Economic and Environmental Impacts of Long-Term Scenarios of Low Emissions Mobility in Spain

Jorge Fernández

Andrés Díaz Casado

Pablo Frías

7th June 2021

OBSERVATORIO DE LA MOVILIDAD ELÉCTRICA Y SOSTENIBLE

COMILLAS ICAI

Content

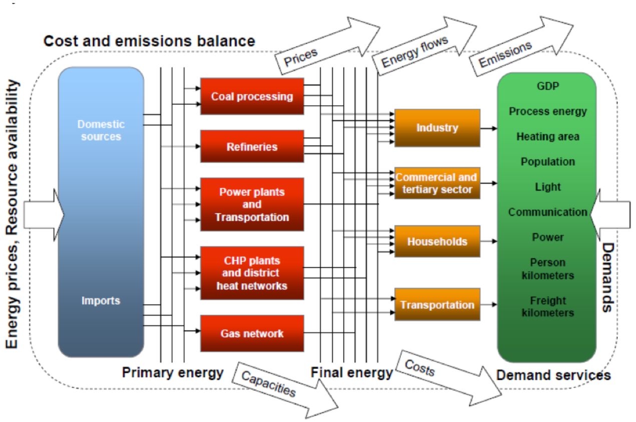
- Motivation
- Model
- Case study and results
- Conclusion and future work

Motivation: EVs are needed

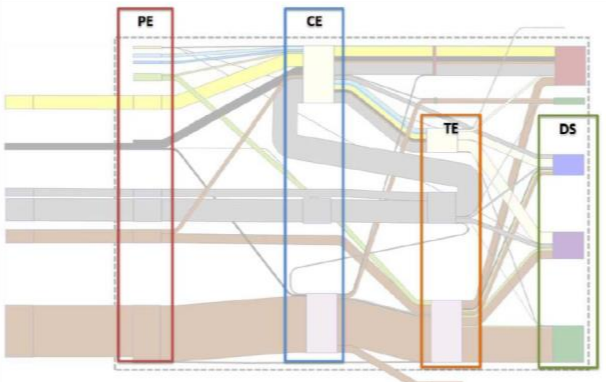
- ICE based road transport
  - Global: responsible for almost 25%*75% of CO_2 emissions
  - Local: responsible for air pollution (NO_X & PM_X) and noise
- Transition towards sustainable transportation
  - International regulation of emissions reduction: Paris Agreement, Directive (EU) 2019/1161
  - Although Technology neutral ➡ EV is a main tool towards sustainability
  - Countries and carmakers set mid and long term targets
  - But decision making is
    - On the consumer
    - On the municipalities
    - Requires detailed long term analysis including demand dynamics

Motivation: existing models

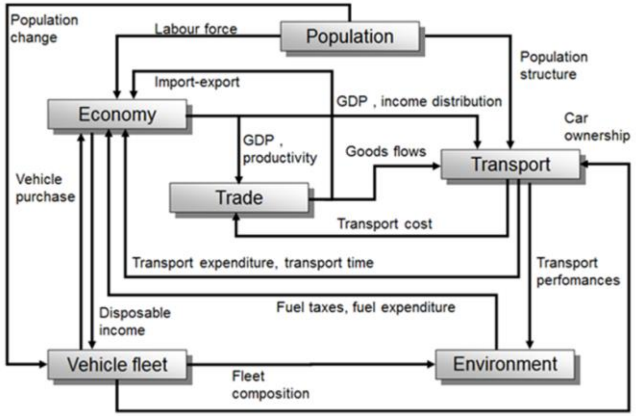
- Long term models to evaluate transport traction technology transition
  - **Energy based**:
    - Markal-TIMEs (opt. model, min cost)
    - MASTER.SO (opt. model, max welfare)
  - **Travel modelling & land use**:
    - AsTra
    - MARS



iea-etsap.org



iit.comillas.edu

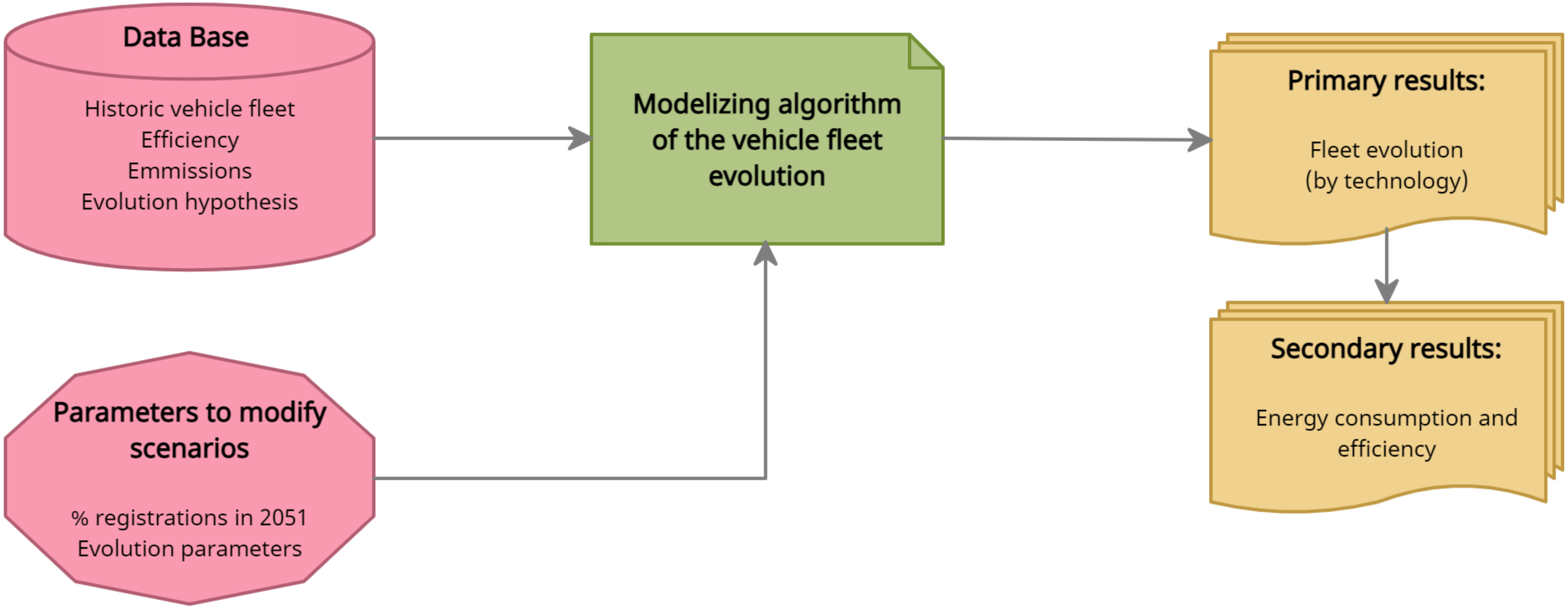


astra-model.eu

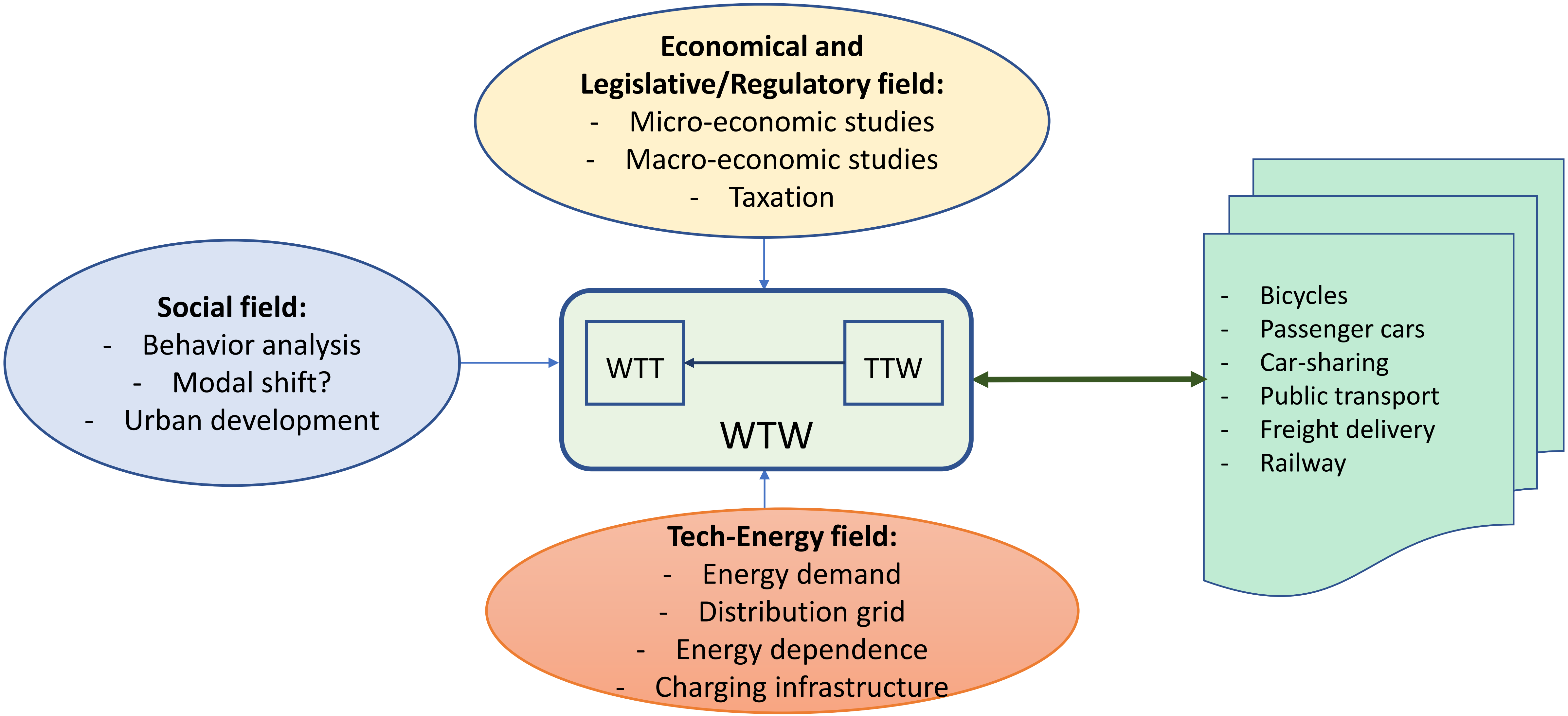
Model: introduction

- **Focus and improvements**
  - Focus on fleet-aging dynamics
  - Detailed historical data of existing fleet
  - Aging of fleet impact on characteristics and use
  - Flexible modelling to incorporate inputs from demand side and transport policies
  - Scalability and replicability
  - Open source model at evobservatory.iit.comillas.edu

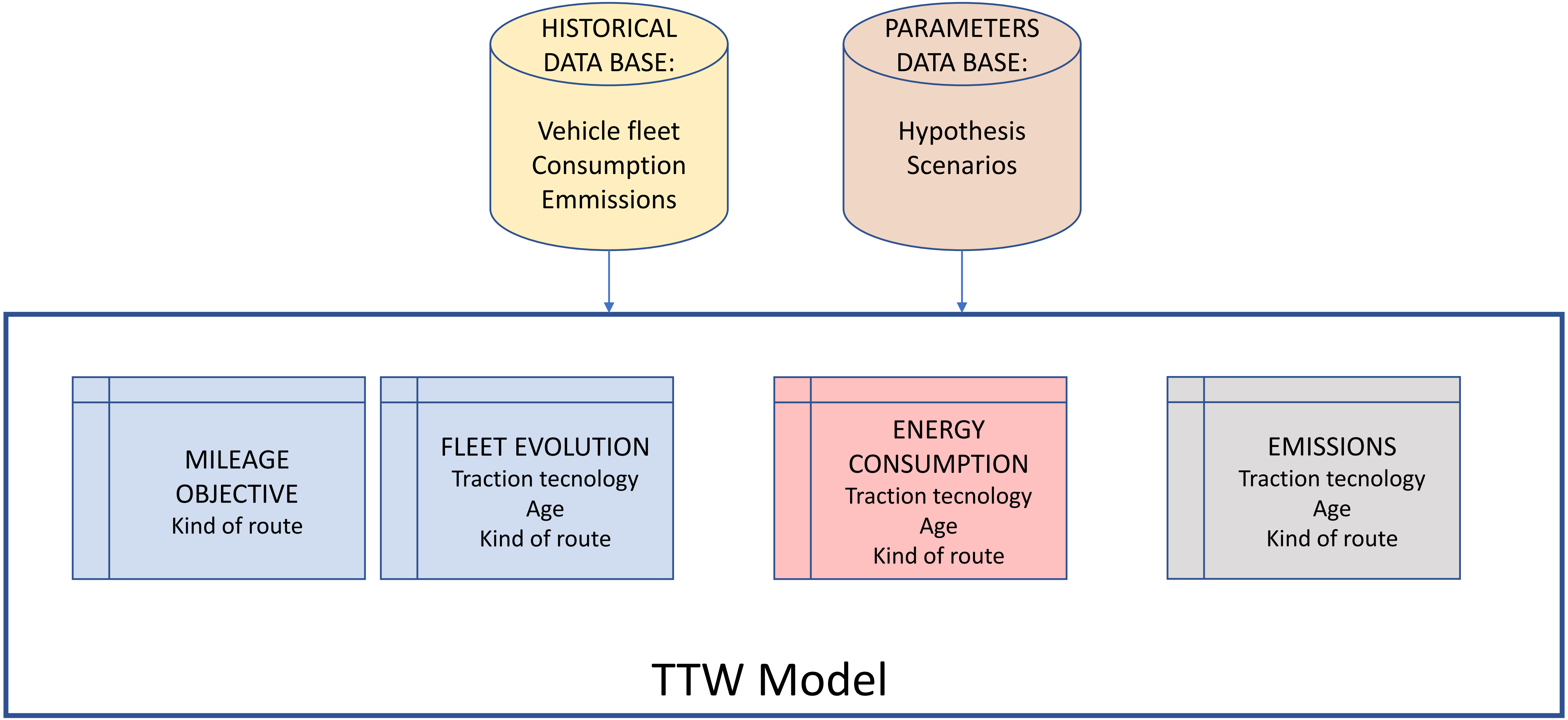
Model: structure



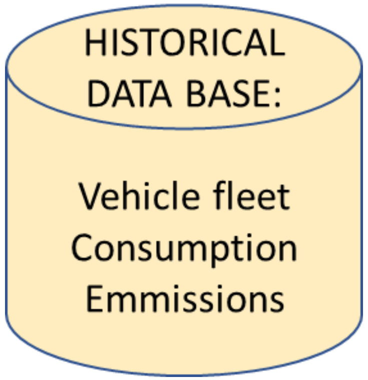
Model: structure

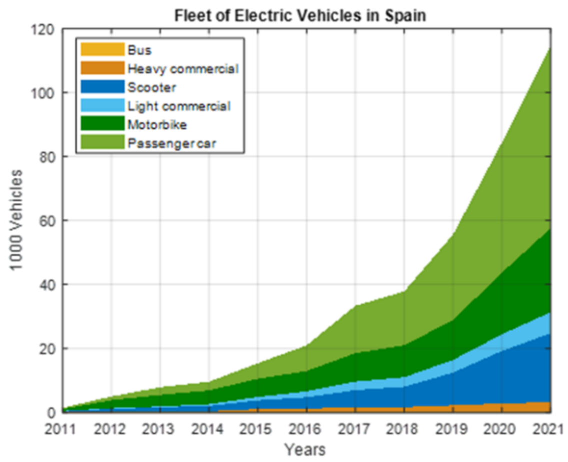


Model: mathematic formulation



Model: formulation





Fuel Type	Fuel consumption [l/100km]	CO_2 emissions [g/km]	NO_X emissions [mg/km]
Diesel	5.93	155.93	341.41
Petrol	7.31	165.16	67.35
HEV	5.96	135.60	6.55
LPG	8.81	156.90	72.01
BEV	0.00	0.00	0.00
PHEV	2.09	48.14	41.44
CNG	5.00	130.10	52.51

- Fleet evolution since 1990
  - Different types of traction technologies
- Energy consumption and emissions
  - Trends
- Use of car
  - Considering urban and road

Power generation Scenario	2020	2030	2050
RES (%)	44	68	79
Average CO_2 emissions (tCO_2/MWh)	0.154	0.059	0.035

Model: formulation

MILEAGE
OBJECTIVE
Kind of route

OPTIMIZATION

$\tau_{rep}(a)$ ← $Mileage_{OBJ}(r, t)$

Social field:
Behaviour model

Economical model

- Annual driven distance depends on the age of the vehicle:

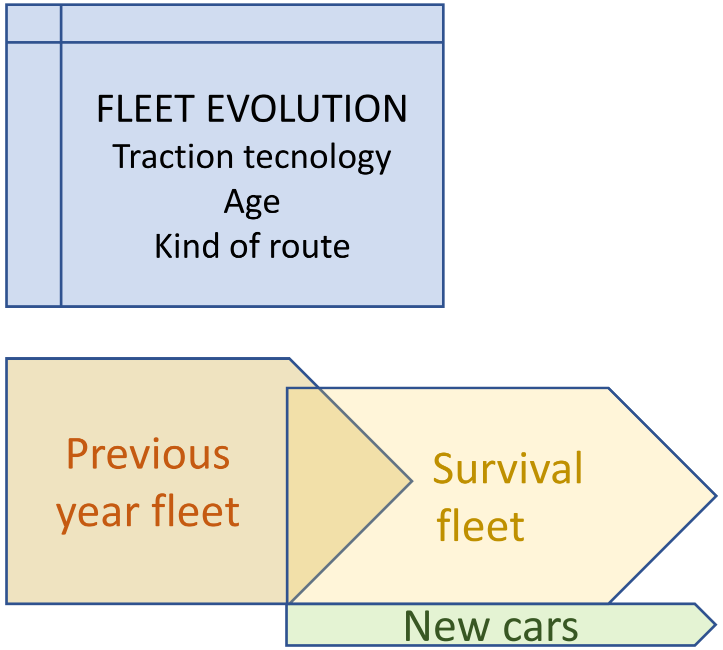
$$Mileage(m,r,a,t) = Mileage^{ref}(m,r,t) \cdot \beta_{dis}(m,r,t-a)$$

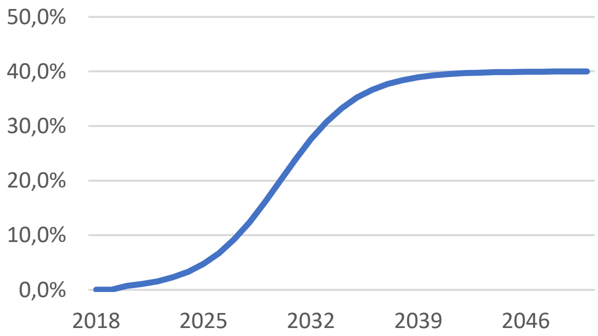
- Objective function to fit the objective driving distance for every year:

$$min \left\{ \sum_{t,r} \left(\sum_{m} Mileage_{TOT}(m,r,t) - Mileage_{OBJ}(r, t) \right)^2 \right\}$$

- The number of new cars in the year a, $\tau_{rep}(a)$ is the result of the optimization algorithm

Model: formulation





BEV sales share

- Fleet classified depending on registration year, a, and motorization, m:

$$Fleet_{TOT}(m,t) = \sum_{t} Fleet(m,a,t)$$

- Probability of being decommissioned, i_{dec}, depending on age and motorization:

$$Fleet(m,a,t) = Fleet(m,a,t-1) \cdot i_{dec}(m,t-a,t)$$

- New cars technology depending on technology maturity:

$$Fleet_{new}(m,a) = Fleet_{new}(a) \cdot \alpha_{sales}(m,a)$$

$$Fleet_{new}(a) = \sum_{m} Fleet(m,a-1) \cdot \tau_{rep}(a)$$

Model: formulation

ENERGY CONSUMPTION Traction tecnology Age Kind of route

- Energy consumption is a function of ran distance, type of driving (road, urban), motorization and age of the vehicles.
- Engine efficiency depends on age, type of route and fuel.

EMISSIONS Traction tecnology Age Kind of route

- Emmisions are a function of consumed energy:
- Emissions rate depends on age, type of route, fuel and pollutant.

RESULTS can be obtained per:

- Motor technology
- Year
- Fleet age
- Fuel
- Pollutant (CO_2, NO_X, particulates)

Model: formulation

MILEAGE OBJECTIVE
Kind of route

FLEET EVOLUTION
Traction tecnology
Age
Kind of route

ENERGY CONSUMPTION
Traction tecnology
Age
Kind of route

EMISSIONS
Traction tecnology
Age
Kind of route

TTW Model

HISTORICAL DATA BASE:

Power sector
Energy balance

PARAMETERS DATA BASE:

Hypothesis
Scenarios
RES objectives

FUEL CONSUMPTION
Gasoline
Diesel
Compresed Natural Gas
Electricity

FINAL ENERGY CONSUMPTION
Oil
Natural Gas
Electricity

PRIMARY ENERGY CONSUMPTION
Oil
Natural Gas
Nuclear
Renewables

ENERGY CONSUMPTION DUE TO RAW MATERIALS EXTRACTION

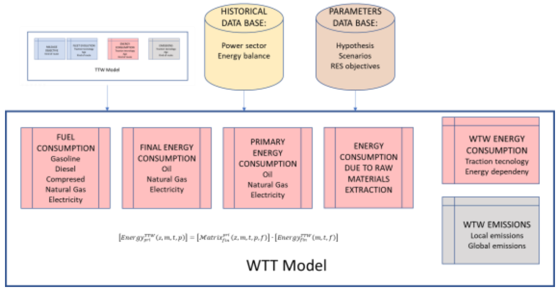
WTW ENERGY CONSUMPTION
Traction tecnology
Energy dependence

WTW EMISSIONS
Local emissions
Global emissions

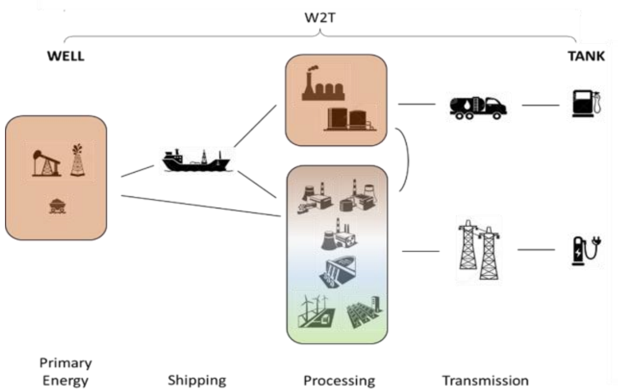
$$\left[Energy_{pri}^{TTW}(z,m,t,p)\right] = \left[Matrix_{fin}^{pri}(z,m,t,p,f)\right] \cdot \left[Energy_{fin}^{TTW}(m,t,f)\right]$$

WTT Model

Model: formulation



- Emissions and energy consumption in raw material transformation processes are computed.
- There are matrix relationships between the primary and final energies
  - Primary energy: COAL, OIL, NATURAL GAS, NUCLEAR, RENEWABLES.
  - Final energy: Gasoline, fuel oil, compressed natural gas, electricity, biofuel.
- Total **energy consumption**: addition of consumption in tranformation processes plus TTW.
- There are considered **two sources of emissions**:
  - Those due to extraction and shipping of raw material
  - Those due to transformation processes (power generation and refining)



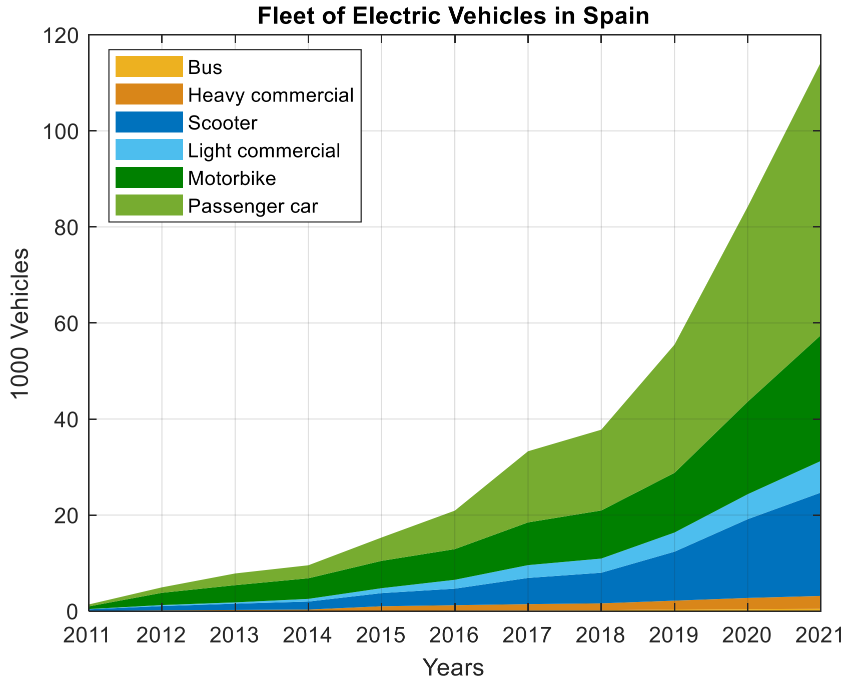
RESULTS can be obtained per:
- Motor technology
- Year
- Fleet age
- Fuel
- Pollutant (CO_2, NO_X, particulates)
- Area (domestic, imports)

OBSERVATORIO DE LA MOVILIDAD ELÉCTRICA Y SOSTENIBLE | COMILLAS ICAI

Case study

- Objectives:

- Scalability
- Replicability
- Long term dynamic performance



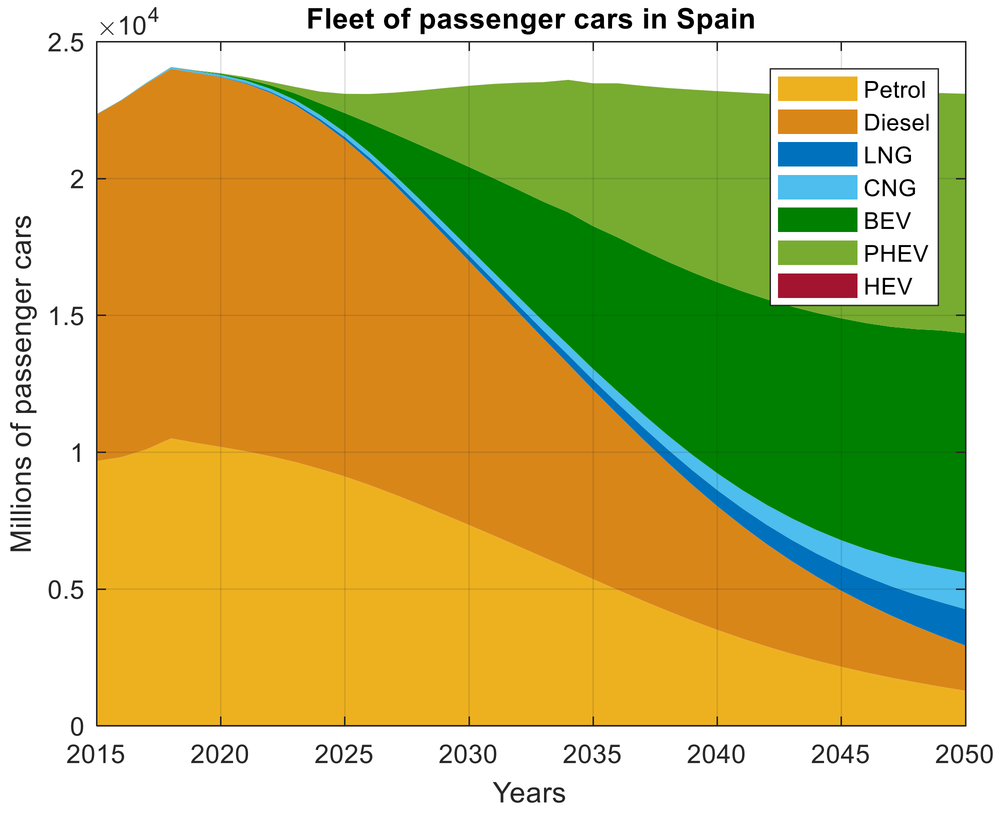
- Framework:

- **European Green Deal** Targets:
  - 55% emissions reduction from 1990 to 2030
  - transition towards zero emission transportation
- Spain's **PNIEC**:
  - 74% of RES in electricity generation for 2030
  - 5 million EV in 2030 (3 million cars)

- Main hypothesis:

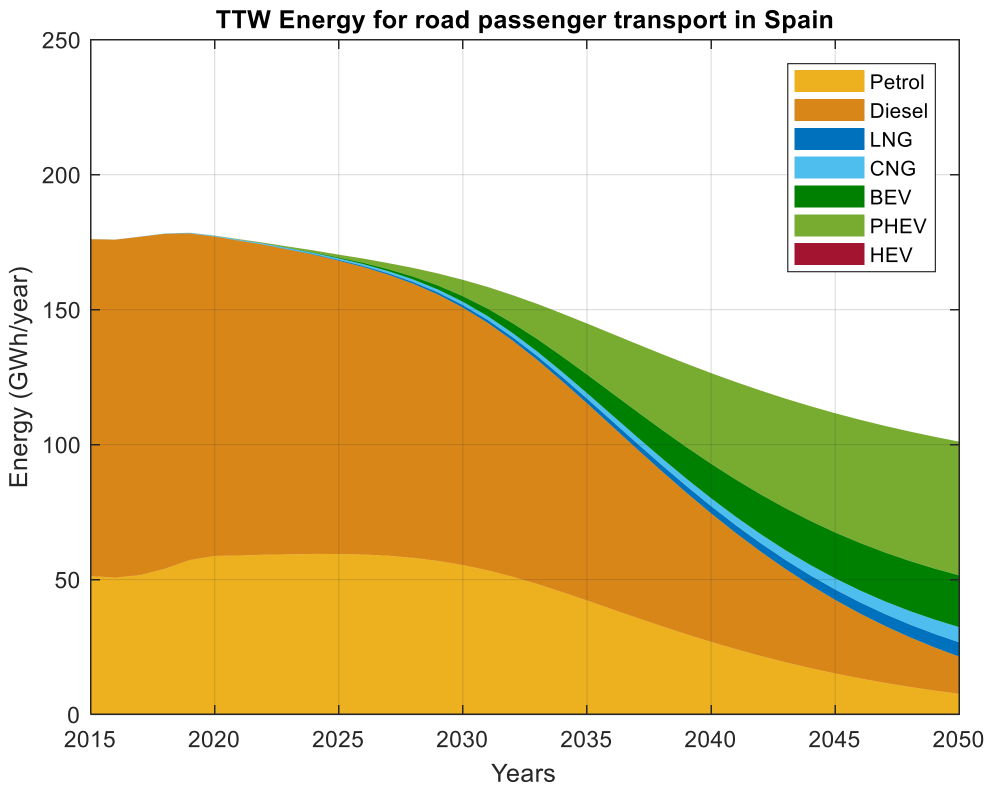
- Single intermediate scenario
- Sales EV:
  - 40% in 2030
  - 80% in 2050
- 70% of RES in electricity generation for 2030
- Steady demand on road and urban routes

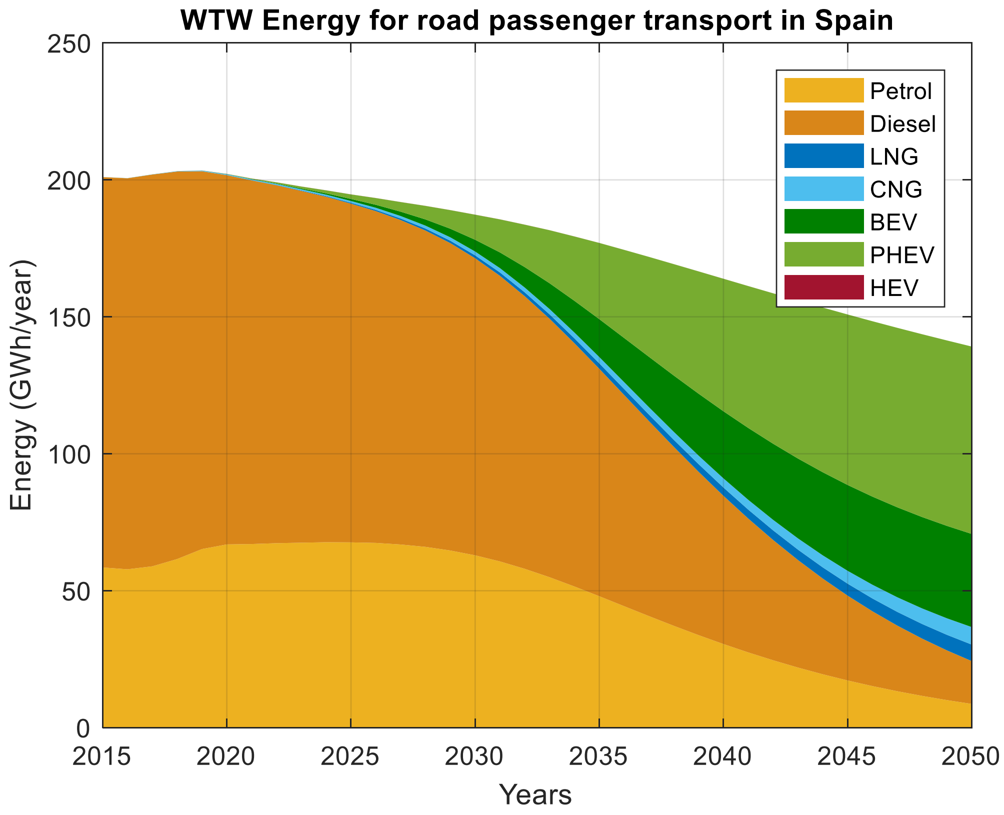
Case study results: passenger fleet



- changes in the fleet will need almost 15 years to be representative
- a full transformation of the passenger car fleet will require more than 30 years
- sales of vehicles between 1.3 and 1.5 million per year
- depending on purchasing power and needs of consumers in Spain

Case study results: energy consumption

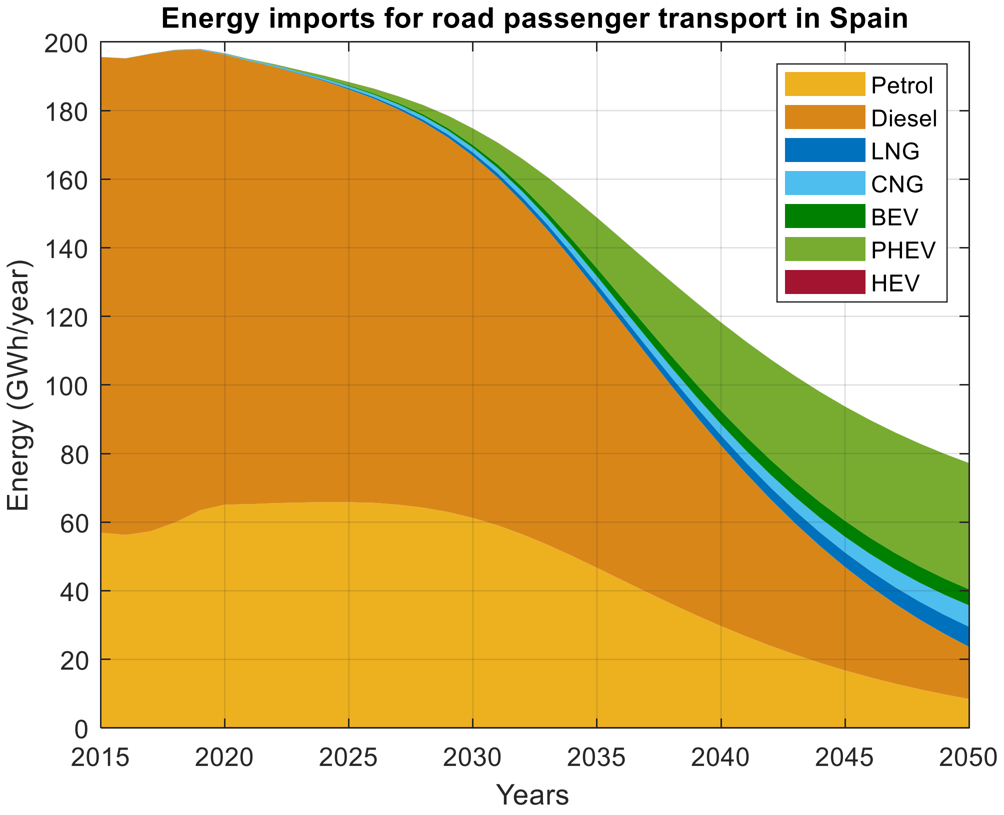


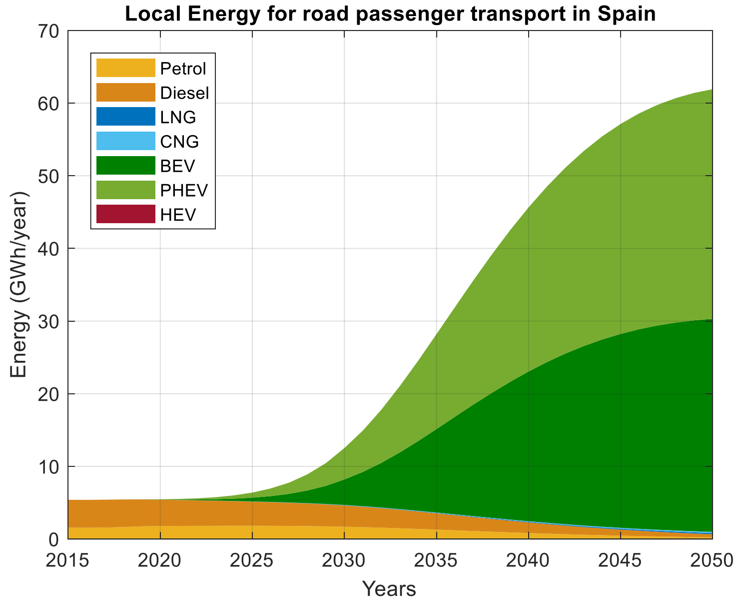


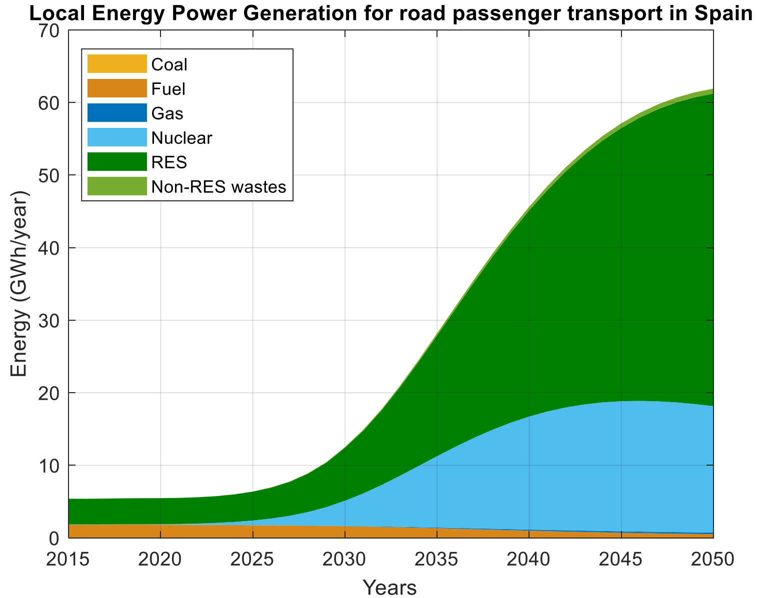
Case study results: energy consumption

OBSERVATORIO DE LA MOVILIDAD ELÉCTRICA Y SOSTENIBLE

COMILLAS ICAI

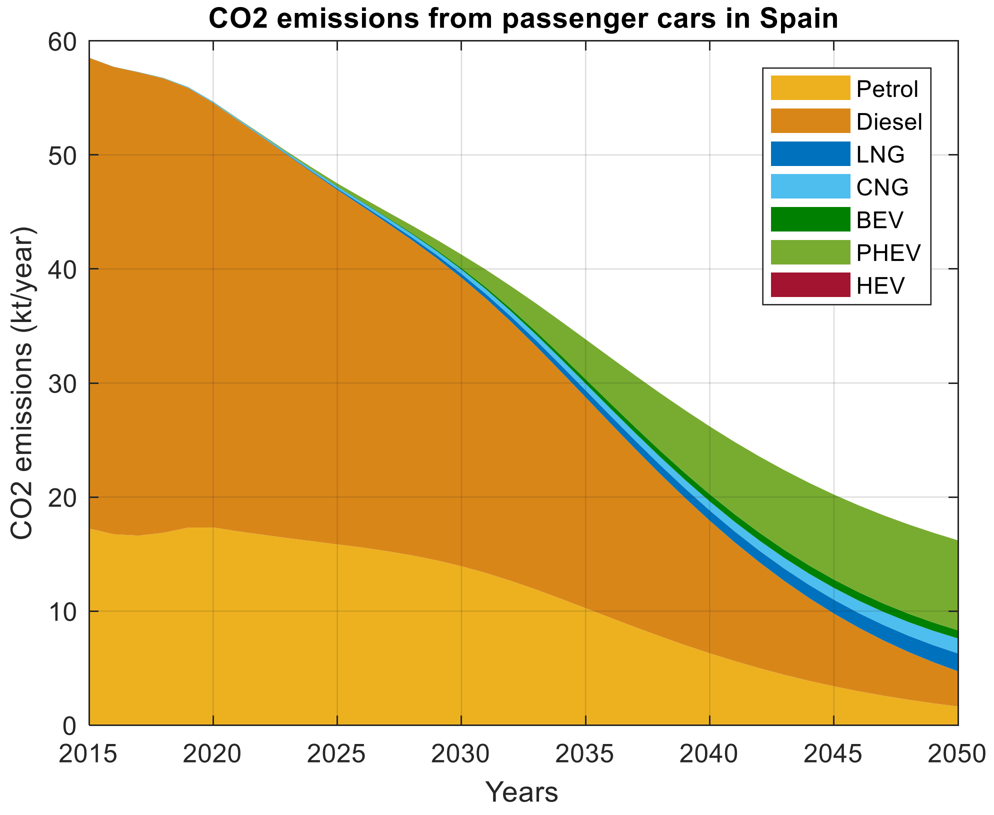


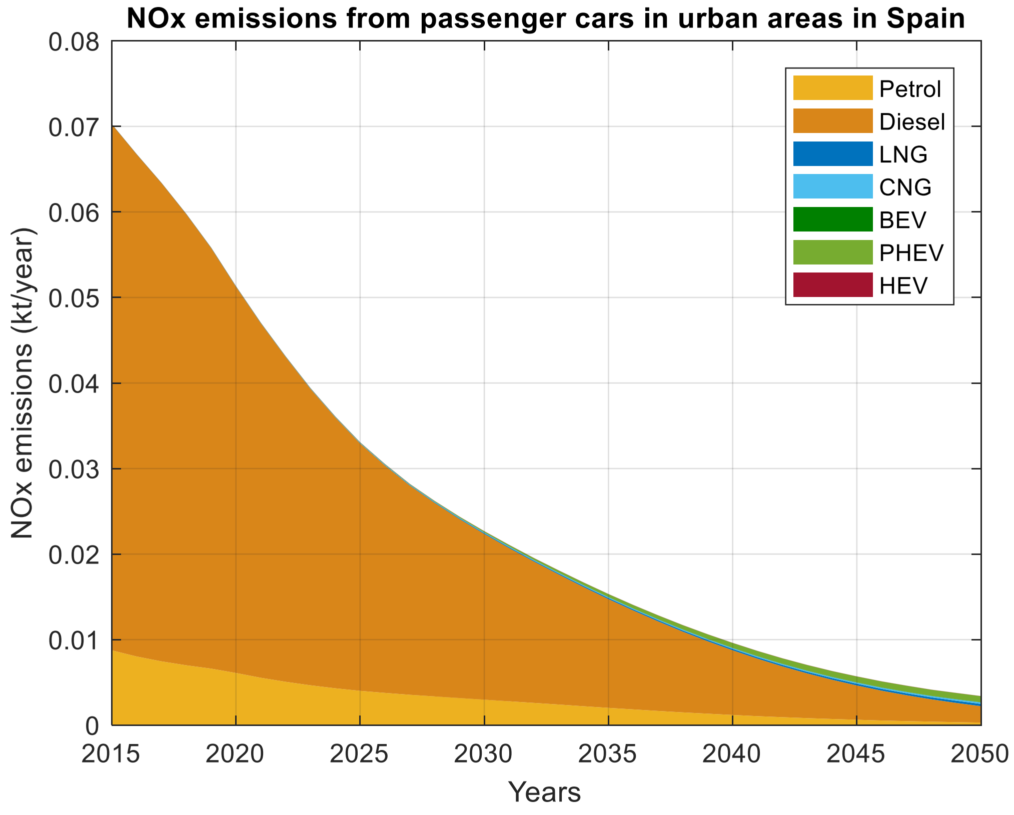




OBSERVATORIO DE LA MOVILIDAD ELÉCTRICA Y SOSTENIBLE
COMILLAS ICAI

Case study results: Emissions





Conclussions and future work

- Proposed model:
  - Allows to study **long term** economic and environmental **effects**.
  - **Power generation** is considered.
  - **Updated** technical **data**
    - fleet and technological trends
    - obtained from other studies or specialized models
- Impact and effects of the electric vehicle:
  - Transition to a sustainable transport **takes time**
  - EV **reduces dependence** on energy imports.
  - **Environmental benefits**.
  - Help to achieve strategic **European** and Spanish **targets**
- Future studies and developments:
  - **Integration of other transport alternatives**:

    Heavy trucks and busses, light commercial vehicles, motorbikes, flights, maritime and railway
  - **Coordination with other models** (economic, social)

Thank you very much!