POLITECNICO
MILANO 1863

Planning of fast charging stations along island roads

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atlante
FASTCHARGING ON-THE-GO

2022

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FASTCHARGING ON-THE-GO

Leading the way towards electrical mobility

NHΩA

FROM TECHNOLOGY PROVIDER, **TO OWNER AND OPERATOR**

NHΩA

OWNER & OPERATOR NETWORK DEVELOPER AND STORAGE SYSTEM INTEGRATOR

eSolutions Free2move

INDUSTRIAL SPONSOR AND CHARGING TECHNOLOGY PROVIDER

UNPARALLELED FAST TRACK DEVELOPMENT

UNIQUE ACCESS IN EU TO:

- STELLANTIS DEALERSHIP NETWORK
- CUSTOMERS: 25% MARKET SHARE IN EU (1)

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FASTCHARGING ON-THE-GO

European Commission

100%

ZERO-EMISSION CARS IN 2035

60KM

CHARGING POINTS MAX DISTANCE

STELLANTIS

PREFERRED NETWORK

(1) Source: Stellantis First Half 2021 Results – Aug 3, 2021

ATLANTE AMBITION

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First network "on-the-go" of fast chargers along Italy, Spain, France and Portugal

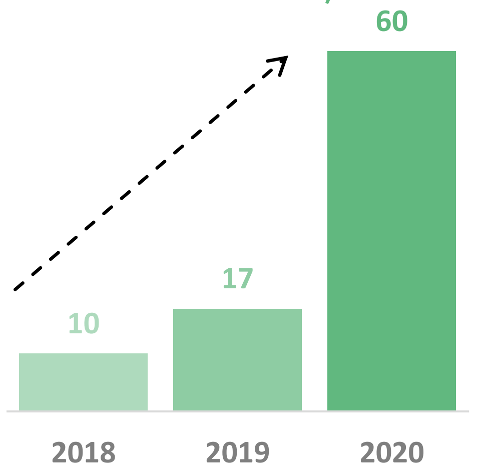
2025		2030		MARKET SHARE
5,000 Fastchargers	**1,500** Locations	**35,000** Fastchargers	**9,000** Locations	**15%** in Southern Europe

A bit of context about electrical mobility

2020

The electric car market was grown by more than 150% in 2020 with respect to 2019

Nº OF ELECTRIC CARS SOLD IN SPAIN (IN THOUSANDS)



2030

Main car manufacturers are planning to eventually dedicate all of their production chain to produce only 100% electric cars

2032

Aproximatedly 50% of all sold cars will be electric

2035

From the reforms "**Fit for 55**", the European comisión has set the target of 100% production of zero-emisión cars

Introduction of the methodology

CHARGER LOCATION PROBLEM

1. How many chargers have to be installed each year to allow the electrification of the car parc in a certain amount of years?

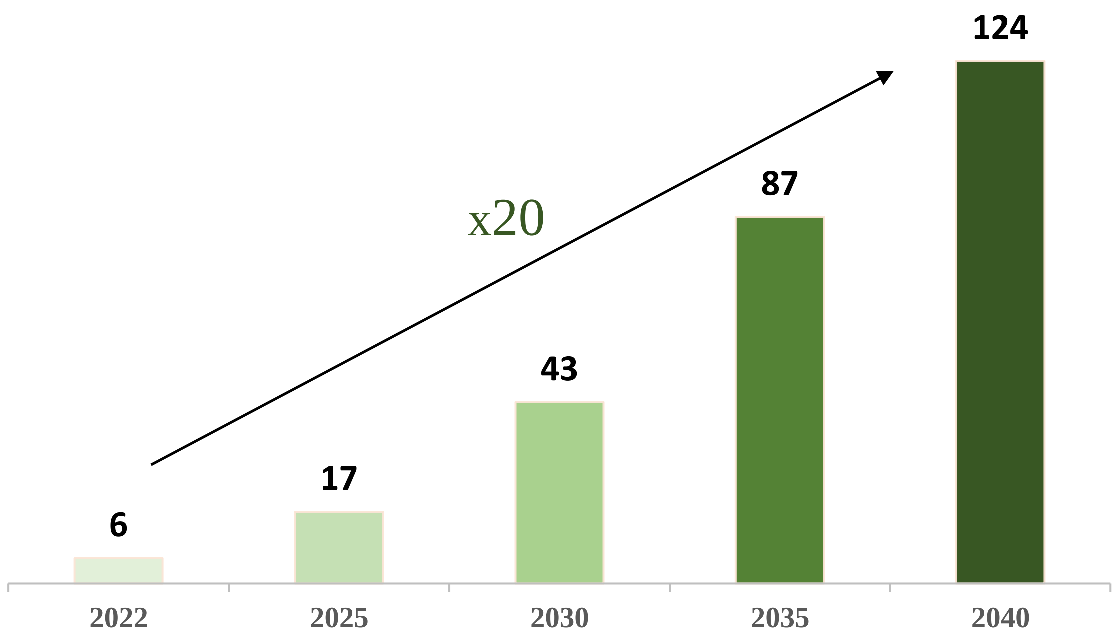
2. Where should they be located?

Simulation to analyse charging demand based on traffic flows, statistical analysis of available car parc data and road network.

Station deployment plan geographic and temporal

CASE STUDY: Electrification of Lanzarote

Electric cars in Lanzarote (in thousands)



Font: Estrategia del vehículo eléctrico de Canarias

AMBITION

100%

ELECTRIC

by 2040

Methodology

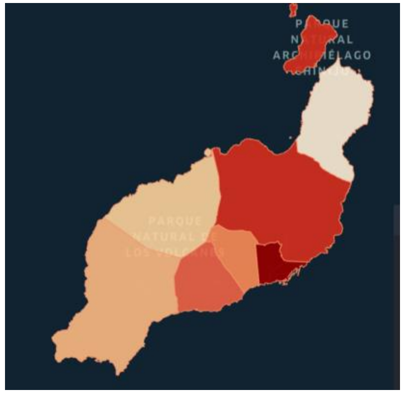
1) Identification of input data (TOM TOM traffic data), road network, POIs, demographics.

2) Data processing on QGIS, fastest path for O/D matrix

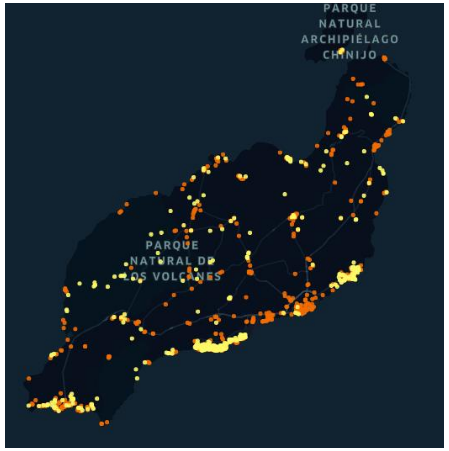
3) MILP optimization in MATLAB, simulating driving behaviour starting from O/D data and network of fastest paths calculated in QGIS.

4) Probabilistic analysis of the charging necessity in each population nucleus.

Population by regions



Main POI's



INPUT DATA

Geographical data
Regional limits
Main population nucleus
Road network (Length and maximum speed of each road)

Traffic data
O/D matrix between main population nucleus

Car parc
Amount of Electric vehicles each year.
Share of small, medium and large cars in the island, average consumption and battery size.

O/D traffic matrix from TOMTOM

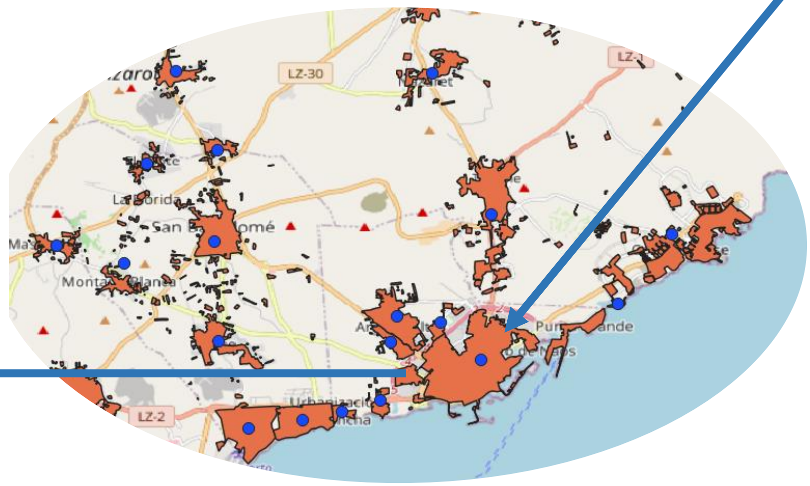
Main population nucleus

Traffic on road network

QGIS fastest paths network

Input

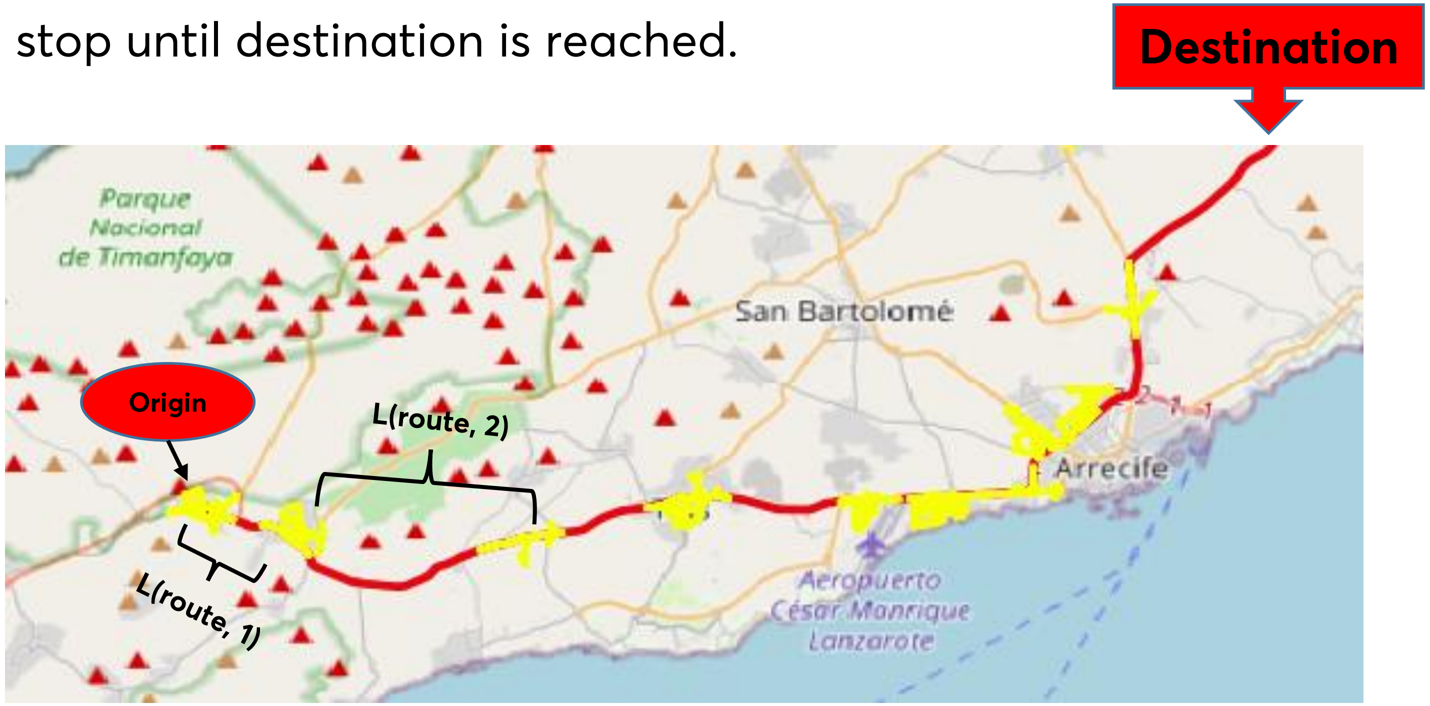
- Coordinates of origin and destination points→ The centroid of each population nucleus represents an O/D point
- A charging station can be placed at any O/D point and it covers a service area of 1.5 km.
  1.5km is considered the maximum distance someone deviates from their route to charge



78 population nucleus are considered, in total 6084 routes to cover all posible trips in the island

Output

- Fastest paths between all O/D pairs, (based on length and máximum speed allowed on the road)
- Possible stops along each route. Candidate stations are found where service areas intersect with the roads along the route.
- Length between each stop until destination is reached.



Driver simulation in MATLAB

Mixed interger linear optimization

Goal

To simulate EV driver behaviour in order to understand where to place charging stations and to capture the highest possible demand while covering all routes in the island.

Input

From QGIS fastest path tool

1) O/D route matrix, candidate stations that covered each route in the island.
2) O/D distances matrix, distance between all the posible stops in a route.

From TOMTOM O/D stats data.

1) Traffic in each route.

Assumptions

1) A route is considered covered if it can be done back and forth without the battery reaching a SOC lower than 10%
2) The car can charge at any stop identified in QGIS along the route, this meant that all population nucleus where candidate stations.

MILP parameters and variables

Parameters
j: routes in O/D matrix
i: nodes in each route (candidate stations)
R(i,j): Matrix with the nodes i that cover a certain route j.
L(j,i): distance between node i+1 and i in route j (input from QGIS)
Cap = battery capacity of the EV
Cons = average consumption of the EV

Variables
SOC_a(i,j): State of charge of the EV battery when arriving to a stop i along route j.
SOC_d(i,j): State of charge of the EV when leaving the stop i along route j.
E(i,j): Amount of battery charged in each stop.
S(i,j): binary variable, 1 if a charging station should be located at a certain stop; 0 if no one stops at node i, route j.

Formulation of the problem

Constraints

[1] $0.1 \leq \mathrm{SOC_a}(\mathrm{j},\mathrm{i}) \leq 1$
[2] $0.1 \leq \mathrm{SOC_d}(\mathrm{j},\mathrm{i}) \leq 1$
[3] $0.5 * \mathrm{S}\,(\mathrm{j},\mathrm{i}) \leq \mathrm{E}\,(\mathrm{j},\mathrm{i}) \leq \mathrm{S}\,(\mathrm{j},\mathrm{i})$
[4] $SOC_a(j,1) = SOC_o$
[5] $SOC_a(j,i+1) = S0C_d(j,i) - L(j,i) * \frac{Cons}{Cap}$
[6] $SOC_d(j,i) = SOC_a(j,i) + E(j,i)$

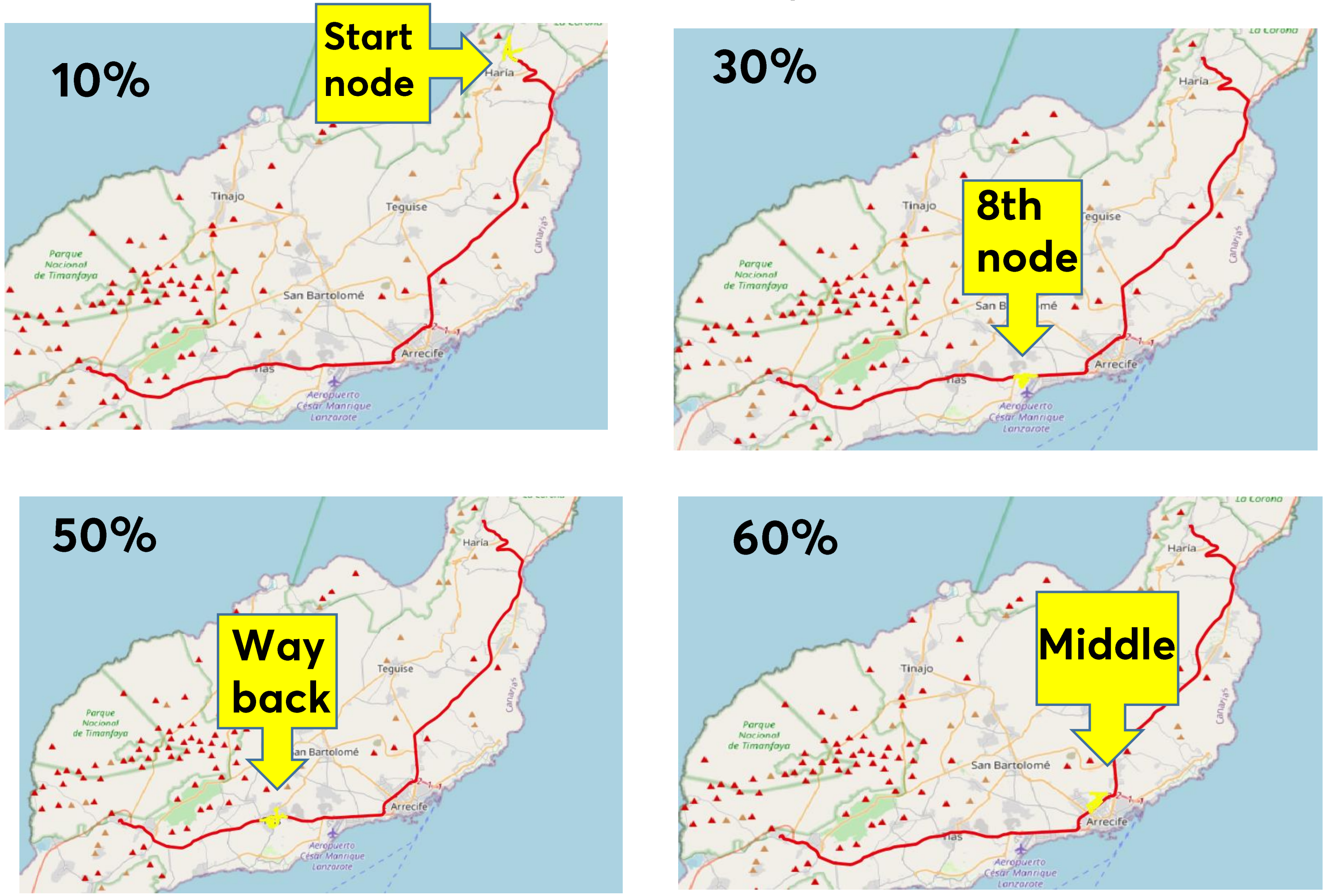
[1] and [2] SOC can't go lower than 10% or the route is not covered and is limited to 100%.
[3] The minimum a person can charge the battery is 50% each time they stop.
[4] The Initial SOC for each route is set
[5] The SOC decreases proportionally to the distance between stops and the average car consumption
[6] The SOC increases from arrival to departure when the car is charged at a stop.

Objective function

$$\mathrm{OF} = \min\left(\sum_{j=1}^{routes}\sum_{i=1}^{stops} \mathrm{E(j,i)}\right)$$

The objective funciton is to minimize the amount of energy charged at all nodes and routes.

Optimal location according to initial SOC



- **This results were obtained for: all routes and all initial SOC [10-100%]**
- **They served as input to identify most trafficated nodes.**

Statistical generation of traffic profiles.

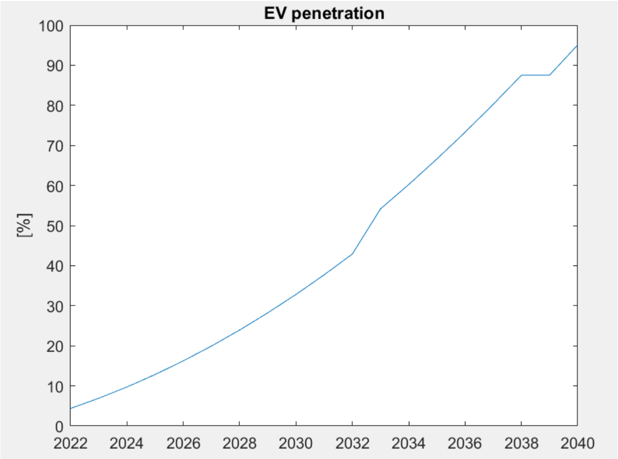
Loop for traffic simulation → Average of 100 typical days

Inputs

- Average traffic on peak hour on each route
- EV penetration on total car parc on each year
- Results from MILP in Matlab→Energy charged in each stop for every route and for a car starting with a SOC_o:

$$0{,}95 * SOC_o \leq \; SOC_a(j,1) \leq 1{,}05 * SOC_o$$

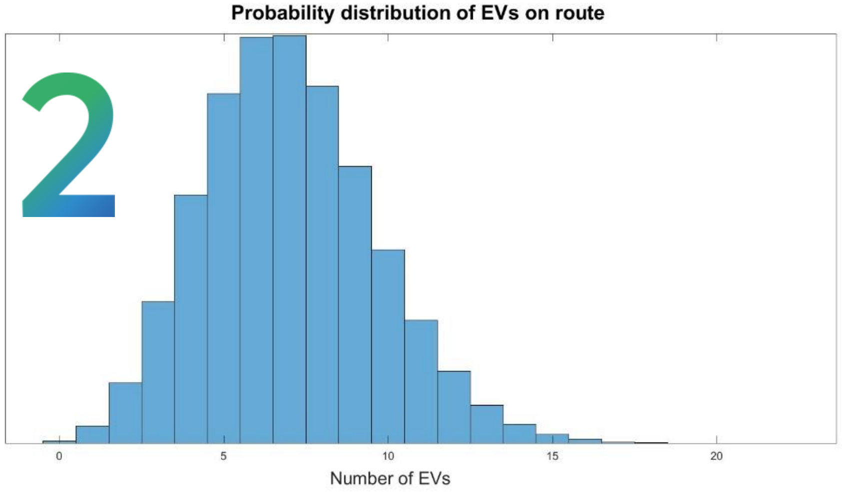
1



1) **Generation of traffic on a typical day.**
Average traffic on each route at peak hour is multiplied by EV penetration on that year

2) Traffic on each route is generated following a poisson distribution centered in the average daily traffic on that route.

3) The inital SOC_o is generated randomly with values between 10% and 95%.



Generation of traffic profiles

Input data about traffic on a typical day

Generation of the traffic profile on each route for a typical day

Simulation of 100 typical days each year

Average the results to get a representative day for each year

EV penetration

Average traffic of EV on all routes

Number of EV's doing the route:
Poisson distribution centered at average number of EV's

Stops according to SOC

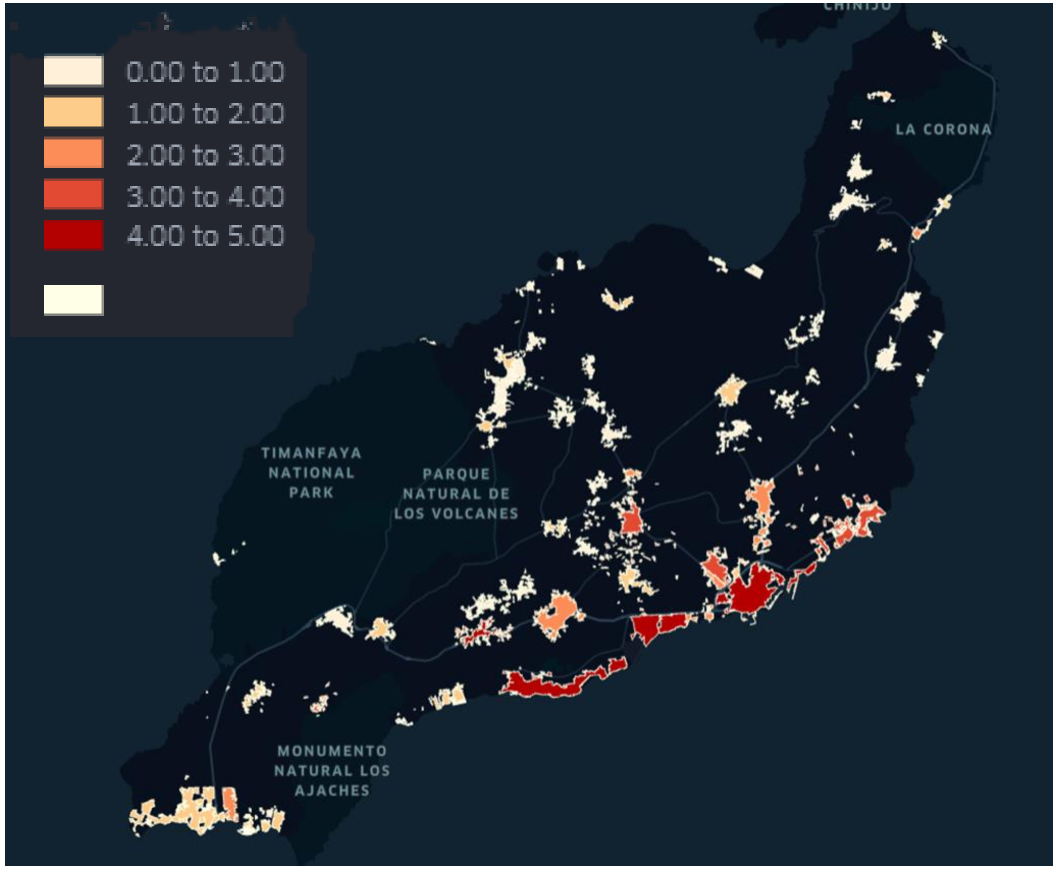
SOC of each EV at the beggining:
RANDOM GENERATION

Traffic profile on 100 typical days for each year.

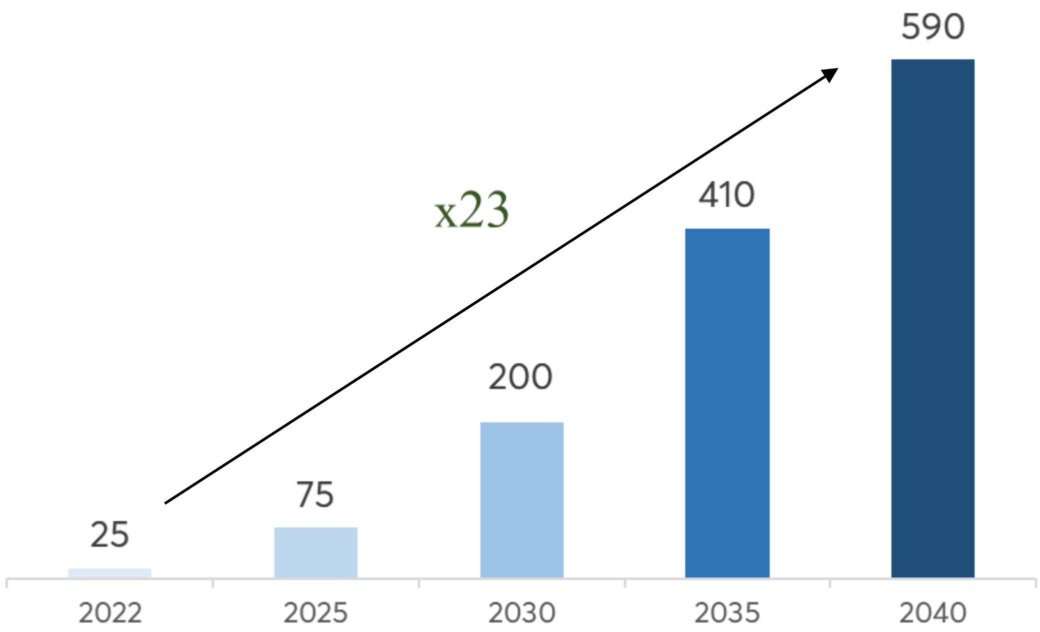
Traffic profile on a year

Results

Geographical distribution of the chargers in 2024



Estimation of fast chargers (50kW) to be installed from 2022 until 2040



Thank you for your attention!

Any questions?