Integration of electric vehicles into transmission grids: a case study on the economic impacts in Europe in 2040

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Outline

1. Introduction / Scope of the presentation
2. Electric mobility demand modelling
3. Case study : EV demand at the 2040 time horizon
4. Conclusion

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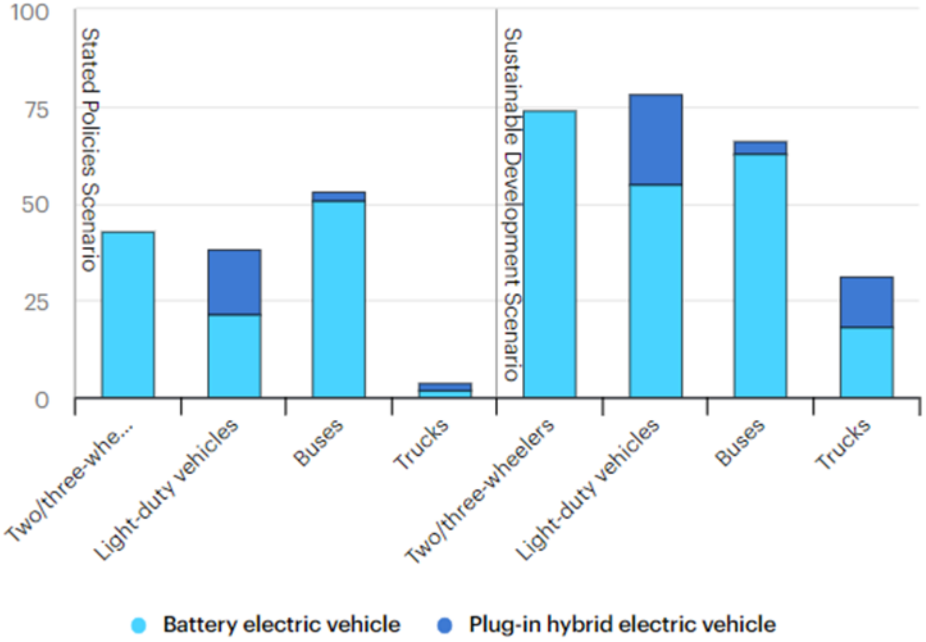
Introduction
Scope of the presentation

Background: electric vehicle (EV) development in Europe

- Transport is **one the main CO_2 emitting** sector in Europe
  ➔ Governments tend to promote EVs as an alternative to thermal powered vehicles
- Thermal vehicles sales bans :
  2025 in Norway,
  2030 in Germany, the Netherlands and the UK
  2040 in France
- The French government has planned EV development of **5 Million EVs by 2028** (PPE)
- IEA expect EVs in Europe to reach **up to 75%** of personal vehicle sales by 2030

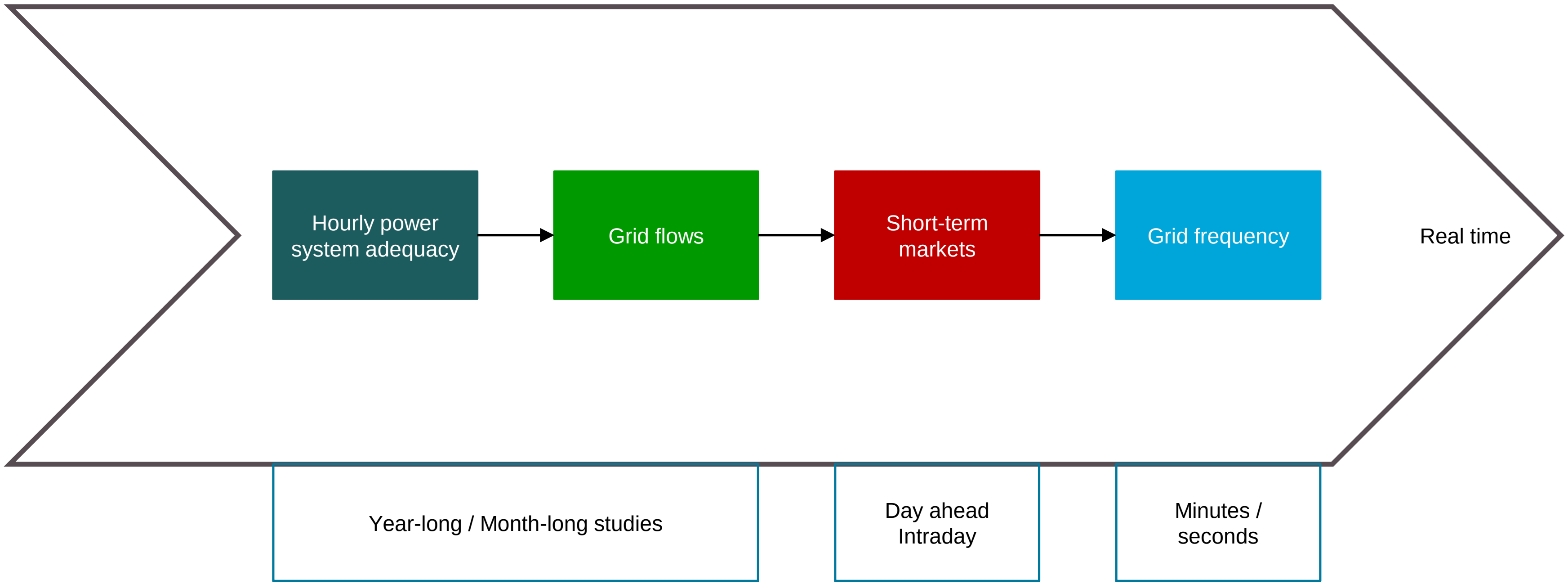
➔ Researchers and policy makers need to anticipate such a fast EV development

Electric vehicle share of vehicle sales by mode and scenario in Europe, 2030



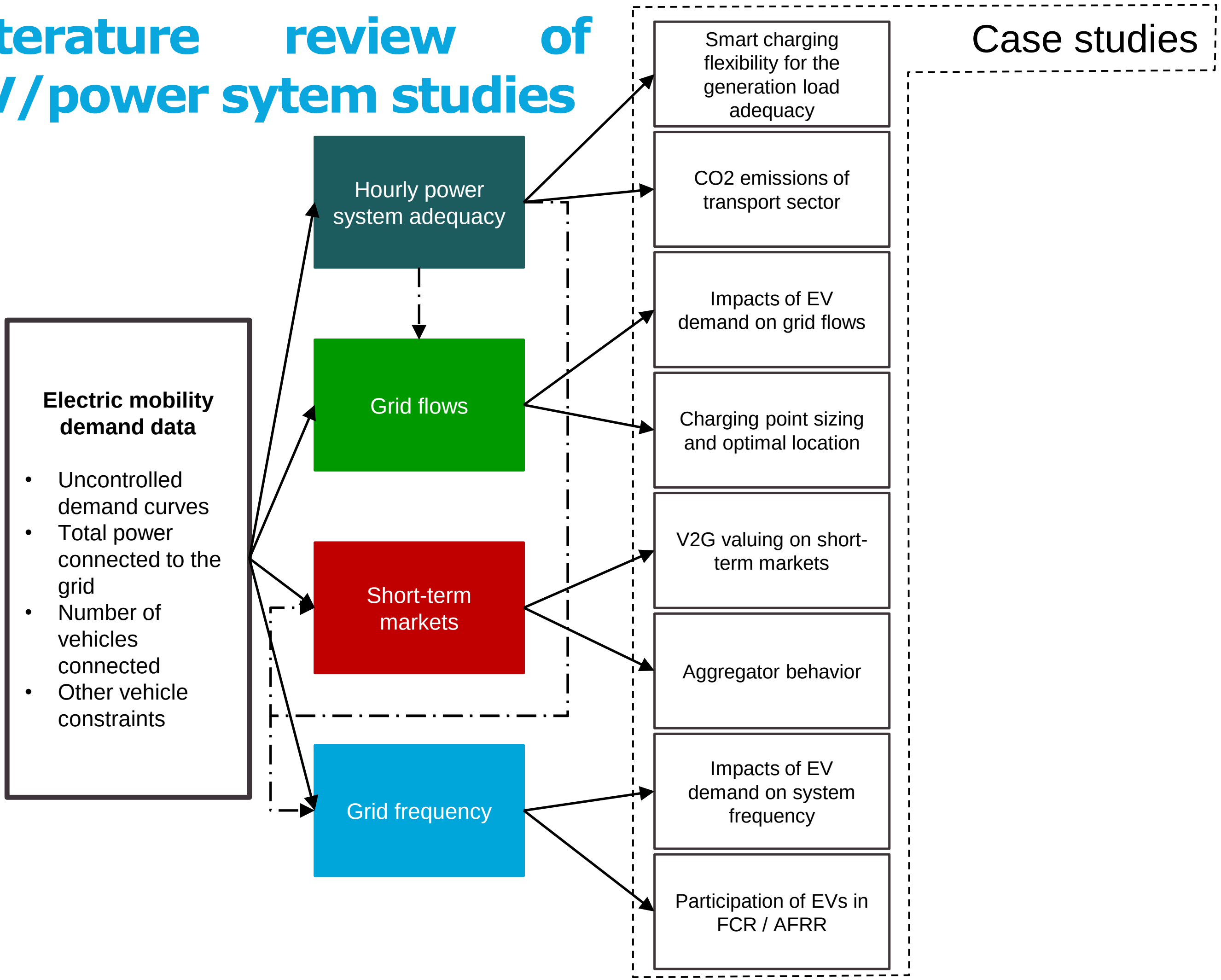
Source : IEA Global EV Outlook 2021

Interaction between electric mobility and power systems

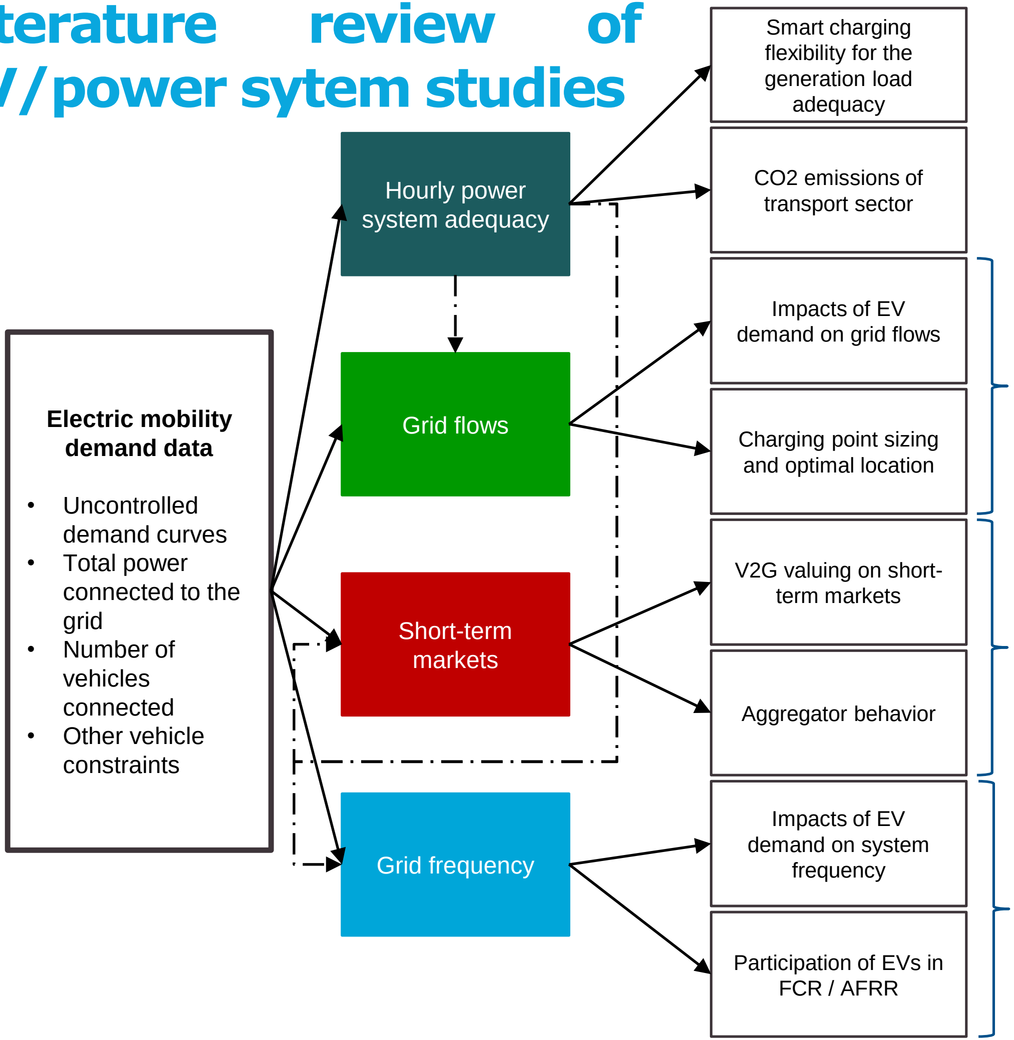


- Interaction with different markets at different time scales are to be expected

Literature review of EV/power sytem studies



Literature review of EV/power sytem studies



Many studies from consumer / agregator perspective, but not as much from TSOs / national level

Macro studies (IEA, governments)

Some studies at the local scale (DSO)
Gap at the national/regional scale (TSO)

Some studies in the short term (1-5 years)
Not much in the long term (2030 and after)

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Not much in the long term (2030 and after)

Research question

- **Focus on hourly power system adequacy**

- Main gaps in the literature to be filled :
  - Study the prospective impacts of a large diffusion of Evs (taking into account the diversity of vehicles and their usage)
  - Study at the national scale, from system operator perspective
  - Impacts of a large share of EVs on prices

- **To what extent and under which conditions can the electricity system accommodate a large number of electric vehicles in the middle to long term ?**

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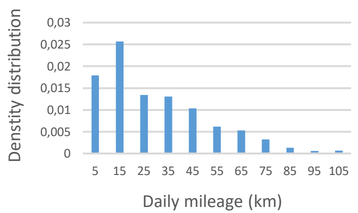
Electric mobility demand modelling

Mobility model definition

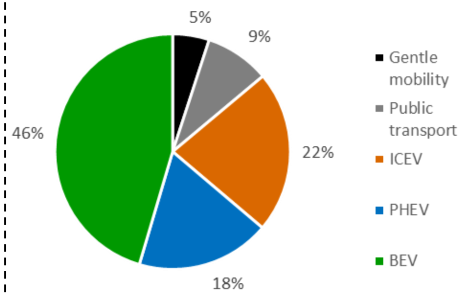
Travel data of electric vehicles

Distribution of daily distances



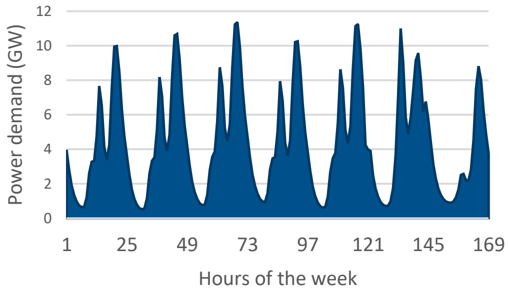
Hypotheses :
Vehicle fleet modelled,
EV owners' behavior …

Distribution of the French vehicle fleet (2050)



Vehicle travel and connection algorithm

EV load curve of a typical week (France 2035, uncontrolled charge scenario)



Charging module

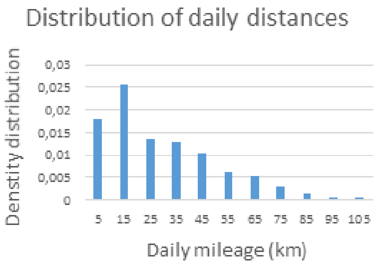
EV demand curve TOU tariff users

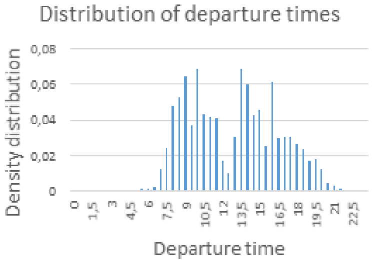
…

EV demand curve V2G users

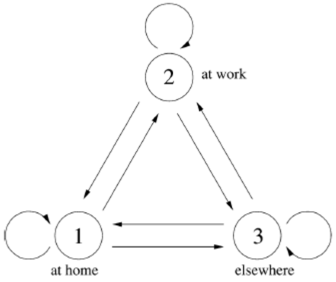
Main mobility algorithm groups

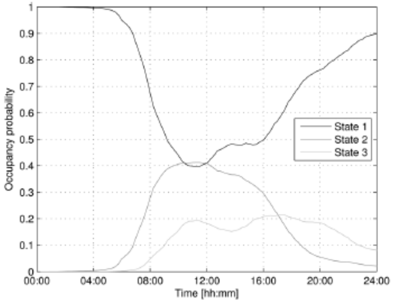
Statistical usage of travel data models :
Random generation of the travel data of each vehicle from histograms or distributions (travel surveys)



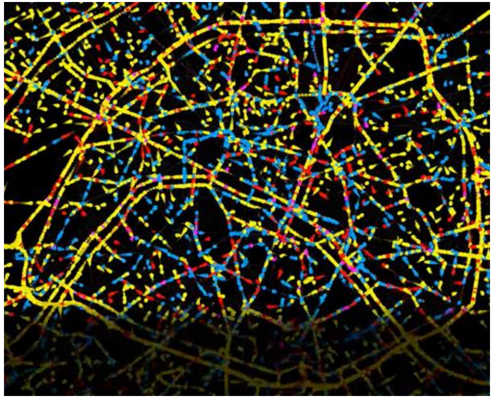


Markov chain State models :
Modelling the travels and destinations of each vehicle from state transition probabilities





Activity-based models :
Spatial modelling of every individual daily travels (but in a restricted simulation area)

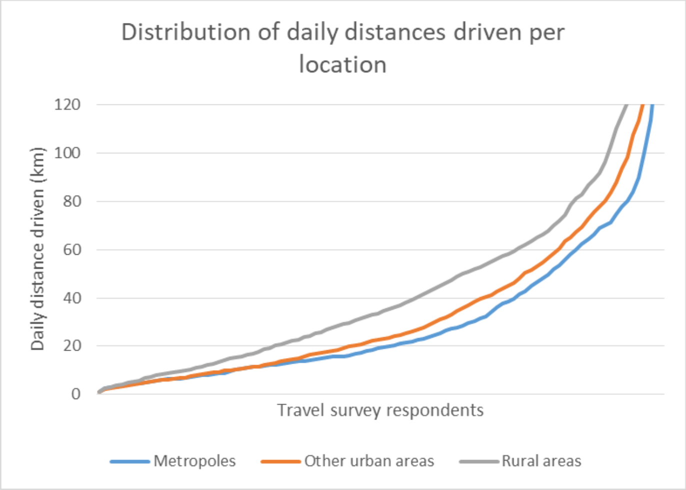


MATSim model
(focus on Paris)

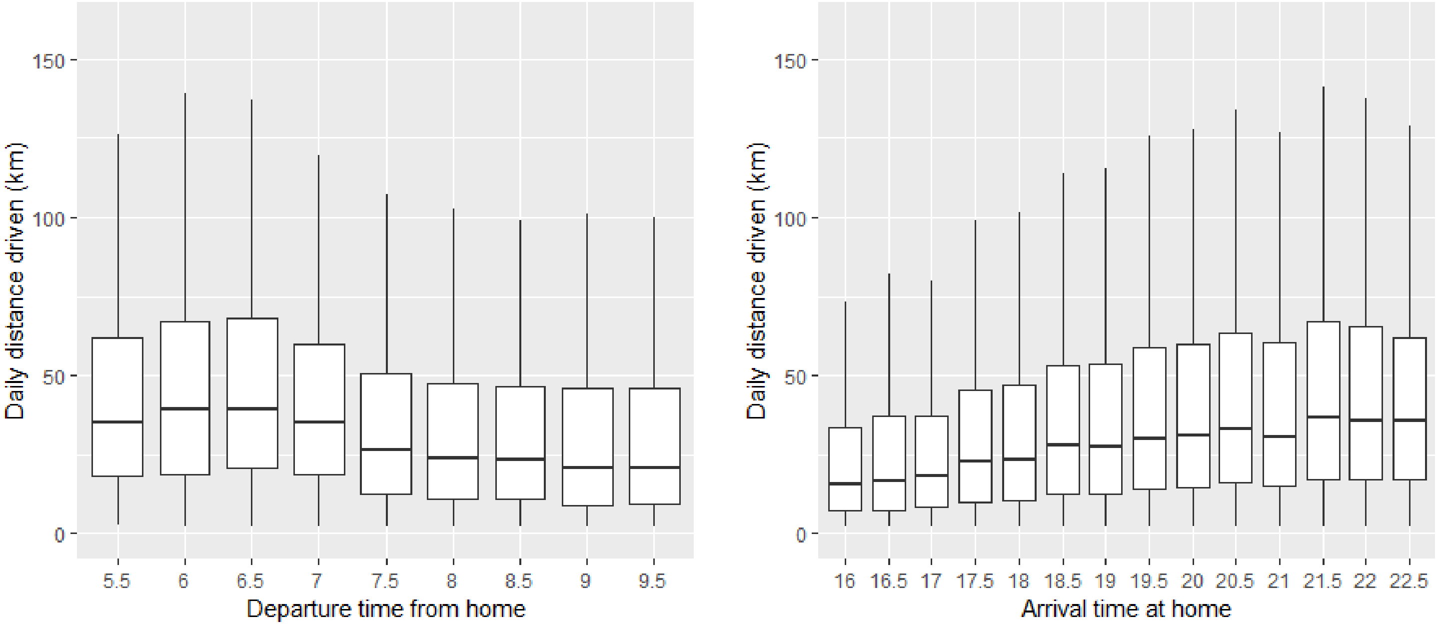
Travel survey data analysis

- Need for EV trip data as an input of EV load modelling (trip departure times and distances driven) ➔ Most EV studies are based on a **travel survey**

- Analysis from French national travel survey (ENTD 2008) shows that travel data differ according to:
  - Local mobility and long distance trips
  - The residence area of the EV user
  - The socio-professional type of the EV user
  - The day of travel (working day or week-end)



Taking into account trip distance/times correlation



Source : French National travel survey data (2008)

- **Observed correlation** between car users departure time and distances driven!
- What it implies: Longer recharge time for those arriving later at home.
  ➔ Uncontrolled load curve (plus smart charging constraints) **shifts towards the night**

Conversion of trip planning to consumption data

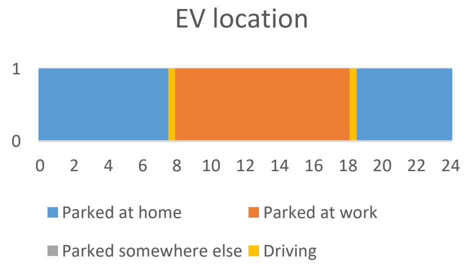
- Main factors of EV consumption: driving speed, exterior temperature and use of ancillary equipment

For each time step t,

$$Consumption_{ev,n}(t) = distance\ travelled(t) * consumption_{per\ km}(temperature(t), speed_{ev,n}(t))$$

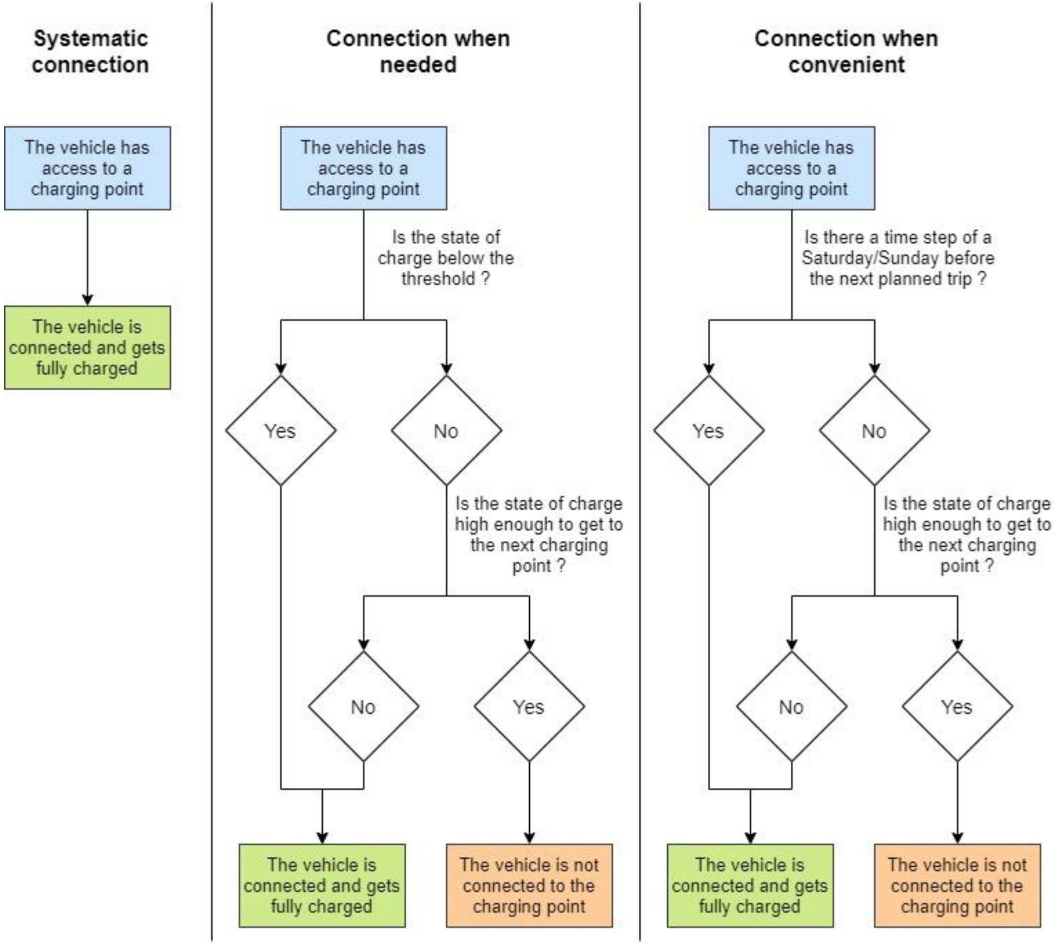
- Selection of a time step relative to the scope of study
  (1 hour for annual power system adequacy studies)
  Travel survey data approximation : not realistic to model at less than 15 min time step

- Step 3 output (for each vehicle): evolution of EV consumption and location



EV connection to the grid behavior studied

- Soares et al. (2011) and Enedis (2019) show that EV owners connection and recharge behavior can be gathered in 3 groups :
  - Whenever possible
  - When needed
  - When convenient



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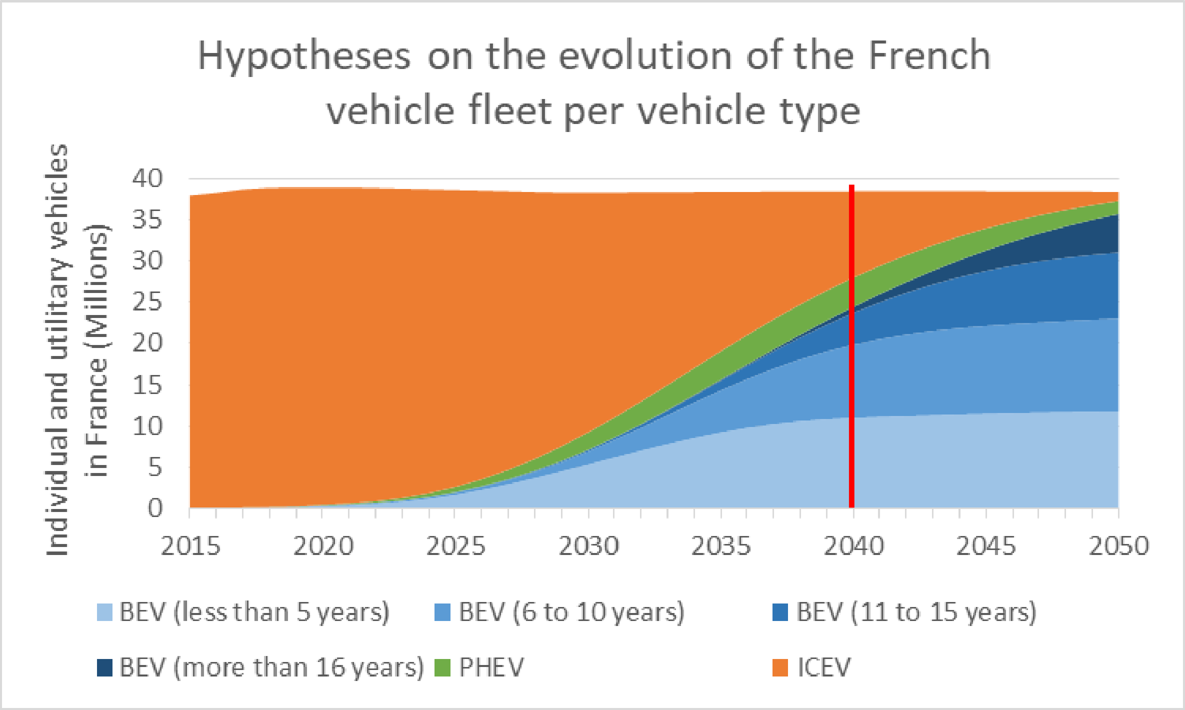
Case study : EV demand at the 2040 time horizon

Prospective EV development in France

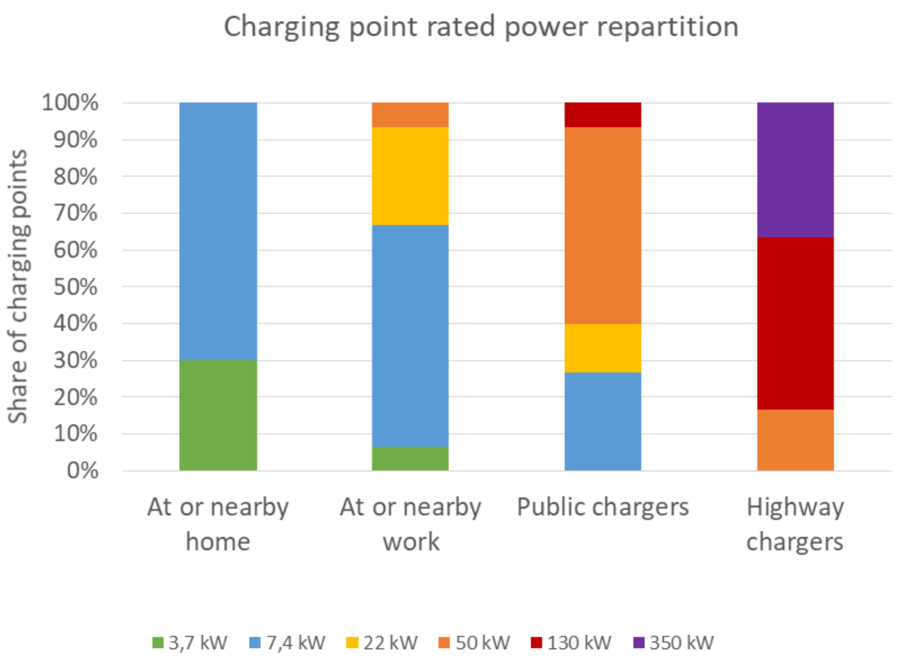
- Hypotheses in line with RTE studies (on EV development and 2050 prospective scenarios)



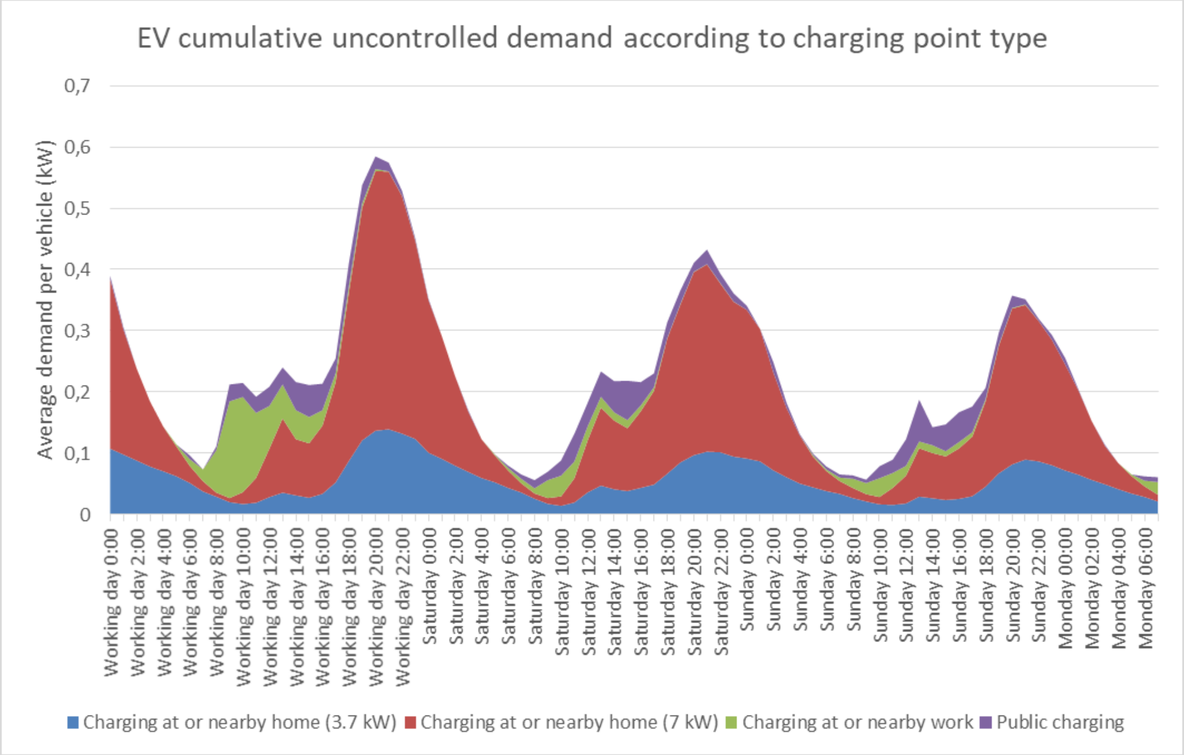
24,4 Million EVs at the 2040 time horizon (most optimistic EV development scenario)

Main EV development hypotheses

Number of electric vehicles in France	**24,4 Million**
Number of thermal vehicles in France	12 Million
Share of BEVs in the vehicle stock	85%
Share of PHEVs in the vehicle stock	15%
Battery capacity of BEVs (mean value)	78 kWh
Standard deviation of BEV battery capacity	15,6 kWh
Battery capacity of PHEVs (mean value)	15,6 kWh
Standard deviation of PHEV battery capacity	3 kWh

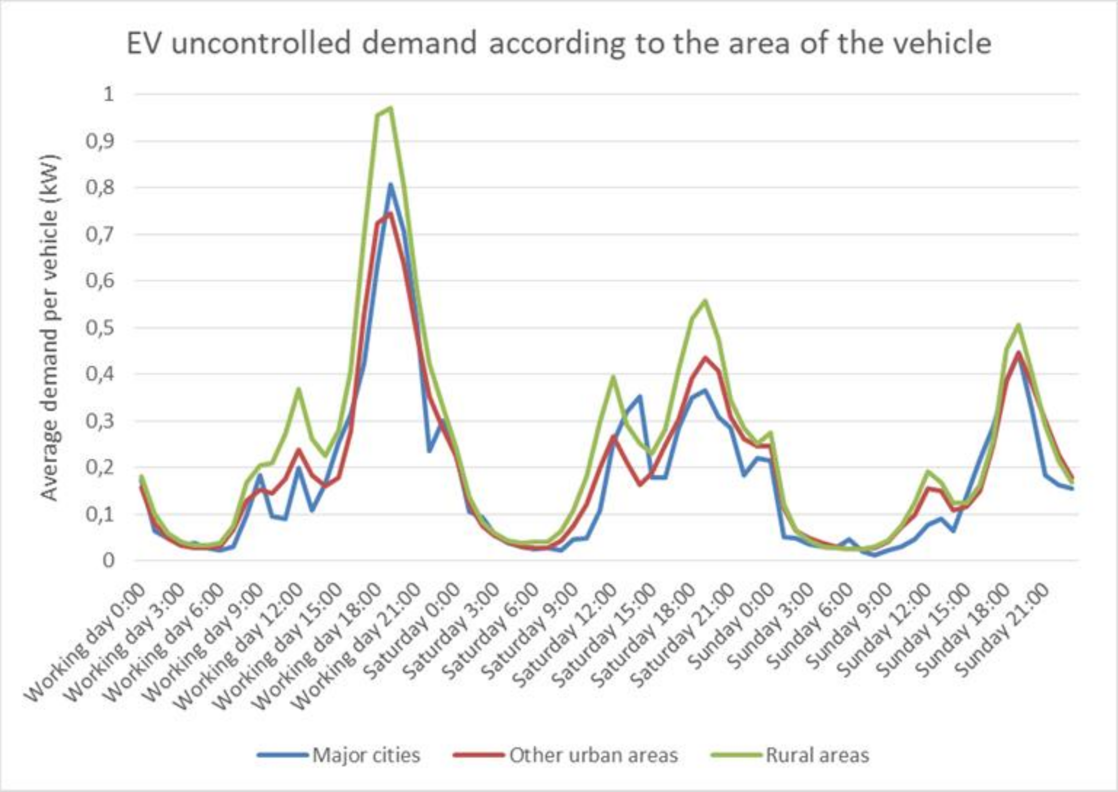


EV demand data per charging point location



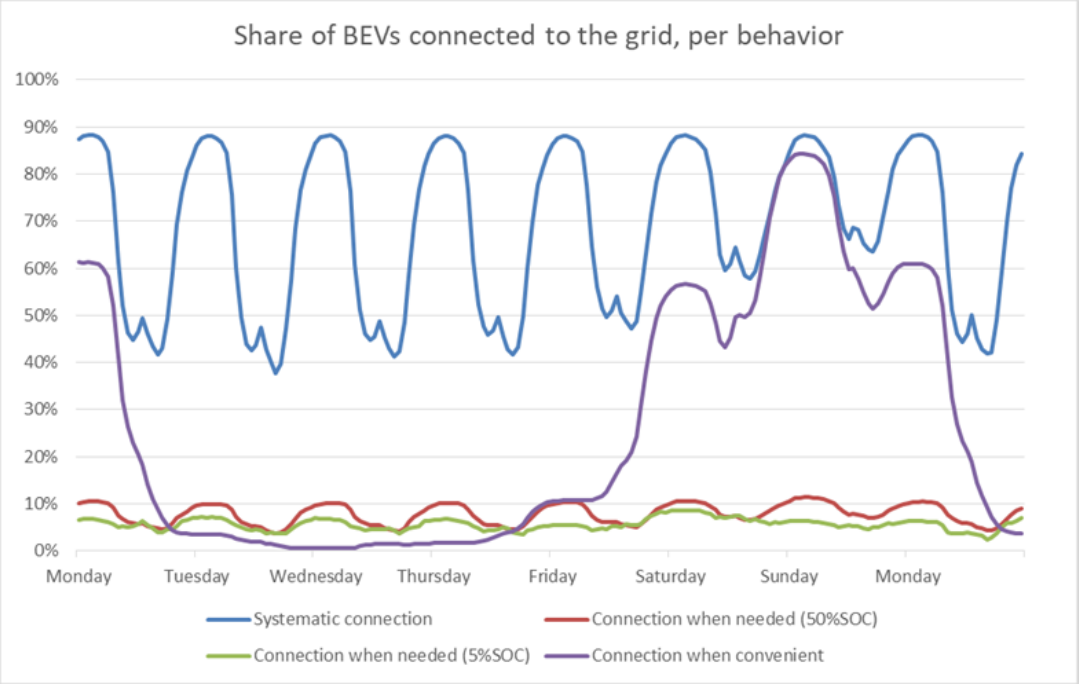
- Significantly more distances travelled on working days implies larger demand than on weekends
- Most of the charge in our model at or close to home

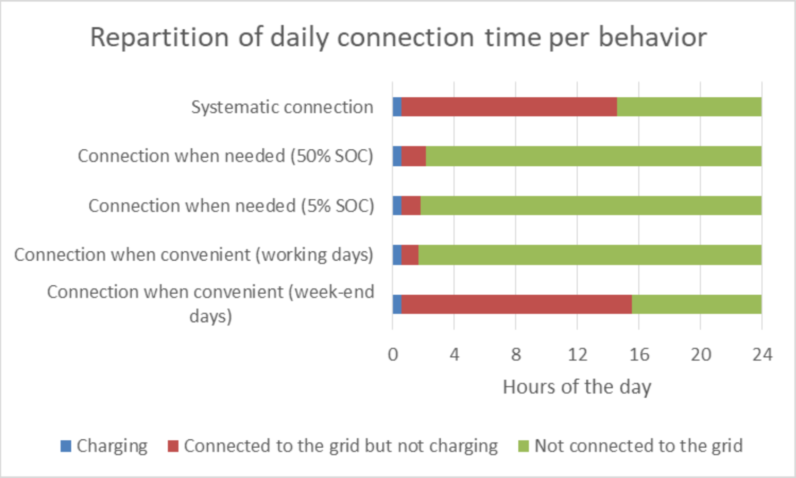
EV demand per residential area



- **EV diffusion (more urban or rural)** has a notable impact on total and peak energy demand (as implied by travel survey data)

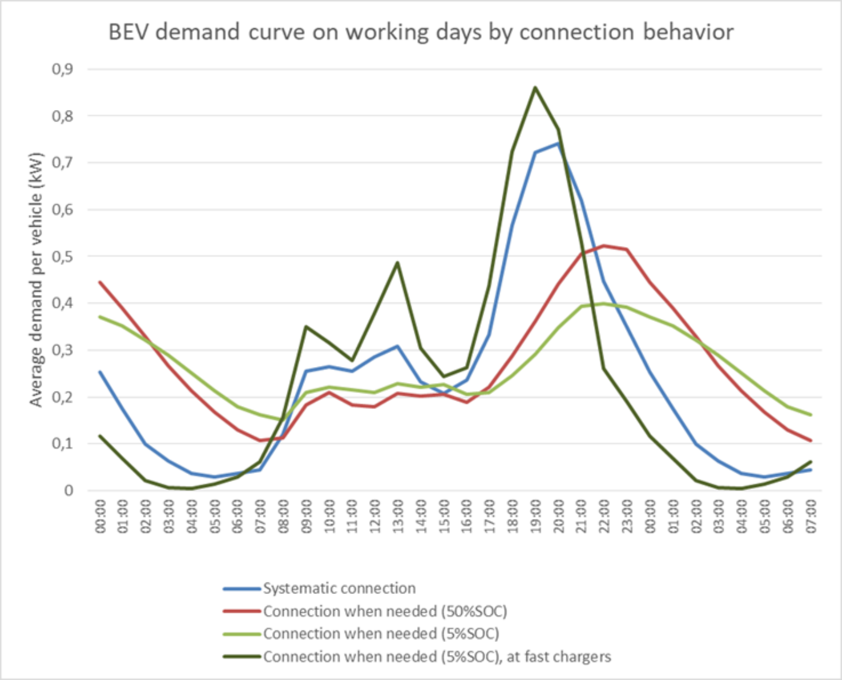
EV connection need per behavior studied

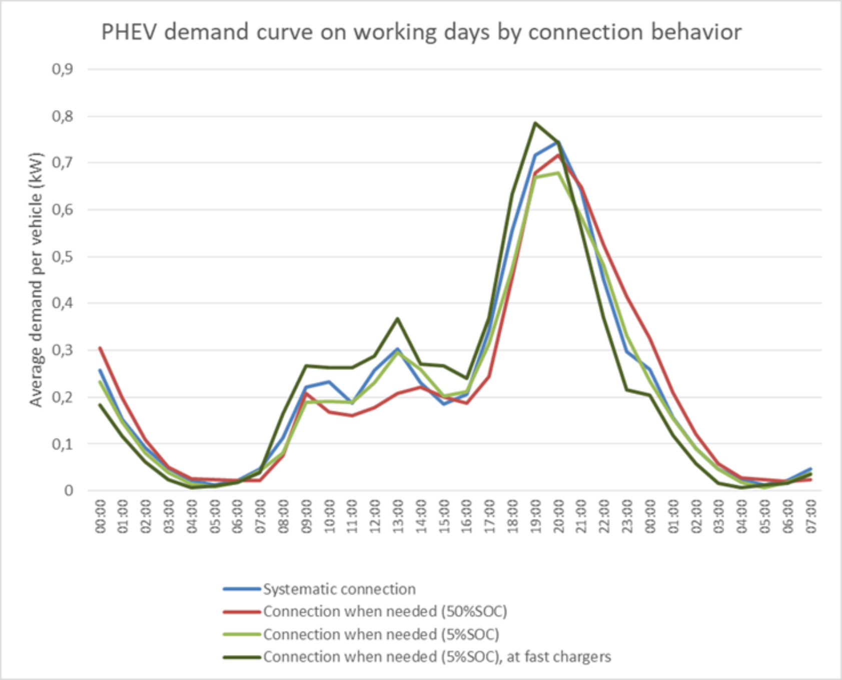




- **EV flexibility potential** (connection time / charging time ratio) is relatively low on connection when needed behavior
- High and synchronised peak demand of Friday evenings (2.3 kW / vehicle) in connection when convenient

EV demand data per behavior studied





- **Higher peak demand** per BEV in the systematic connection behavior, and slightly more for last minute recharge at fast chargers (130 kW)
- Negligible differences between behavior for PHEVs (short charging time even in connection when needed)

4

Conclusion

Main results and future work recommendations

- **Mobility modelling approach** for studies of impacts of a large share of EVs at the national scale
- Under these optimistic hypotheses, personal electric vehicles total consumption **reaches 54 TWh / year** in France in 2040 (about 12% of total electricity consumption)
- EV diffusion in the population and the **connection behavior** of EV users have a significant effet on electricity demand curves of EVs
- To go further:
  - Study of these results into a **power system adequacy model**, in order to study EV smart charging modes, and its impact of prices
  - Study of transport of goods and passengers of heavy mobility, to take into account the whole transportation sector