Hydrogen Trucks Charging Stations

Data Analytics for Sustainability

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TO SIZE THE H2 TRUCK CHARGING STATIONS NETWORK IN 2030 AND 2040 WE DEVELOPED A FLEXIBLE RULED-BASED MODEL

METHODOLOGY

A very flexible and interpretable model which takes into account:

1. Initial assumptions/parameters:
   a. On the manufacturers: tank size, autonomy, type of PL (short or long distance), etc.
   b. On the stations: costs, storage onsite, footprint, etc.
   c. On the market: split between the manufacturers, daily average distance (for each type of PL), the security buffer, the activation rate of the fleet, the desired split between the station types (small, medium, large), etc.
2. The current distribution of trucks (based on the government traffic data)
3. The chosen positioning strategy with the strategic positioning index: 1 = meet the demand, 1.5 = get 50% ahead of the demand, etc.

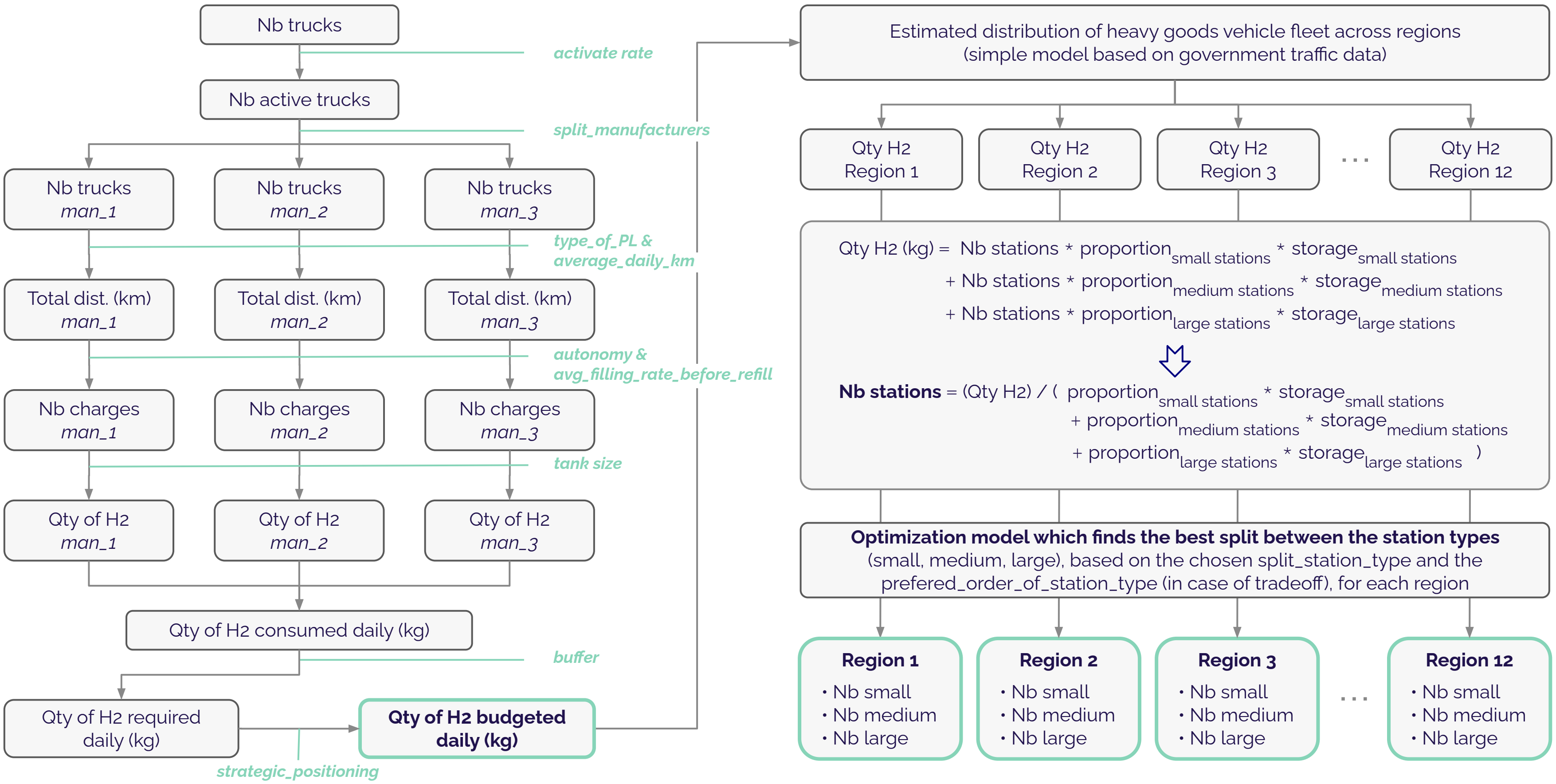
```
manufacturers_desc = {
      'man_1': {'name': 'Daimler Truck & Volvo', 'prototype': 'GenH2 Truck', 'technology': 'Hydrogen fuel cell'
    , 'man_2': {'name': 'DAF', 'prototype': 'XF, XG and XG+', 'technology': 'Internal combustion','tank_size':
    , 'man_3': {'name': 'Iveco & Nikola & Hyundai', 'prototype': 'Nikola TRE', 'technology': 'Hydrogen fuel cel
}

stations_desc = {
      'small': {'capex': 3*10**6, 'depreciation': 15, 'yearly_opex': 0.10, 'storage_onsite': 2000, 'constructio
      'medium': {'capex': 5*10**6, 'depreciation': 15, 'yearly_opex': 0.08, 'storage_onsite': 3000, 'constructi
      'large': {'capex': 8*10**6, 'depreciation': 15, 'yearly_opex': 0.07, 'storage_onsite': 4000, 'constructio
}

parameters = {
      'year': 2030
    , 'nb_trucks': 10000
    , 'manufacturers_desc': manufacturers_desc
    , 'split_manufacturer': {'man_1': 0.4, 'man_2': 0.4, 'man_3': 0.2}
    , 'activation_rate': 0.8
    , 'avg_daily_km': {'short-distance': 290, 'long-distance': 458}
    , 'stations_desc': stations_desc
    , 'split_station_type': {'small': 1/2, 'medium': 1/3, 'large': 1/6}
    , 'average_tank_filling_rate_before_refill': 0.2
    , 'security_buffer': 0.2
    , 'strategic_positioning_index': 1
    , 'prefered_order_of_station_type': ['small', 'medium', 'large']
```

region	quantity_h2_to_reach	quantity_h2_proposed	small	medium	large	total
Auvergne-Rhône-Alpes	62993	64000	12	8	4	24
Bourgogne-Franche-Comté	26739	28000	6	4	1	11
Bretagne	11219	12000	3	2	0	5
Centre-Val de Loire	11978	12000	3	2	0	5
Grand Est	25802	26000	5	4	1	10
Hauts-de-France	14583	15000	4	1	1	6
Normandie	14007	15000	4	1	1	6
Nouvelle-Aquitaine	31159	32000	6	4	2	12
Occitanie	23645	24000	4	4	1	9
Pays de la Loire	10352	11000	2	1	1	4
Provence-Alpes-Côte d'Azur	12228	13000	3	1	1	5
Île-de-France	33274	34000	7	4	2	13
Total	277979	286000	59	36	15	110

H2 TRUCK CHARGING STATIONS NETWORK MODEL IN DETAILS



```python
national_strategy = size_the_network.define_best_national_strategy(parameters=parameters,
                                                                  manufacturers_desc=manufacturers_desc,
                                                                  stations_desc=stations_desc,
                                                                  verbose=True)
national_strategy
```

✓ 0.2s

```
Estimated number of H2 trucks in 2030: 10000

Number of daily active H2 trucks (activation_rate: 0.8)
  - Man.1 (Daimler Truck & Volvo): 3200 (40.0%)
  - Man.2 (DAF): 3200 (40.0%)
  - Man.3 (Iveco & Nikola & Hyundai): 1600 (20.0%)
  - Total: 8000

Distance travelled daily based on the type of PL (in km, short-distance: 290; long-distance: 458)
  - Man.1: 1465600
  - Man.2: 928000
  - Man.3: 732800
  - Total: 3126400

Actualised autonomy of a truck (in km, average_tank_filling_rate_before_refill = 0.2)
  - Man.1: 800
  - Man.2: 120
  - Man.3: 320

Number of necessary daily charges for a truck:
  - Man.1: 0.57
  - Man.2: 2.42
  - Man.3: 1.43

Daily consumed quantity of H2 (in kg)
  - Man.1: 145920 (tank_size: 80)
  - Man.2: 27360 (tank_size: 15)
  - Man.3: 58368 (tank_size: 32)
  - Total: 231648

Daily required quantity of H2 (in kg, with a security buffer of 20%)
  - Total: 277977.6

Daily budgeted quantity of H2 (in kg, with a strategic positioning index of 1)
  - Total: 277978
```

```
Estimated number of stations needed
  - Small: 52.5
  - Medium: 35.0
  - Large: 17.5
  - Total: 105

First proposition - number of stations
  - Small: 53
  - Medium: 36
  - Large: 18
First proposition - quantity of H2: 286000

> Performing optimization...
> Optimization done!

Final number of stations
  - Small: 53
  - Medium: 35
  - Large: 17

Quantity of H2 to reach: 277978
Proposed quantity of H2: 279000
```

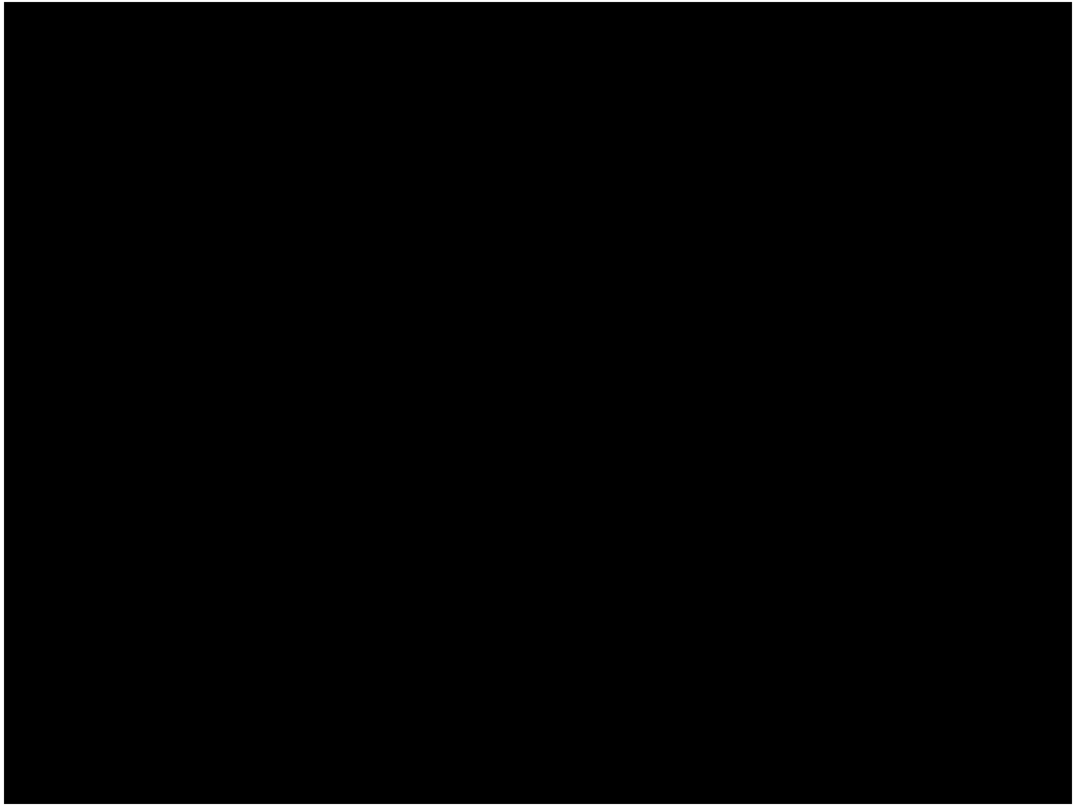
	region	quantity_h2_to_reach	quantity_h2_proposed	small	medium	large	total
0	Total	277978	279000	53	35	17	105

```python
regional_strategies = size_the_network.define_best_regional_strategies(parameters=parameters,
                                                                        manufacturers_desc=manufacturers_desc,
                                                                        stations_desc=stations_desc,
                                                                        region_breakdown=region_breakdown,
                                                                        verbose=False)
regional_strategies
```

✓ 0.0s

	region	quantity_h2_to_reach	quantity_h2_proposed	small	medium	large	total
0	Auvergne-Rhône-Alpes	62993	64000	12	8	4	24
1	Bourgogne-Franche-Comté	26739	28000	6	4	1	11
2	Bretagne	11219	12000	3	2	0	5
3	Centre-Val de Loire	11978	12000	3	2	0	5
4	Grand Est	25802	26000	5	4	1	10
5	Hauts-de-France	14583	15000	4	1	1	6
6	Normandie	14007	15000	4	1	1	6
7	Nouvelle-Aquitaine	31159	32000	6	4	2	12
8	Occitanie	23645	24000	4	4	1	9
9	Pays de la Loire	10352	11000	2	1	1	4
10	Provence-Alpes-Côte d'Azur	12228	13000	3	1	1	5
11	Île-de-France	33274	34000	7	4	2	13
12	Total	277979	286000	59	36	15	110

Visualisation of Scenarios and H2 stations per region



5 panels :

Description of the steps & positions taken

- Number of stations per region for the scenarios
- Optimal locations of H2 stations
- Competition strategies
- Optimal location of H2 production plants

BASED ON AIR LIQUIDIC STRATEGIC POSITIONING, WE IDENTIFIED THREE SCENARIOS

Here, we considered a setup with those parameters:

- nb_trucks: 10k (2030) and 60k (2040)
- activation_rate: 80% - security_buffer: 20%
- manufacturer_split: {'man_1': 1/3, 'man_2': 1/3, 'man_3': 1/3}
- station_split: {'small': 1/2, 'medium': 1/3, 'large': 1/6}

We get those results:

- 2030: 231,648 kg of H_2 → 93 stations (49 small, 34 medium, 10 large)
- 2040: 1,389,888 kg of H_2 → 529 stations (269 small, 178 medium, 82 large)

Conservative: Playing it Safe

Scenario description

- Low coverage of H_2 station need *strategic_positioning_index:* ***50%***
- Certainty to have high demand.
- Possible drawback : slow down of the trucks replacement.

Number of stations to build

- 2030: 47 (25 - 17 - 5)
- 2040: 265 (135 - 89 - 41)

Medium: Patiently Progressive

Scenario description

- Cover the estimated demand *strategic_positioning_index:* ***80%***
- High probability to have matching demand.
- In line with current previsions.

Number of stations to build

- 2030: 75 (40 - 27 - 10)
- 2040: 423 (215 - 142 - 66)

Bold: Visionary Leadership

Scenario description

- Plan to build more than needed *strategic_positioning_index:* ***120%***
- Less demand than offer.
- Expectations : accelerate trucks replacement and have higher number of trucks than predicted

Number of stations to build

- 2030: 111 (71 - 37 - 12)
- 2040: 635 (323 - 213 - 99)

Part 2 - Location Identification

- Identify what makes a good location for a H2 Station
- Find best spots for such stations across the country

Output of Part 1 on a region-to-region basis to get the number of different stations to build

The data

Locations of existing Total stations

Locations of major industrial areas

Mapping of the French road network

Road traffic data throughout the years

Identified locations per region

First model - Greedy Permutations

- Use “points de repères” from motorway traffic data as potential locations for stations
- Proceed on a station type basis (big then medium then small)
- Assign a “fitness” score to each PR based on profitability threshold, traffic and distance to industrial areas
- Randomly select a permutation of PRs and evaluate their total fitness, compounded by their distance to each other
- Output the “fittest” found permutation

Profitability = F (Traffic, consumption, Station type)

Point fitness = F (profitability, distance to IA)

Permutation fitness = F (point fitness, distance between points)

Greedy Permutations

- Explainability
- Customizability
- Large network

- Computational cost
- Simple approach
- Randomness

Example: Say we want 1 large, 2 medium and 2 small stations in the department 66

Big

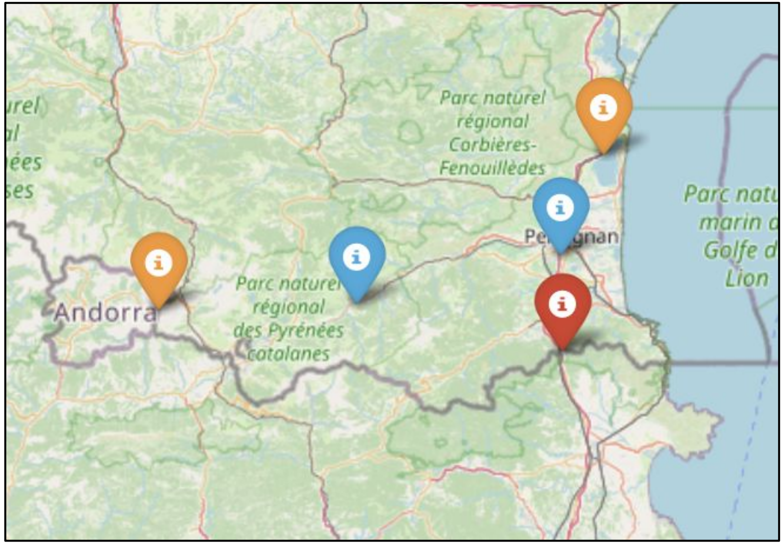
	point	coords	fitness
0	227A000911	(698585.43, 6196493.63)	1.319786

Medium

	point	coords	fitness
0	280A000966	(688911.76, 6151643.75)	1.388219
1	5N002266	(596176.86, 6161871.46)	1.855467

Small

	point	coords	fitness
0	56N011666	(641612.81, 6162697.65)	1.017484
1	255A000966	(688619.9, 6173843.4)	1.111118



Alternative model - priority based

1. Create area around each road section

Number of areas based	**H2 need based**
2. Define the number of areas you want 3. Pick the busiest road section and increase the area around it until it encompases area of france / number of areas 4. Do the same for the next busiest road section that is not in the previous area 5. Iterate until you have the number of areas you want 6. For each area, determine the center and pick the closest existing station	2. Define the weight of H2 you want to serve 3. Pick the busiest road section and increase the area around it until it encompases the maximum traffic servable by the chosen station size 4. Do the same for the next busiest road section that is not in the previous area 5. Iterate until all the weight can be served 6. For each area, determine the center and pick the closest existing station

Competition Scenarios & Strategies (Part 3)

3 cases :

1. Monopoly :
   - Define priorities on the charging stations for deployment plan without competition
   - Estimate frequency of usage & revenues/cost of each station
   - Adapt to the scenarios of part 1
2. Duopoly :
   - Market shares ?
   - Find competition strategy : aggressive/complementary.
3. Late entrant :
   - Apply Monopoly strategy for incumbent & see the potential barriers to entry / network effect
   - Choose a strategy same than 2 and see if possibility to generate revenues.

Important factors:

- Best location for stations (part 2) & deployment strat (part 1)
- Total revenue from the strategy & individual revenue from stations (ranking)
- Model the decision of other player (maybe RL ?) Game Theory

Part 3 Methodology for each scenario

Monopoly

Same model than for part 2

Set priority to have a timed deployment plan

Implement return on investment needs

Define time steps for re-estimation of the trucks deployment & therefore of our station development plan

Duopoly

Same MARL model

Possible to set the type of strategy for both players by modifying reward.

Each player is updating 1 or n limited stations per round

Both players start at the same point

Strategy will be similar for both

Late Entrant

Only the entrant strategy is chosen.

The incumbent already have N stations and a plan to convert/build some N others in K years

Set N and estimate potential profitability

Time threshold for entrance

Part 3 Duopoly & Entrant Scenarios

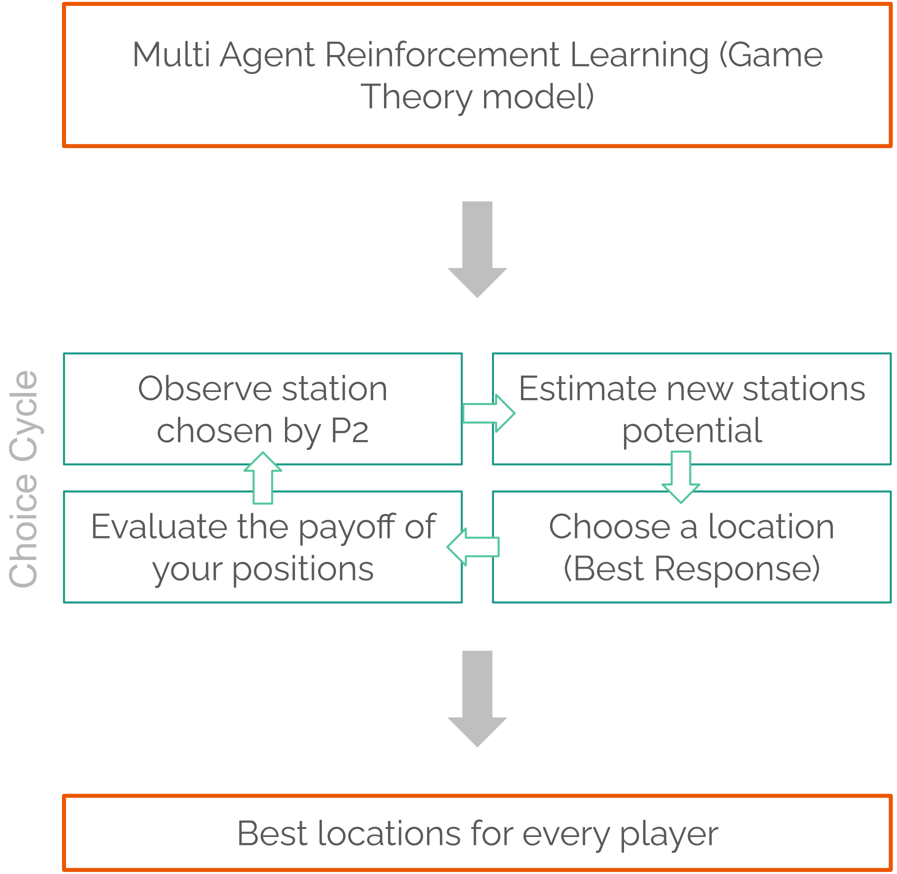
Flexibility :

Type of competition :

- Aggressive (reward if the other loses payoff)
- Pacific (reward if we are not exposed to competition)

Other features :

- Number of stations chosen per round
- Max date for rentability
- Coverage of total space
- Pattern of H2 trucks deployment over time
- H2 price evolution
- Market shares = means to deploy



Part 4 Localization of the H2 production infrastructure

- Use the same architecture as the model for part 2 - greedy permutations
- Define new fitness metric customized for station location
- Use different dataset of points for identification (grid, industrial areas…)