0.247 kWh/mol methane = 0.21 kWh methane

STEMS

"The system produced an average of 0.15 m3 of methane per kg of grass."
https://pubmed.ncbi.nlm.nih.gov/11942700/

Note that this is technically methane per kg of grass. I ASSUME grain stems will produce approximately the same amounts.

I USE 150 liters of methane/kg stems

Stems provide no microbes, but lots of stuff to be digested. I have arbitrarily ASSUMED 3 times the weight of all three types of waste in weight of stems is a good balance for speed (from the cow manure) plus stuff to digest (from the horse manure and stems). What is your best guess?

140 kg cow + 49 kg horse + 2 kg human = 191 kg wastes/week
191 kg wastes/week *3 = 573 kg stems to add/week
573 kg stems * 150 liters methane/kg stems =85,950 liters methane
85,950 liters methane * 0.044 mol/liter = 3,781 mol methane
3,781 mol methane * 0.247 kWh/mol methane = 933 kWh methane

ACREAGE

Table 1. Forage Realistic Yield Potential
2 to 4 Tons/acre/year Small Grains for forage (Oats, Rye, Wheat, Barley)
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_014887.pdf

I USE 3 tons/acre/year

Because this is from the US government, I ASSUME 2,000 lbs/ton.
573 kg stems/week * 2.2 lbs/kg = 1,260.6 lbs stems/week
1,260 lbs stems/week * 50 weeks/year = 63,030 lbs stems/year
63,030 lbs stems/year / 2,000 lbs/ton = 31.515 tons stems/year
32 tons stems/year / 3 tons/acre/year = 10.6666 acres needed
I USE 12 acres needed.

METHANE

0.044615 mol/liter methane
at standard temperature and pressure (273.15 K, 101.325 kPa)
https://planetcalc.com/7916/

Note that the liters/kg is at 20C=293.15 K while mol/liter is at 0C=273.15 K. I have not increased the mol/liter to match, but effectively round against myself again by using mol/kg on the lower temperature.

I USE 0.044 mol/liter methane

“Heat of combustion -890.8 kJ/mol”
https://www.engineeringtoolbox.com/methane-d_1420.html
“1 kJ = 0.000278 kWh”
https://www.inchcalculator.com/convert/kilojoule-to-kilowatt-hour/
890.8 kJ/mol methane * 0.000278 kWh/kJ = 0.247 kWh per mol methane
I USE 0.247 kWh/mol methane.

HOUSEHOLD ENERGY USE
In table: “In 2015, high US household energy use was 100 million Btu.”
https://www.eia.gov/energyexplained/use-of-energy/homes.php
“100,000,000 Btu = 29307.106944 kWh”
https://www.rapidtables.com/convert/energy/BTU_to_kWh.html
The average U.S. household consumes about 11,000 kilowatthours (kWh) per year. (of electricity)
https://www.eia.gov/energyexplained/use-of-energy/electricity-use-in-homes.php
29,000 kWh/year total – 11,000 kWh/year electricity = 18,000 kWh/year non-electrical energy.
18,000 kWh/year / 50 weeks/year = 360 kWh/week for non-electrical energy
11,000 kWh/year electricity / 50 weeks/year = 220 kWh/week of electricity
To get 220 kWh/week out of an 85% efficient generator requires 258 kWh/week put in to generator.
To get 258 kWh/week into a generator out of a 25% efficient engine requires 1,032 kWh/week put in to the engine.
I USE 1,032 kWh/week for generating electricity and 220 kWh/week for non-electrical energy.

ELECTRIC CAR ENERGY USE
“The average electric car kWh per 100 miles (kWh/100 mi) is 34.6. This works out as 0.346kWh per mile. In other words, on average, electric cars consume 34.6kWh to travel 100 miles and 0.346kWh to travel 1 mile.”
https://ecocostsavings.com/average-electric-car-kwh-per-mile/
I use 0.5 kWh/mile for an electric car.
“The average distance a US driver travels is 13,476”
https://ecocostsavings.com/average-electric-car-kwh-per-mile/
“On average, there are 1.88 vehicles per U.S. household.”
https://www.statista.com/statistics/551403/number-of-vehicles-per-household-in-the-united-states/

I allow for two cars/household.
I allow for 20,000 miles/year/car.
20,000 miles/year/car * 0.5 kWh/mile = 10,000 kWh/year/car.
10,000 kWh/year / 50 weeks/year = 200 kWh/week/car
I USE 400 kWh/week for two electric cars.

Interesting to compare to gas car efficiency.
GASOLINE CAR EQUIVALENT
gallon of gasoline 1.3x10^8 Joules
https://www.ocean.washington.edu/courses/envir215/energynumbers.pdf
Heat of combustion-890.8kJ/mol-55528kJ/kg-23.9
https://www.engineeringtoolbox.com/methane-d_1420.html
I ASSUME 20 mpg as average fuel efficiency
I allow for 20,000 miles per year/car.
20,000 miles/year/car / 20 mpg = 1,000 gallons gas/year/car
1,000 gallons gas/year/car / 50 weeks/year = 20 gallons gas/week/car
20 gal gas/week/car * 1.3*10^8 J/gal gas = 2,600,00,000 J/week/car
2,600,00,000 J/week/car / 3.6*10^6 kWh/J = 722 kWh/week/car.

GENERATING ELECTRICITY
"there is a significant energy loss in converting energy from the gas form to the electrical form. Internal combustion engines are about 25 percent efficient and generators are about 85 percent efficient."
https://extension.missouri.edu/publications/g1881

220 kWh/week electricity / 85% generator efficiency = 258 kWh input
258 kWh input / 25% engine efficiency = 1,032 kWh methane needed

Please note that I have not personally built a digester. This info is my best knowledge and belief from my "armchair research". I am working on my digester design and will publish it when it is done.
You do not need me. If having your own independent source of power interests you, do your own research, develop your own approach,
BE CAREFUL, and make it happen! :-)
May God bless you, Phil