# Economic and environmental benefits of electric vehicle smart charging in a large-scale EV integration scenario for France

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**Simona De Lauretis** (RTE, presenter), Alberto Tejeda de la Cruz (RTE), Florian Bourcier (RTE), Mathilde Françon (RTE), Cécile Goubet (AVERE-France), Cédric Léonard (RTE)

# Introduction

Massive transport electrification is an important tool for reducing both greenhouse gas emissions and air pollution :

- More than 20 countries have already announced a ban on sales of ICE cars over the next 10-30 years.
- France has put into the legislation a **ban on sales of ICE vehicles using fossil fuels by 2040**

As the French electricity transmission system operator, **RTE** has a **legal duty** to ensure **real-time adequacy** between electricity supply and demand and to **provide long-term scenario analyses** to anticipate major changes in the power system, such as the development of renewable energy sources or the massive development of e-mobility.

- RTE conducted a **large study on the integration of electric vehicles into the power system**, supported by a working group steered by AVERE-France and RTE, with the participation of a large panel of stakehoklders (energy utilities, car manufacturers, charging infrastructure providers and operators, NGOs, researchers)

# Objectives of the study

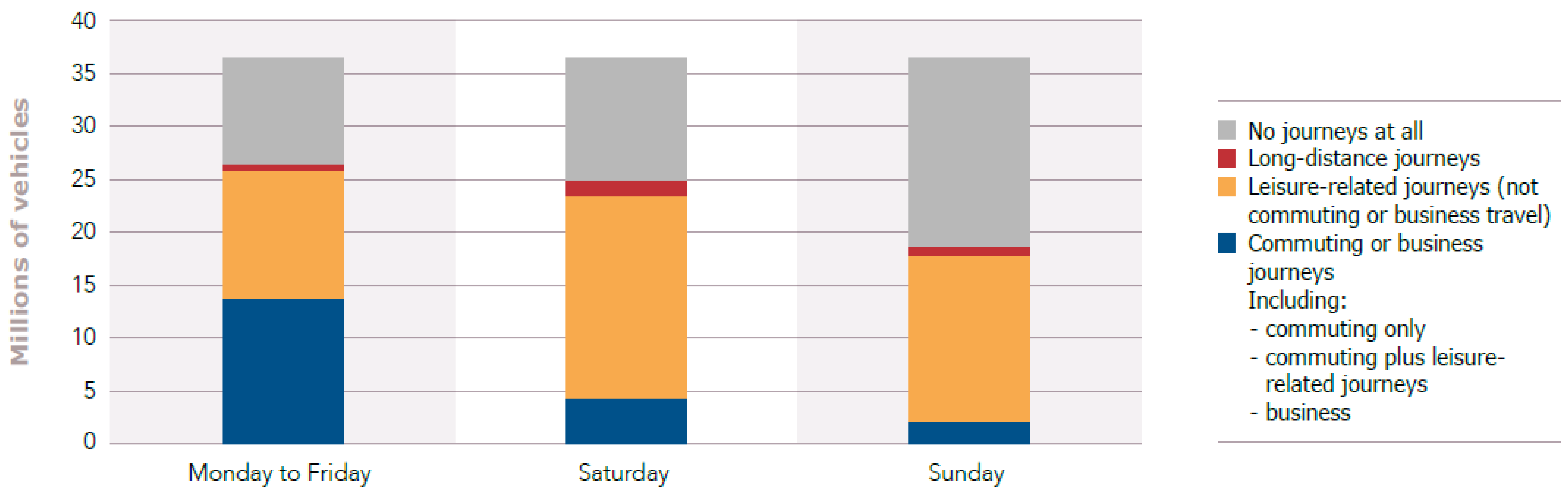
1. Analysis of the potential effects of e-mobility development on the security of electricity supply

2. Quantification of the economic and environmental implications of e-mobility

3. Analysis of the opportunities associated with smart-charging and V2G, for the power system and the consumer

# Methodology : combination of an EV-behaviour model and a power system model

## EV model (uncontrolled charging)

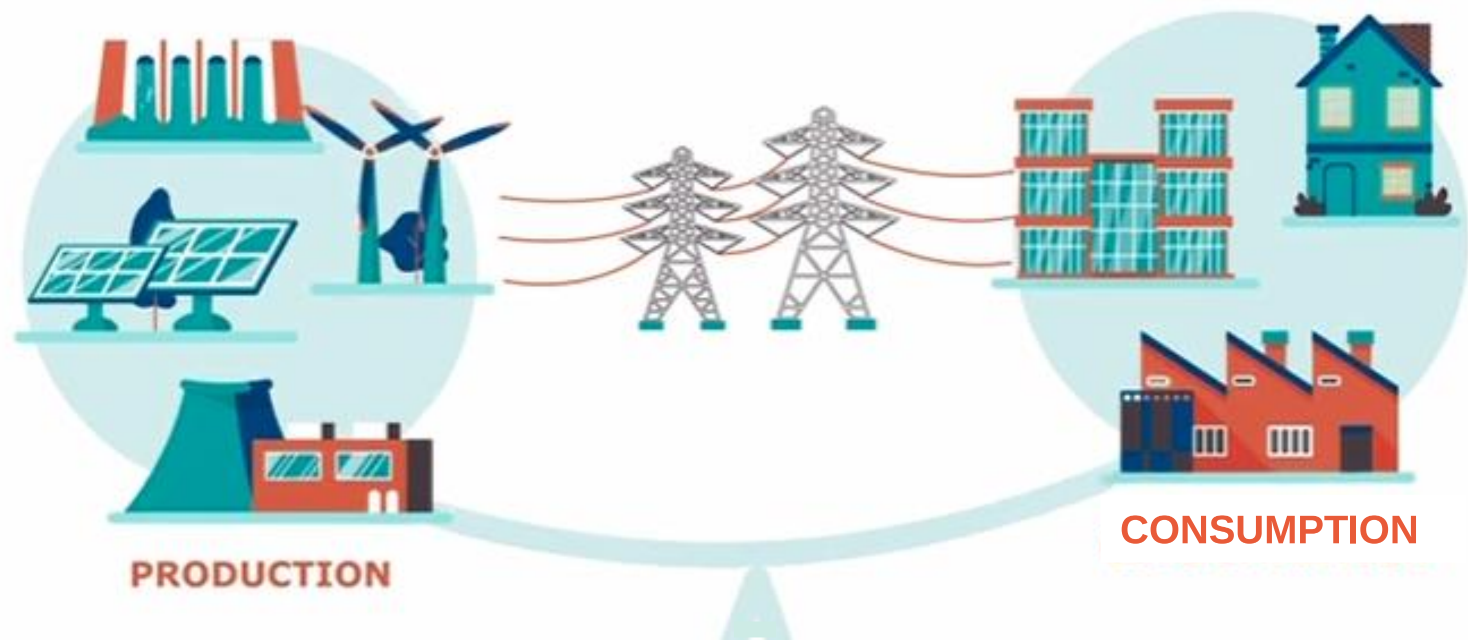



Travel behaviour profiles + vehicle characteristics

Monte Carlo simulation

- number of plugged-in vehicles and their location
- plug-in power
- state of charge (SOC)
- uncontrolled charging demand

## Power system simulator (+ EV smart charging)




- Antares power system simulator : minimization of the expected operating cost of an interconnected transmission-generation power system, at an hourly resolution
- Detailed representation of EV charging flexibility, including constraints on vehicle use and SOC
- Monte Carlo approach to represent production and consumption variability

# 2035 scenarios for e-mobility development : main parameters

### Vehicle fleet

- **Intermediate trajectory**: 11.7 M units
- **High trajector**: 15.6M units
- **Including autono-mous vehicles**: 8.4M + 1M units

### Share of PHEVs

- **Low PHEV**: 22% PHEV
- **Intermediate PHEV**: 40% PHEV

### Battery capacity

- **Low**: 56kWh – 330 km
- **Intermediate**: 73kWh – 440km
- **High**: 89kWh – 530km

### Number of charging points

- **Low**
- **Intermediate**
- **High**

### Power of charging points

- **Low**: Average power at home: 5.2kW
- **Intermediate**: Average power at home : 7.3kW
- **High**: Average power at home : 6.7kW

### Distances travelled

- **Intermediate without long distance**: km 11500
- **Intermediate with long distance**: km 12500
- **High without long distance**: km 14000
- **High with long distance**: km 15300

### Plug-in behaviour

- **Low frequency**: 45 % ASAP
- **Intermediate frequency**: 65 % ASAP
- **High frequency**: 85 % ASAP

### Charging management

- **No management**
- **Low Management**: 40% – 0% V2G
- **Intermediate management**: 60% – 3% V2G
- **High management**: 80% – 20% V2G

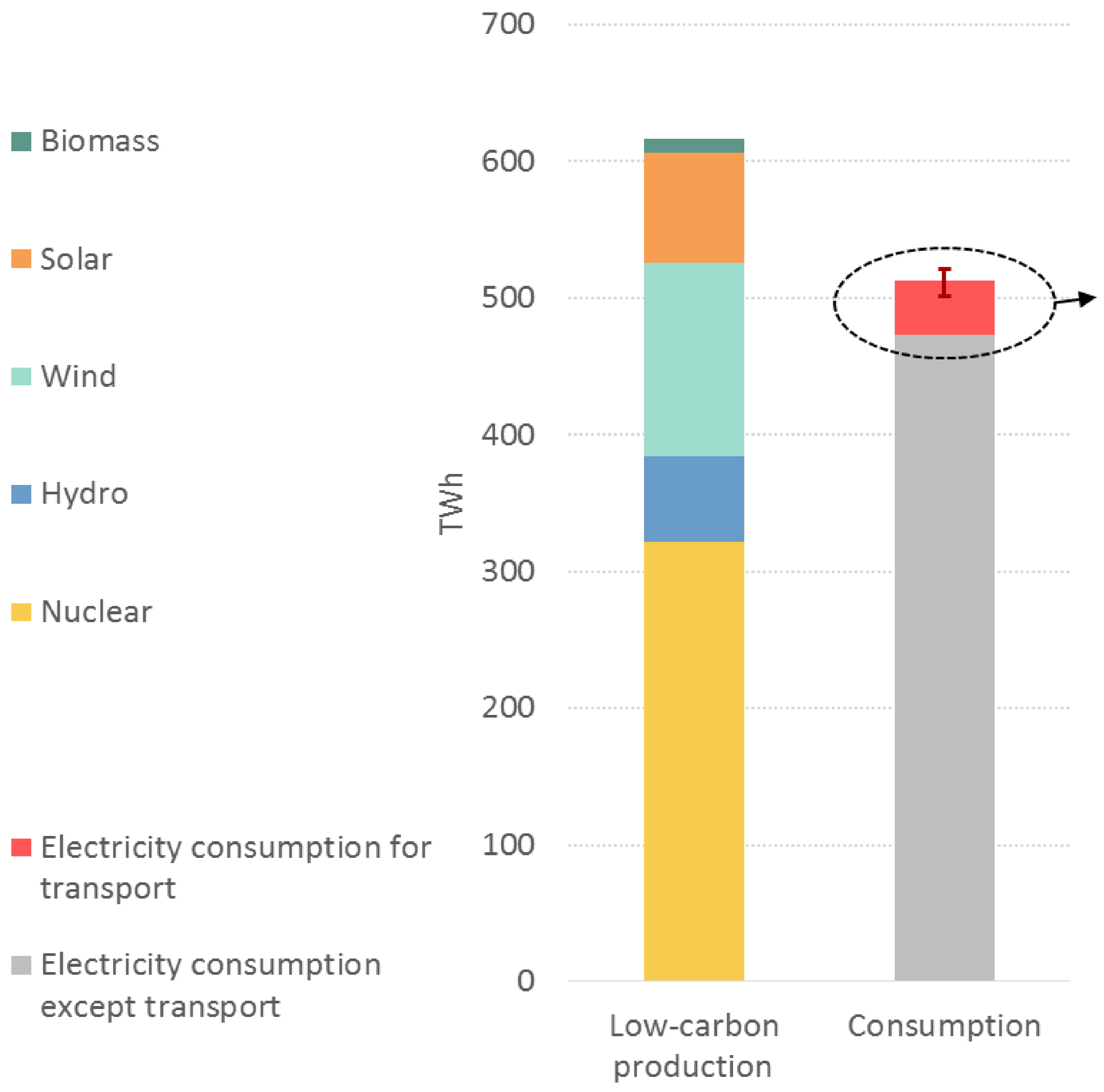
# Five widely contrasting 2035 scenarios to test the impacts of EV development

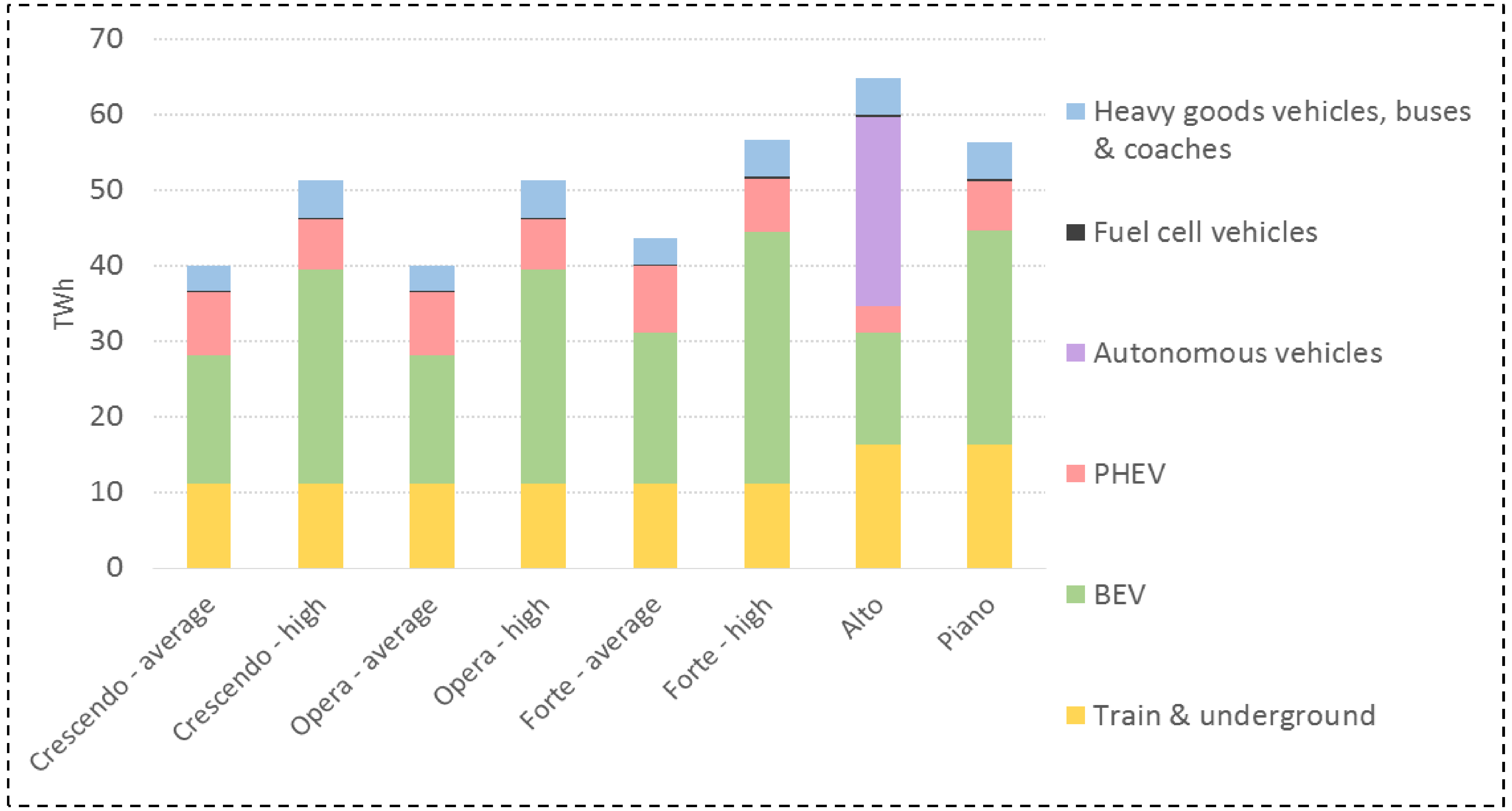
| Scenario | Description | |
|---|---|---|
| *Crescendo* | **Standard projections**: Substantial development of EVs, with marginal evolution of travel habits and other parameters, following actual trends | Between 11.7 and 15.6 million EVs in France in 2035 |
| *Opera* | **High flexibility:** This scenario explores opportunities offered by EV flexibility, with generalised smart charging and V2G | |
| *Forte* | **Stress for the power system :** The most challenging scenario for the power system : little development of smart charging, no V2G, long-distance travels with EVs... | |
| *Alto* | **Development of electric autonomous vehicles:** 1 million autonomous EVs replace 7 million traditional cars, combined with higher modal shift towards electric public transport | 1 million autonomous EVs + 8.2 million “classic EVs” in 2035 |
| *Piano* | **Low-carbon mobility:** The development of electric mobility goes with substantial modal shift towards electric public transport | 11.7 million EVs in 2035 + modal shift |

# Electricity demand associated with EVs

Low-carbon electricity generation in 2035 (nuclear and renewables according to the national energy strategy) will widely be enough to meet French electricity demand, including EVs, which will represent **between 5% and 10% of the French electricity consumption** in scenarios with up to 16 million EVs in 2035.

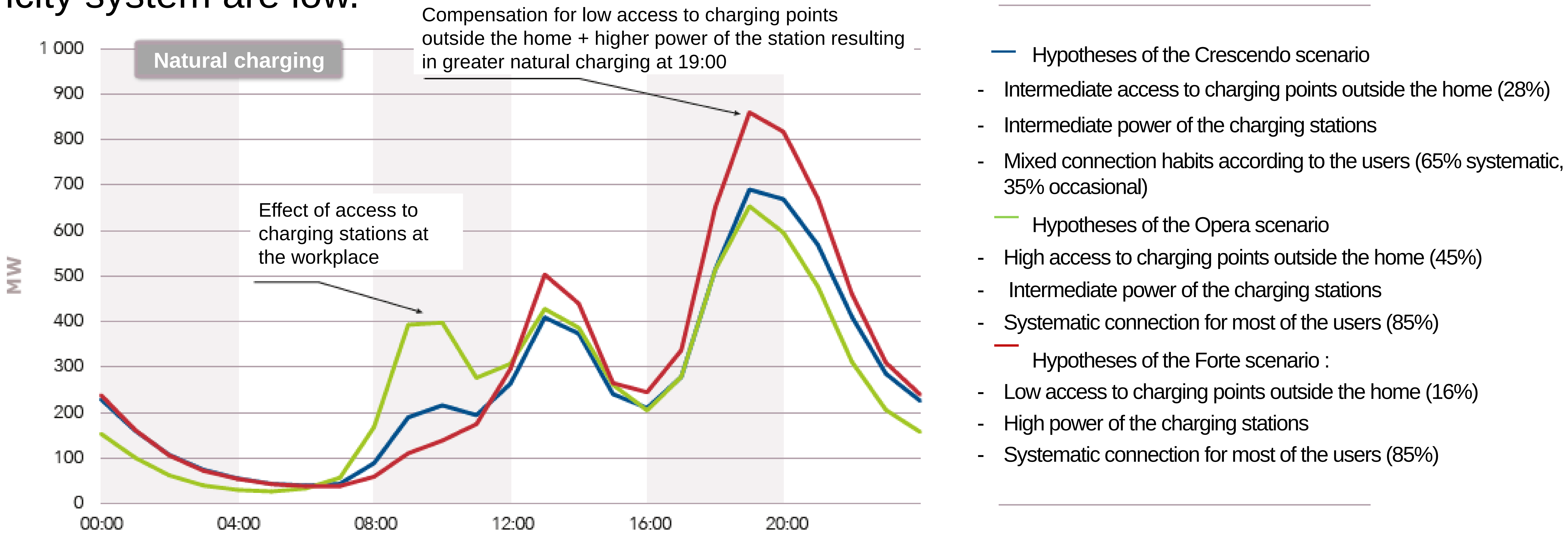
➢ The analysis needs to focus on **peak demand** and adequacy.



# Daily mobility charging needs have a greater impact on power demand than long-distance travel

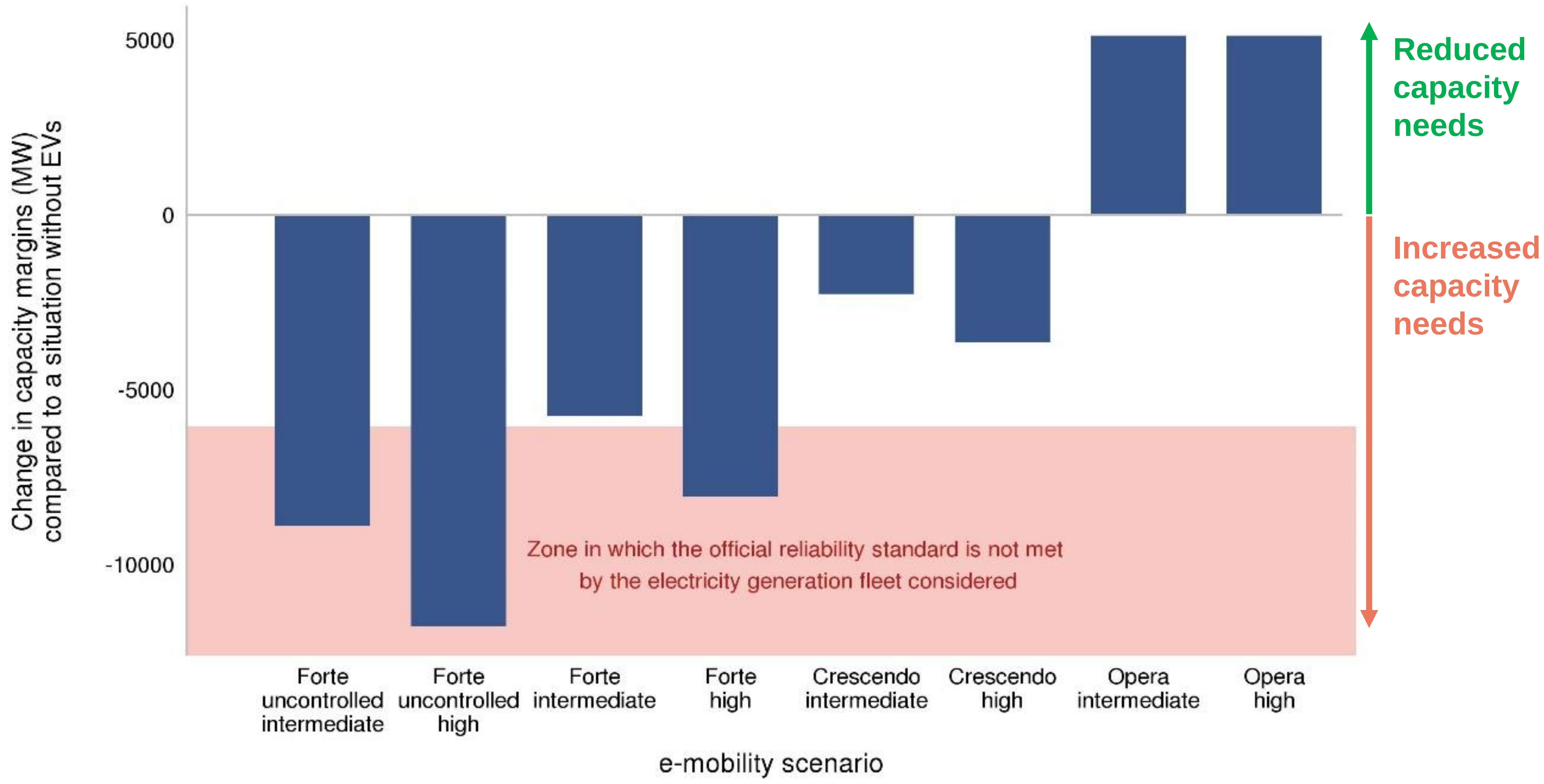
- **Long-distance travel** leads to charging peaks during week-ends and public holidays, when total electricity demand is low and concerns about adequacy between electricity production and consumption are low
- Power demand for **daily local mobility** (75% of total distance travelled) presents the biggest challenge for the power system, if charging is uncontrolled or only very partially controlled. Peak demand for uncontrolled charging falls between 7 and 9 p.m., when adequacy margins of the electricity system are low.



# A minimal level of smart charging is sufficient to ensure adequacy, at any moment

- With **smart-charging**, EV charging takes place during periods when generation costs are the lowest, mainly during periods of **high renewable generation**
- In scenarios with a high level of charging flexibility, capacity needs can even be reduced compared to a scenario without EVs
- Even in the worst case scenario (high mileage, low number of charging points), around 50% of smart charging is enough to ensure security of supply

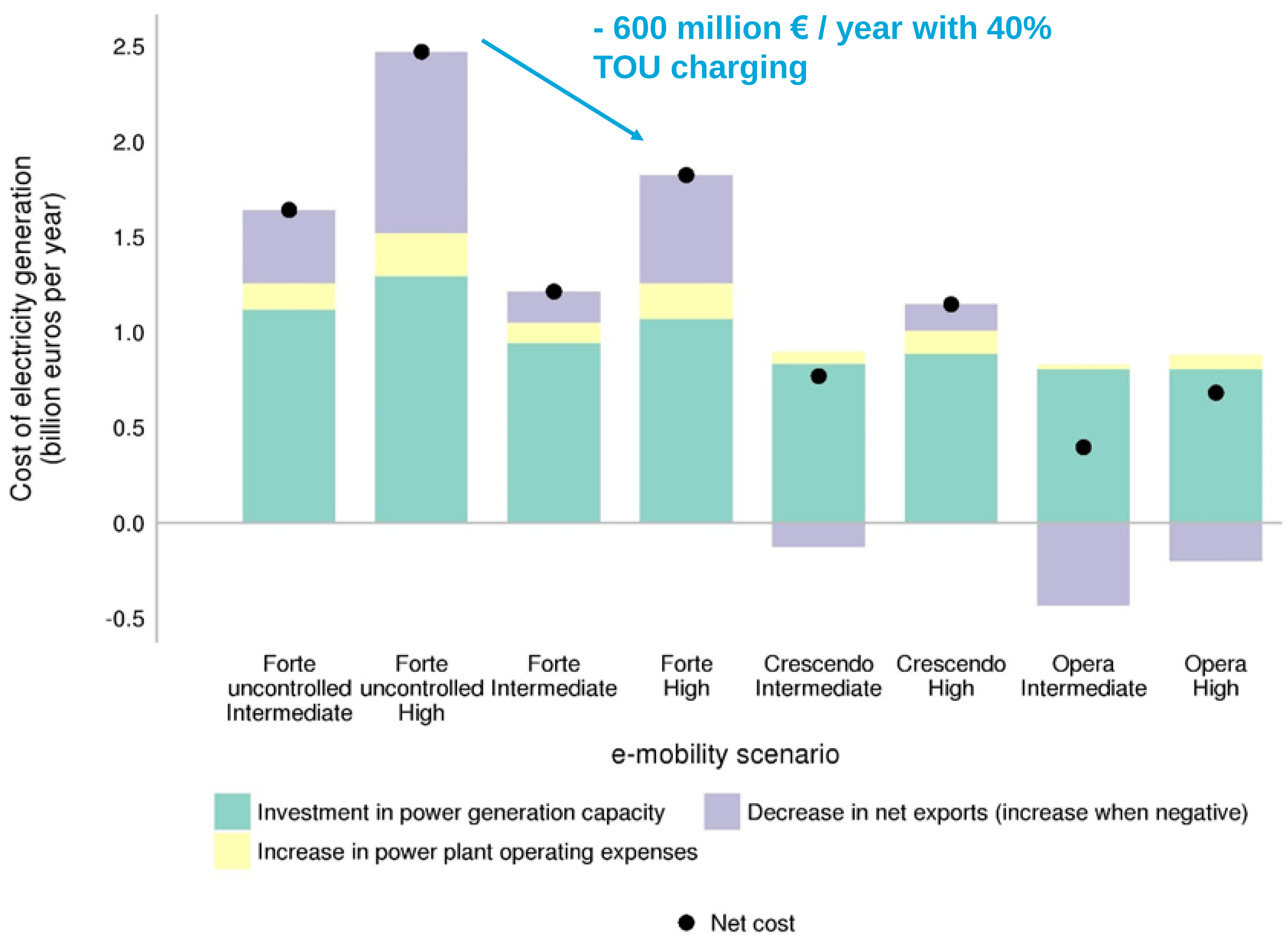
*Impact of electric vehicles on adequacy margins, compared to a scenario without EVs*



# Economic benefits of flexible EV charging

- The optimization of electricity generation and the **better integration of renewables** thanks to EV flexibility reduce the cost of electricity generation for charging electric vehicles
- A large part of total value can be accessed through using **simple time-of-use tariff charging**
- Dynamic price signal charging and V2G lead to substantial additional savings

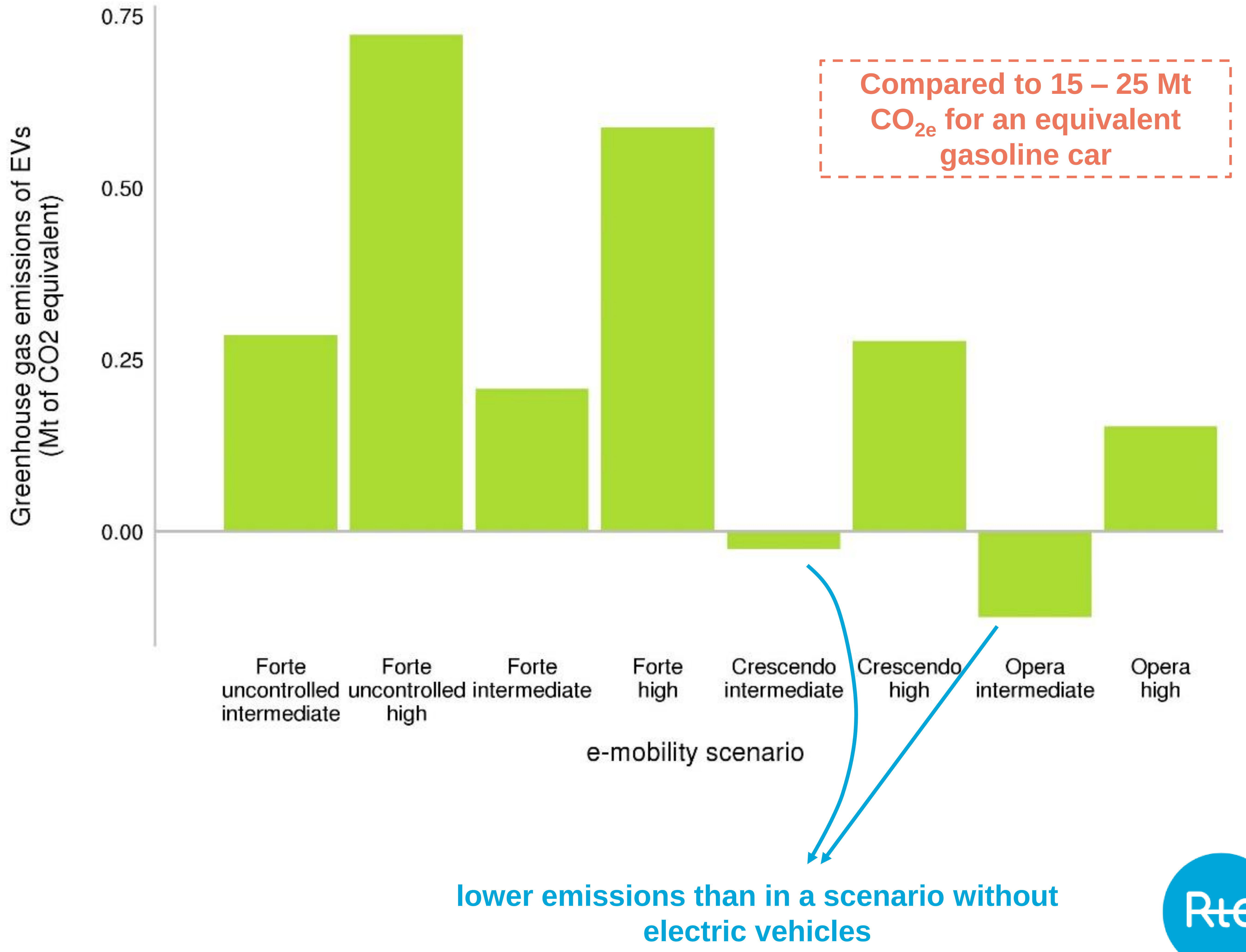
*Cost of electricity generation in different e-mobility scenarios, compared to a 2035 scenario without development of e-mobility*



# GHG emissions associated with EV charging

- The volume of **greenhouse gas emissions from electricity generation** associated with EV charging is low in all 2035 scenarios considered
- It can be further reduced thanks to EV charging flexibility, resulting in increased use of renewable generation
- In some scenarios, emissions can even be reduced compared to a scenario without EVs

*Direct greenhouse gas emissions from electricity generation in France due to EV charging in different smart-charging scenarios, compared to a 2035 scenario without development of e-mobility*

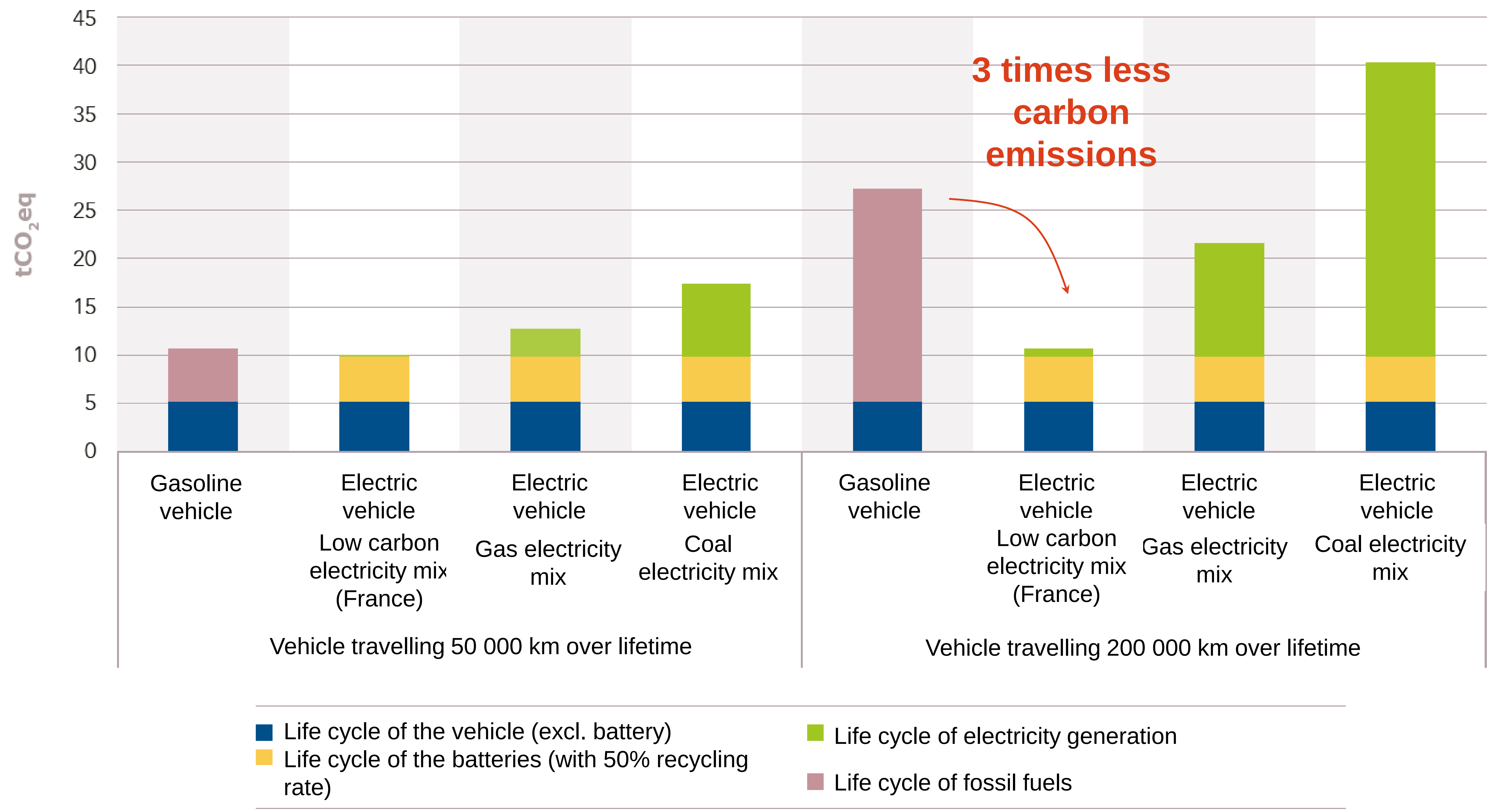


# Carbon footprint of EVs in 2035

- The reduction of emissions during the use phase largely offsets the emissions associated with the manufacturing phase (for an average vehicle travelling around 200 000 km over its lifetime).

- Depending on the battery capacity, manufacturing location and recycling rate, the carbon footprint of **an electric vehicle is 2 to 4 times lower than the one for an equivalent thermal vehicle**

*Carbon footprint of a vehicle over its entire life cycle according to the type of engine, the electricity production mix and the distance travelled (in 2035)*



# Conclusions

- The French power system is **ready for a massive development of EVs**, with the necessity of a minimal level of smart charging. Even in a challenging scenario, ~50% of simple (TOU) smart charging would be sufficient to ensure security of supply
- **Smart charging and V2G represent an economic opportunity for the power system** (helping to optimize the use of low-carbon electricity) and EV users (helping to reduce energy costs for EV users).
- With a low-carbon power mix, the development of e-mobility in France can **reduce the carbon footprint** of road transport (even when including LCA emissions of battery production). Different choices (development of smart charging, battery capacity, location of battery production,…) can help to further reduce GHG emissions.

## Next steps

The technical and economical issues have to be tested in a large scale in order to provide guidance for the development of EV industry :

- Test different smart charging solutions, including vehicle-to-grid
- Verify the acceptability of smart-charging and V2G for EV users
- Test and adapt regulatory framework to ensure relevant decision-making on the whole value chain

*The complete results of the study are available online*

# Questions ?