1. Later in the semester, we will have a guest speaker, Kevin Staples, Senior and Sustainability Coordinator at Salt Lake City International Airport. One of the Kevin's responsibilities is to estimate the greenhouse gas emissions produced at the Salt Lake International Airport.

Draw a Systems Boundary for the greenhouse gas emission caused by the Salt Lake International Airport.

Include in your drawing:

- In-flight emissions
- Landing and take-off (LTO) emissions
- Airport taxiing operations
- Airport Construction
- Heating/Cooling
- Baggage Equipment
- Electricity generation
- Personal vehicle transportation to the airport
- Drop/off and pick-up at the airport
- Airport shuttles
- Transportation as a service (Uber, Lift) operations
- Public Transit at the airport

What sources did you not include in the boundary of the airport? Why not?

Does the Salt Lake Airport Authority have the same control to reduce the emissions from the different sources of emissions at the airport within the system boundary?

2. Draw a casual loop diagram with the following elements to begin with:
    - Gasoline Price
    - Gasoline Demand
    - Gasoline Vehicles
    - Electric Vehicles
    - Rare earth metals
    - Battery Costs

Add additional elements, and relationships among the elements. Label balancing "B" and reinforcing "R" Loops. Discuss limitations and assumptions included in your analysis.

3. Estimate the penetration of electric vehicles as a fraction of total light-duty **cars** for calendar years 2020 until 2050 using logistic regression, using data from the last 9 years (2011-2019).

Logistic growth Equation: $f(t) = \frac{e^{a+bt}}{1+e^{a+bt}}$

Where

f(t) = fraction of electric vehicles at year, t

t = calendar year (2020 to 2050)

a,b = coefficients

Using the logistic growth equation, at what year do electric vehicles make up more than 50% of car sales?

Resources:

Historic Electric Vehicle sales: (2010-2019)

https://afdc.energy.gov/data/

Table: U.S. Plug-in Electric Vehicle Sales by Model Trend of sales by PEV model, 2011-2019

Note: In this analysis, we are only considering the fully electric vehicles as electric. You can also assume that all the full electric vehicles listed in afdc in 2011-2019 are passenger cars (in other words, they are not light-duty trucks).[1]

Historic Passenger Car and LDT sales (2010-2020):

https://www.epa.gov/automotive-trends/explore-automotive-trends-data#SummaryData

From epa.gov, I used Table A-2. View by Weight Class—but other A-tables would work for estimating the total passenger cars).

Suggested analysis tips:

Several possible methods to solve. Note: using different methods may give you different results.

a. Transform the logistic equation to a linear equation. Fit a model using a linear model (Excel, or software package like R or MATLAB)

b. Use Excel solver—solve for the two logistics coefficients by minimizing the sum of the squared error from the data fit and the model

c. Fit the logistic using a logistic model fit (using a software package such as R)

[1] See Figure 4-15 from the 2021 EPA Fuel Economy Trends Report (https://www.epa.gov/automotive-trends)

Hint: You may need to try to 'seed' the starting coefficients with different values in order for solver to converge to the correct solution. You can first experiment with values that give you somewhat reasonable predictions before running the solver.

4. Graphically compare your estimate to the penetration estimated by the 2022 Annual Energy Outlook:

   Future LD Vehicle sales: https://www.eia.gov/outlooks/aeo/tables_ref.php

   Table 38 - https://www.eia.gov/outlooks/aeo/data/browser/#/?id=48-AEO2022&cases=ref2022&sourcekey=0

   How do your logistic estimates compare to most recent EV car sales fractions compiled by Argonne National Laboratory?

   See Figure 3- https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates

   How do you projections align with recent EV commitments by auto manufacturers and regulations by states?

For example:

https://apnews.com/article/technology-joe-biden-business-environment-and-nature-economy-88fe6ca8e333f3d00f6d2e98c6652cea

https://apnews.com/article/technology-california-air-resources-board-climate-and-environment-dc75c11280f85a8ab134cf392497be68

https://www.pbs.org/newshour/nation/everything-you-need-to-know-about-the-new-electric-vehicle-tax-credit

FHWA (2022). National Electric Vehicle Infrastructure Funding by State. https://www.fhwa.dot.gov/bipartisan-infrastructure-law/evs_5year_nevi_funding_by_state.cfm

What are the pros and cons of the AEO estimates and the logistic regression estimates? Based on these or other references, what do you think the likely EV penetration will be for light-duty cars in the future?

5. The average fuel economy (miles per gallon) for conventional internal combustion engine (ICE) cars is reported in the Annual Energy Outlook (AEO).[2] In addition, the average electric vehicle equivalent miles per gallon MPGe (accounting for electricity generation) is
   Also reported.

[2] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=50-AEO2022&cases=ref2022&sourcekey=0

Fuel burned is directly proportional to the CO2 emissions.[3]

Using your logistic regression projections, estimate when the new model year vehicles CO2 car emissions will be reduced by 50% compared to a scenario with no electrical vehicles.

Would you expect the year that the total light-duty fleet (cars and trucks, old and new model year vehicle) emissions are reduced by 50% to occur before or after the date that the new passenger model year vehicles are reduced? Why?

What other real-world factors might accelerate or delay carbon dioxide emissions reductions from light-duty vehicles?

Discuss the rationale for your assumptions, and any limitations of your analysis.

Grading:

Provide written drawings, answers and graphics in electronic form. You can conduct the drawings by hand, you should scan them into pdf. Also, submit a clear copy of your supporting analysis (spreadsheet or analysis script) with which you conducted the analysis.

[3] https://www.eia.gov/environment/emissions/co2_vol_mass.php