3.3) BATTERIES AND BIOFUELS

Objective: This data gathering exercise utilizes raw data from commercial websites in order to evaluate the pro and cons of alternative fuel vehicles. **Video instructions:** https://vimeo.com/543418249

Introduction: Environmental concerns and political instability in OPEC nations has intensified research into vehicles that run on alternatives to petroleum. The most common alternatives in the U.S. are electric vehicles (EV's) and flex-fuel vehicles that run on 85% ethanol. Another alternative being considered are fuel cell cars.

Cars with internal combustion engines use only 20% of the fuel energy for movement. Fuel cells are more efficient because they convert fuel energy directly to electricity. This is why fuel cell cars usually get about three times more miles per unit fuel than their internal combustion engine counterparts.

Batteries are heavy because they contain all the reactants needed to generate electricity. Fuel cells are lighter because (like internal combustion engines) they run on fuels that react with oxygen from the air. The main disadvantage of fuel cells is that they run on hydrogen, a fuel that is costly to generate and difficult to transport and contain. This is why fuels cell cars are not yet for sale. The technological breakthroughs most needed are lighter batteries and fuel cells that run directly on fossil fuels.

Part 1: Mass Energy Ratios for EV Batteries

1) Look up amp-hours, mass, and costs of similar sized 12-volt batteries using the websites provided by your instructor.
2) Enter these values in Tables 1E and 5B.
3) Calculate watt-hours by multiplying volts by amp hours and enter in Table 1D.
4) Calculate kilowatt hours by dividing watt hours by 1000 (F).
5) Calculate lbs per kilowatt hours by dividing mass by kilowatt hours (G).
6) Optional: Physically weigh batteries and record the volts and amp-hours written on the battery.

Part 2: Mass Ratios for Gasoline

1) Go online and look up the lbs per gallon.
2) Use the website provided by your instructor to look up the kilowatt hours per gallon and enter this value in Table 2B.
3) Calculate lbs per kilowatt hour (D).

Part 3: EV Charging Distance

1) Go online and look up kilowatt hours per mile of the Volkswagon e-Up and enter this value in Table 3B.
2) Calculate kilowatt hours per 100 miles (C).

Part 4: Mass Needed per 100 Miles

1) Enter the values from Tables 1, 2, and 3 to Table 4B and C.
2) Calculate lbs per 100 miles (D).

Part 5: Battery Cost for 100 Mile Range

1) Enter the values from Tables 1 and 3 to Table 5C and E.
2) Calculate cost per kWh (D).
3) Calculate Cost per 100 miles (F).

Part 6: Land Needed for Ethanol Production

1) Look up barrels of gas consumed per day and enter this value in Table 6A.
2) Calculate the ethanol equivalence (B).
3) Calculate gallons needed per day (C).
4) Calculate gallons needed per year (D).
5) Calculate tons switchgrass needed (E).
6) Calculate acres of switchgrass needed (F).
7) Calculate square miles needed (G).

Part 7: Combustion of Switchgrass

1) Calculate the kilowatt hours per ton of switchgrass based on the data in reference 3 and enter this value into Table 7A.
2) Calculate miles per lb switchgrass using the provided conversion factors (B-E).

Part 8: Fermentation of Switchgrass

1) Look up the average mpg for a gasoline-powered Ford Focus and enter this value into Table 8A.
2) Calculate miles per lb switchgrass using the provided conversion factors (B-C).

Table 1: Mass Energy Ratio for EV Batteries

A	B	C	D	E	F	G
Battery	Volts	Amp hours	Wh (B X C)	**Battery mass (lbs)**	kWh (D ÷ 1000)	Lbs / kWh (E ÷ F)
Lithium	12					
Lead	12					

Table 2: Mass Ratios for Gasoline

A	B	C	D
Fuel	**lbs / gal.**	**kWh / gal.**	lbs / kWh (B ÷ C)
Gasoline			

Table 3: EV Charging Distance

A	B	C
EV model	**kWh / mi.**	kWh / 100 mi. (B X 100)
Volkswagon e-Up		

Table 4: Mass Needed per 100 Miles

A	B	C	D
Energy	kWh / 100 miles (from Table 3)	Lbs / kWh (from Tables 1 & 2)	Lbs / 100 miles (B X C)
Lithium			
Lead			
Gasoline			

Table 5: Battery Cost for 100 Mile Range

A	B	C	D	E	F
Battery type	**Cost**	kWh (from Table 1)	Cost / kWh (B ÷ C)	kWh / 100 mi. (from Table 3)	Cost / 100 mi. (D X E)
Lithium					
Lead					

Table 6: Land Needed for Ethanol Production

A	B	C	D	E	F	G
Gas use/day in US bbls	Gas to ethanol ratio[1] ÷ 0.67	Total Gal. needed X 42 gal./bbl	Gal./ year need X 365 day/yr.	Switchgr. need/yr [2] ÷ 80 gal./ton	Total Acres/yr [2] ÷5.2 ton/acre	Total Land need/yr ÷640 acre/squ. mi

Table 7: Combustion of Switchgrass

A	B	C	D	E
Switchgr. [3] kWh/ton	Switchgr. kWh/lb ÷2000 lb/ton	Transmission efficiency[4] X 0.85	Charging efficiency[5] X 0.75	Switchgr. mi./lb for electr. Ford Focus[6] X 3.23 mi./kWh

Table 8: Fermentation of Switchgrass

A	B	C
Gas-powered Ford Focus mpg	Gas to ethanol ratio[1] ÷ 0.67	Switchgr. mi./lb for ethanol-Ford Focus[2] X 0.040 gal./lb

Literature Cited:

1. US Department of Energy. Alternative Fuels Data Center. Accessed on June 17, 2023. https://afdc.energy.gov/fuels/properties
2. USDA. 2019. *Switchgrass for Biofuel Production*. Farm Energy. April 3, 2019. Accessed on June 17, 2023. https://farm-energy.extension.org/switchgrass-panicum-virgatum-for-biofuel-production/
3. *Burn Test Proves Hopeful.* Renewable Energy World. June 19, 2006. Accessed on Jun 17, 2023. https://www.renewableenergyworld.com/baseload/switchgrass-burn-test-proves-hopeful-45188/ (Calculation based on 19,607,000 kWh per 15,647 tons of switchgrass)
4. US Department of Energy. Electrical System Energy Losses. Energy Information Administration. Energy Consumption by Sector. Open Section Notes pdf, Note 2. http://www.eia.doe.gov/emeu/mer/consump.html.
5. *Batteries: What We Know About Them & How to Use Them*. Home Power 1997, April/May, p 66.
6. US Department of Energy. *Fuel Economy Guide*. Model Year: 2018. www.fueleconomy.gov (Calculation based on 100 miles per 31 kWh)

Websites needed:

Lithium batteries**:** https://www.lithiumion-batteries.com/products/lithium-ion-solar-batteries/12v-200ah-lithium-ion-battery.php
Lead acid batteries: https://www.grainger.com/category/electronics-appliances-and-batteries/batteries-battery-chargers/sealed-lead-acid-batteries-chargers/sealed-lead-acid-batteries:
Gas to kW: https://www.convertunits.com/from/kWh/to/gallon+%5BU.S.%5D+of+automotive+gasoline
Electric vehicles: https://pushevs.com/2017/05/23/electric-car-range-efficiency-table-nedc/
State sizes: https://state.1keydata.com/states-by-size.php

Questions:

1. What is the main advantage of lithium batteries over lead batteries?

2. What is the main advantage of lead batteries over lithium batteries?

3. What are two advantages of gasoline-powered vehicles over electric vehicles?

4. How many square miles of switchgrass are needed to satisfy current gasoline demand in the US?

5. Which state is closest in size to the total land needed? (use the link provide below)

6. What is the biggest problem with relying on biofuels grown on land?

7. Does combustion (Table 7) or fermentation (Table 8) get more miles per unit of switchgrass?

8. Which technology is more convenient; flex-fuel or electric vehicles? Explain:

Assignment Checklist:

1. Did you completely answer all the questions?
2. Did you fill out by hand all the blank spaces in Tables 1-8?