Shell.ai Hackathon for Sustainable and Affordable Energy

Fleet Transition Challenge: Problem Statement

Introduction

Welcome to the fifth edition of the Shell.ai Hackathon for Sustainable and Affordable Energy. Shell.ai Hackathon brings together brilliant minds passionate about digital solutions and AI, to tackle real energy challenges and help build a lower-carbon world where everyone can access and afford energy.

In the previous four editions, we addressed some of the digital challenges around the energy transition: windfarm layout optimization (2020), irradiance forecasting for solar power generation (2021), optimal placement of electric vehicle (EV) charging stations (2022), and supply chain optimization for biorefineries (2023). This year, we focus on fleet decarbonization - a transition problem in the mobility sector.

Challenge

Professional, delivery and operational fleets are a significant contributor to global greenhouse emissions. Fleet owners aspire to achieve net-zero emissions promptly; however, the transition presents a complex dilemma. Balancing the urgency of achieving net-zero emissions with business sustainability and customer satisfaction requires a decision-making framework that considers factors such as timing, location, and approach. In this hackathon, you will have a chance to develop mathematical models to optimize fleet decarbonization strategies, to help fleet owners make informed decisions that align with their energy transition objectives and business outcomes. By harnessing the power of data and mathematical models, you will navigate the complexities of demand forecasts, dissect emission profiles, and find ways to meet ambitious emission targets. The end game is to develop ingenious solutions that strike a balance between operational effectiveness and environmental impact.

Problem Statement

Road transport is the backbone of supply chain, playing a pivotal role in moving goods and bolstering the economy. This mode of transport's advantages are flexibility, door-to-door service, and connectivity between cities, towns, and villages. While it comes with convenience and advantage, professional, delivery and operational fleets are a significant contributor to global greenhouse emissions. Fleet owners aspire to achieve net-zero emissions promptly; however, the transition presents a complex dilemma. Balancing the urgency of achieving net-zero emissions with business sustainability and customer satisfaction requires a decision-making framework that considers factors such as timing, location, and approach.

In this hackathon, you will have a chance to develop mathematical models to optimize fleet decarbonization strategies, to help fleet owners make informed decisions that align with their energy transition objectives and business outcomes.

By harnessing the power of data and mathematical models, you will navigate the complexities of demand forecasts, dissect emission profiles, and find ways to meet ambitious emission targets. The end game is to develop ingenious solutions that strike a balance between operational effectiveness and environmental impact. We will provide various yearly 'demand' data from a fleet operator that must be met. The demand data is further divided into various size and distance buckets which indicate what vehicle sizes should be used and how much distance per day they can cover. These are some additional constraints imposed on meeting the customer demand. We provide various vehicles from the following 3 drivetrains: Diesel, LNG, and BEV (Battery Electric Vehicle). For each of these vehicles, the cost, operational yearly range, distance bucket they can cover, and the vehicle ID (unique identifier which helps you reference them in your solution) is provided. We include the information on the fuel consumption by every model of the vehicle and the corresponding fuel types. Furthermore, we also include the cost for every fuel type along with the amount of carbon emissions

by each of them, for every single year. Finally, you are also provided with the total carbon emission limits that must not be exceeded every year. All the data provided spans the years 2023 to 2038 (both years inclusive), for a total of 16 years.

Your solution should provide an optimal fleet composition over the years, which meets all supply-chain demand and constraints while abiding by the carbon emission limits for every year and has the lowest overall cost possible. The data provided to you and the solution expected from you has been further explained in the next section.

Data

We are providing the following datasets:

1. **Demand.csv:** This file gives you the total yearly distance demand (in kms) that needs to be satisfied with vehicles of size Sx (size bucket) which can travel at least a minimum of Dx (distance bucket) per day. For example, row 1 indicates that there is a yearly demand of 869181 km for the S1 sized vehicles which can travel at least a minimum of D1 distance bucket per day.
2. **Vehicles.csv:** This file gives you the vehicle ID (model), type of vehicle (drivetrain), size bucket, year in which you can purchase it, purchase cost, yearly range (in kms), and the daily maximum distance bucket it can travel.
3. **Vehicles_fuels.csv:** This file gives you the fuel consumption (unit of fuel consumed/km) for every vehicle ID using a certain type of fuel.

ID	Vehicle	Size	Year	Cost ($)	Yearly range (km)	Distance
BEV_S1_2023	BEV	S1	2023	187000	102000	D1
:	:	:	:	:	:	:
Diesel_S2_2024	Diesel	S2	2024	107120	106000	D4
:	:	:	:	:	:	:
LNG_S4_2038	LNG	S4	2038	301395	118000	D4

Year	Size	Distance	Demand
2023	S1	D1	869181
2023	S1	D2	2597094
:	:	:	:
2038	S4	D4	306910

ID	Fuel	Consumption (unit_fuel/km)
BEV_S1_2023	Electricity	0.893043
:	:	:
Diesel_S1_2023	B20	0.223016
:	:	:
LNG_S4_2038	BioLNG	0.154568

4. **Fuels.csv:** There are 5 fuel types, and for each, this table provides the carbon emission per unit fuel and the (median) cost per unit fuel across all the years. It also includes the uncertainty in the fuel cost.

Fuel	Year	Emissions (CO_2/unit_fuel)	Cost ($/unit_fuel)	Cost Uncertainty (±%)
B20	2023	3.04858	1.220845	0
:	:	:	:	:
Electricity	2024	0.0	0.184113	2
:	:	:	:	:
LNG	2038	2.486188	0.926499	30

5. **Carbon_emissions.csv:** Provides the total carbon emissions limits that should not be violated for every year. It is a decreasing profile over the years.

Year	Total Carbon emission limit
2023	11677957
2024	10510161
:	:
2038	2404387

Notations:

$C_{\text{total}} \leftarrow$ Total cost of fleet ownership and operations across all the years.

$C_{buy}^{yr} \leftarrow$ Total cost of buying vehicles in year yr.

$C_{ins}^{yr} \leftarrow$ Total insurance cost incurred on the vehicles in the fleet for the year yr.

$C_{mnt}^{yr} \leftarrow$ Total maintenance cost incurred on the vehicles in the fleet for year yr.

$C_{fuel}^{yr} \leftarrow$ Total fuel cost incurred on the operating fleet in the year yr.

$C_{sell}^{yr} \leftarrow$ Amount received by selling some vehicles in the fleet in the year yr.

$V_{yr} \leftarrow$ Set of all vehicles purchased in the year yr.

$C_{v_{yr}} \leftarrow$ Purchase cost of a single vehicle with ID v_{yr}.

$N_{v_{yr}} \leftarrow$ Number of vehicles of ID v_{yr} that have been purchased.

$F_{yr} \leftarrow$ Fleet of vehicles in the year yr.

$C_{v_{yrp}} \leftarrow$ Cost of vehicle in fleet purchased in the year yrp. yrp is the year of purchase and yr is the year of operation such that $yrp \leq yr$.

$N_{v_{yrp}} \leftarrow$ Number of vehicles currently in the fleet in the year yrp.

$I_{(yr-yrp)}^{v_{yrp}} \leftarrow$ Insurance cost in the year yr for vehicle v_{yrp} purchased in the year yrp.

$M_{(yr-yrp)}^{v_{yrp}} \leftarrow$ Maintenance cost in the year yr for vehicle v_{yrp} purchased in the year yrp.

$D_{(yr-yrp)}^{v_{yrp}} \leftarrow$ Depreciation cost in the year yr for vehicle v_{yrp} purchased in the year yrp.

$U_{yr} \leftarrow$ Vehicles being used (driven) in the year yr. This is a subset of F_{yr}.

$F_v \leftarrow$ All fuel types applicable for vehicle v.

$Ds_v^f \leftarrow$ Distance travelled by vehicle v using fuel f.

$N_v^f \leftarrow$ Number of vehicles of type v driving fuel type f.

$m_v^f \leftarrow$ Fuel Consumption of vehicle type v driving with fuel type f.

$C_{uf,f}^{yr} \leftarrow$ Cost of unit fuel of type f in the year yr.

$N_{yr,v_{yrp}}^{sell} \leftarrow$ Number of vehicles v_{yrp} to be sold in the year yr.

$Carbon_{tot}^{yr} \leftarrow$ Total carbon emission in the year yr.

$CE^f \leftarrow$ Carbon emission for the fuel type f.

Objective:

$$C_{total} = \sum_{yr=2023}^{2038} C_{buy}^{yr} + C_{ins}^{yr} + C_{mnt}^{yr} + C_{fuel}^{yr} - C_{sell}^{yr}$$

$$C_{buy}^{yr} = \sum_{v_{yr} \in V_{yr}} C_{v_{yr}} * N_{v_{yr}}$$

$$C_{ins}^{yr} = \sum_{v_{yrp} \in F_{yr}} C_{v_{yrp}} * I_{(yr-yrp)}^{v_{yrp}} * N_{v_{yrp}}$$

$$C_{mnt}^{yr} = \sum_{v_{yrp} \in F_{yr}} C_{v_{yrp}} * M_{(yr-yrp)}^{v_{yrp}} * N_{v_{yrp}}$$

$$C_{fuel}^{yr} = \sum_{v \in U_{yr}} \sum_{f \in F_v} Ds_v^f * N_v^f * m_v^f * C_{uf,f}^{yr}$$

$$C_{sell}^{yr} = \sum_{v_{yrp} \in F_{yr}} C_{v_{yrp}} * D_{(yr-yrp)}^{v_{yrp}} * N_{yr,v_{yrp}}^{sell} \text{Your}$$

Constraints:

1. Vehicle of size Sx can only cater to the demand of size bucket Sx.
2. Vehicle belonging to distance bucket Dx can satisfy all demands for distance bucket D1 to Dx. For example, vehicle belonging to distance bucket D4 can satisfy demand of D1, D2, D3, D4buckets; similarly, D3 can satisfy D1, D2, D3 but NOT D4.
3. Total carbon emitted by fleet operations each year should be within the respective year's carbon emissions limits provided in carbon_emissions.csv. Total carbon emissions for a year is calculated using:

$$Carbon_{tot}^{yr} = \sum_{v \in U_{yr}} \sum_{f \in F_v} Ds_v^f * N_v^f * m_v^f * CE^f$$

4. Total yearly demand for each year must be satisfied for each distance and size buckets.
5. Vehicle model of year 20xx can only be bought in the year 20xx. For example, Diesel_S1_2026 can only be bought in 2026 and not in any subsequent or previous years.
6. Every vehicle has a 10-year life and must be sold by the end of 10th year. For example, a vehicle bought in 2025 must be sold by the end of 2034.
7. You cannot buy/sell a vehicle mid-year. All buy operations happen at the beginning of the year and all sell operations happen at the end of the year.
8. Every year at most 20% of the vehicles in the existing fleet can be sold.

Evaluation:

You are expected to provide the solution in a .csv format file. The column names that should exist in the .csv along with "valid" entries are provided in the table below.

Column Name	Valid entries
Year	2023, 2024, ..., 2038
ID	Should be among list of IDs provided in vehicles.csv
Num_Vehicles	>=1
Type	Should be among "Buy", "Use", "Sell".
Fuel	Should be among "Electricity", "B20", "LNG", "BioLNG", "HVO".
Distance_bucket	Should be among D1, D2, D3, D4.
Distance_per_vehicle(km)	Should > 0 and <= Yearly range of that model.

Note: Distance bucket of the solution file corresponds to the distance bucket in the demand.csv file. Note that this is not the distance bucket of the vehicle itself (we get that from vehicles.csv anyways using the provided ID).

Additional info:

1. Vehicle resale value, insurance cost and maintenance costs as a percentage of its purchase cost is given below for each year after the purchase of vehicle.

	% of Purchase Cost		
End of Year	Resale Value (%)	Insurance Cost (%)	Maintenance Cost (%)
1	90%	5%	1%
2	80%	6%	3%
3	70%	7%	5%
4	60%	8%	7%
5	50%	9%	9%
6	40%	10%	11%
7	30%	11%	13%
8	30%	12%	15%
9	30%	13%	17%
10	30%	14%	19%

To illustrate the calculations, let us take an example of purchase cost = $100 for a vehicle bought on Jan 1st, 2025. Using the percentages in the above table, the values can be calculated as follows:

Year of Operation	End of Year	Resale Date	Resale Value (RV) ($)	Insurance Cost (IC) ($)	Maintenance Cost (MC) ($)	Insurance & Maintenance Period
2025	1	31st Dec, 2025	90	5	1	1st Jan – 31st Dec, 2025
2026	2	31st Dec, 2026	80	6	3	1st Jan – 31st Dec, 2026
2027	3	31st Dec, 2027	70	7	5	1st Jan – 31st Dec, 2027
2028	4	31st Dec, 2028	60	8	7	1st Jan – 31st Dec, 2028
2029	5	31st Dec, 2029	50	9	9	1st Jan – 31st Dec, 2029
2030	6	31st Dec, 2030	40	10	11	1st Jan – 31st Dec, 2030
2031	7	31st Dec, 2031	30	11	13	1st Jan – 31st Dec, 2031
2032	8	31st Dec, 2032	30	12	15	1st Jan – 31st Dec, 2032
2033	9	31st Dec, 2033	30	13	17	1st Jan – 31st Dec, 2033
2034	10	31st Dec, 2034	30	14	19	1st Jan – 31st Dec, 2034

2. Distance bucket mappings.

Distance bucket	Name of category
Up to 300 km daily	D1
Up to 400 km daily	D2
Up to 500 km daily	D3
Up to 600 km daily	D4

3. Vehicle size bucket mappings

Vehicle size	Name of category
17 tons	S1
44 tons	S2
50 tons	S3
64 tons	S4

4. Please note that insurance and maintenance costs should be calculated for all vehicles in the fleet (irrespective of whether they are used in a particular year), whereas fuel costs are only for those vehicles that will be used (driven) in that year.

Scoring:

If your solution satisfies all constraints, we will first calculate your solution's total cost of fleet ownership and operations using the overall cost function. Your cost (the lower the better) will then be converted to a score (the higher the better) between 30 to 100 using the following transformation function for the leaderboard ranking:

$$Leaderboard\ Score = \max\left[30, \left(100 - \frac{70 \times cost}{Reference\ Cost}\right)\right]$$

Scores between 0 to 26 are reserved for the error codes detailed below.

As you can see from the fuels.csv, there is a median fuel cost along with an uncertainty band that has been provided. The final cost (which will also comprise of fuel costs), will be a statistical aggregate over 1000 randomly drawn samples from the provided fuel distribution. There are two leaderboards: Public and Private. The public leaderboard is shown to you during the entire duration of the competition. Here, you will be evaluated until the year 2028. The private leaderboard will not be shown to you and will only be revealed at the end of the competition. This is evaluated for the full course of 16 years from 2023 to 2038. The reference cost for private leaderboard is 172,000,000, and for public leaderboard it is 65,000,000.

Error codes:

0 → Any unaccounted error code.
1 → Year entry must be of type integer.
2 → ID entry must be a string.
3 → Num_Vehicles entry must be of type integer.
4 → Type entry must be a string.
5 → Fuel entry must be a string.
6 → Distance_bucket entry must be a string.

7 → Distance_driven_per_vehicle(km) must be of type float.

8 → Year entry must be >=2023 and <=2038.

9 → ID must be from the given list of vehicle IDs.

10 → Num_Vehicles must be > 0.

11 → Type must take values among "Buy", "Sell", "Use".

12 → Fuel must be among "Electricity", "LNG", "BioLNG", "HVO", "B20".

13 → Distance bucket must be among "D1", "D2", "D3", "D4".

14 → Distance driven must be >= 0 and <= Yearly range for that model.

15 → Constraint 2 violations.

16 → Constraint 5 violation. Vehicle bought in year YYYY should have YYYY in its ID.

17 → Constraint 6 violation. Vehicle purchased in YYYY can only be used for 10 years.

18 → Demand.csv has the demand pertaining to 16 combinations (S1_D1, S1_D2, ..., S4_D4) for each year. Your solution.csv file should also have all these combinations present.

19 → Constraint 4 violation. For example, in demand.csv for year 2023 S1_D1 demand is 869181 km. In the solutions you provide, sum of all distance travelled in the year 2023 by vehicles with S1 size which satisfy D1 distance demand must be >= 869181 km.

20 → You should use the right type of fuel for a given vehicle.

21 → Constraint 8 violation. You must sell only a max of 20% of the fleet every year and nothing more.

22 → You can only "Use" vehicle IDs that you have in fleet.

23 → You can only "Use" as many vehicles that you have in fleet for each ID.

24 → You can only "Sell" vehicle IDs that you have in fleet.

25 → You can only "Sell" as many vehicles that you have in fleet for each ID.

26 → Constraint 3 violation. Total Carbon emission by fleet operations <= Carbon budget for that year.