# Load as a Resource: Demand Response and Electric Vehicles


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# Outline

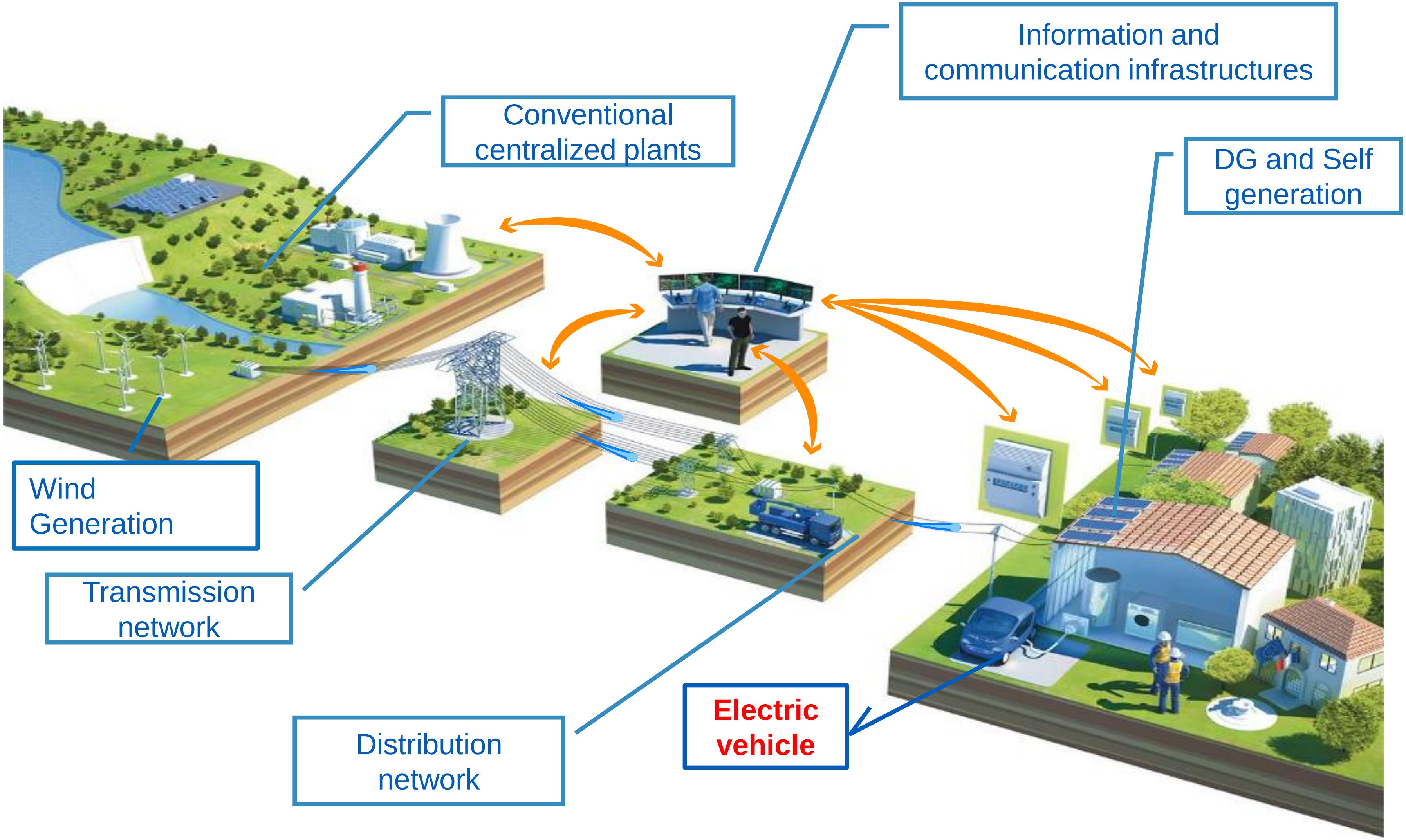
1. Electric vehicles integration into the electricity system: Impacts on and opportunities of

2. Electric vehicles charging control

3. Aggregation of electric vehicles flexibility

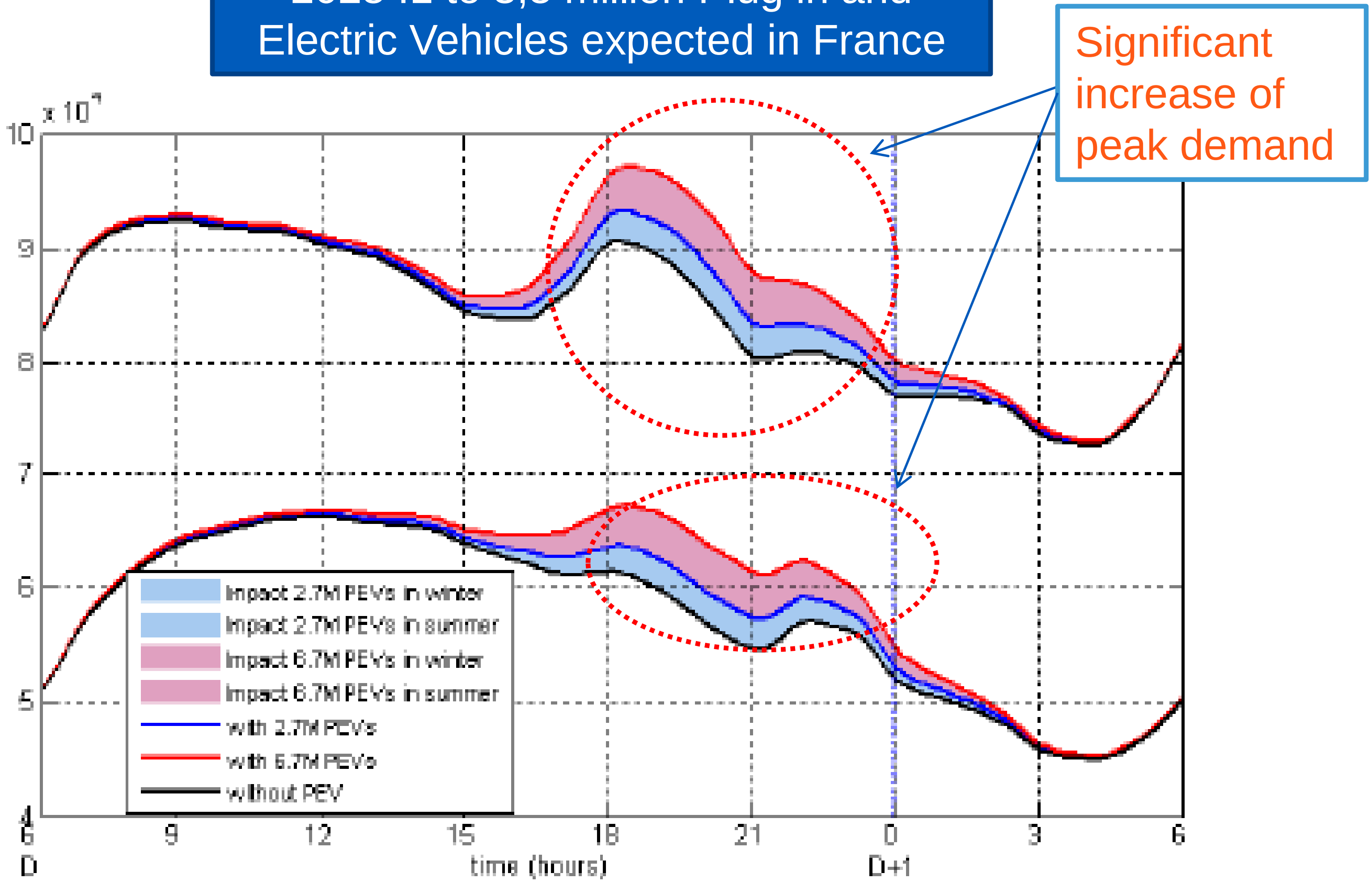
4. Conclusions

# The electric power system



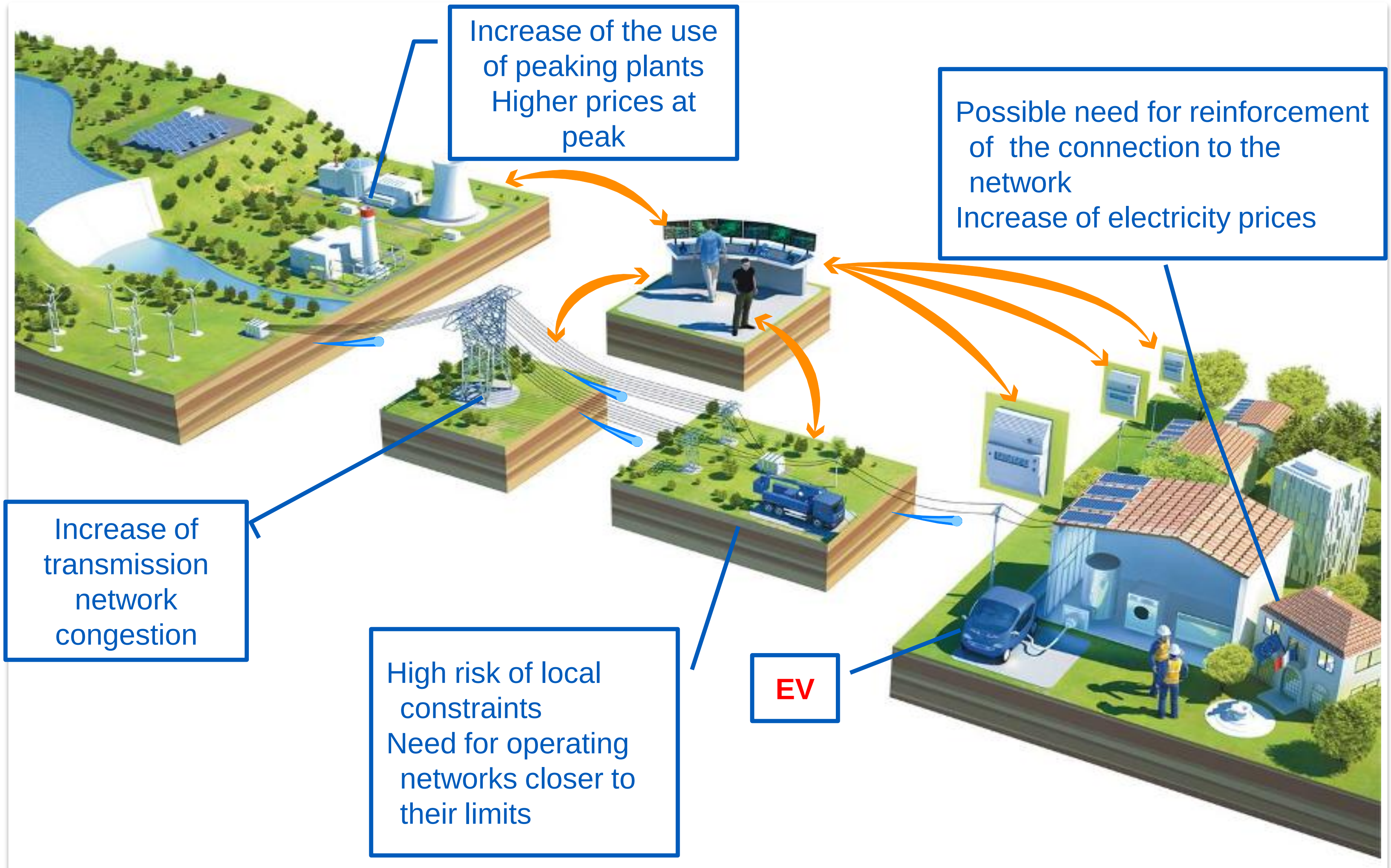
# Impact of uncontrolled electric vehicle charge on electricity demand

2025 :1 to 3,5 million Plug in and Electric Vehicles expected in France

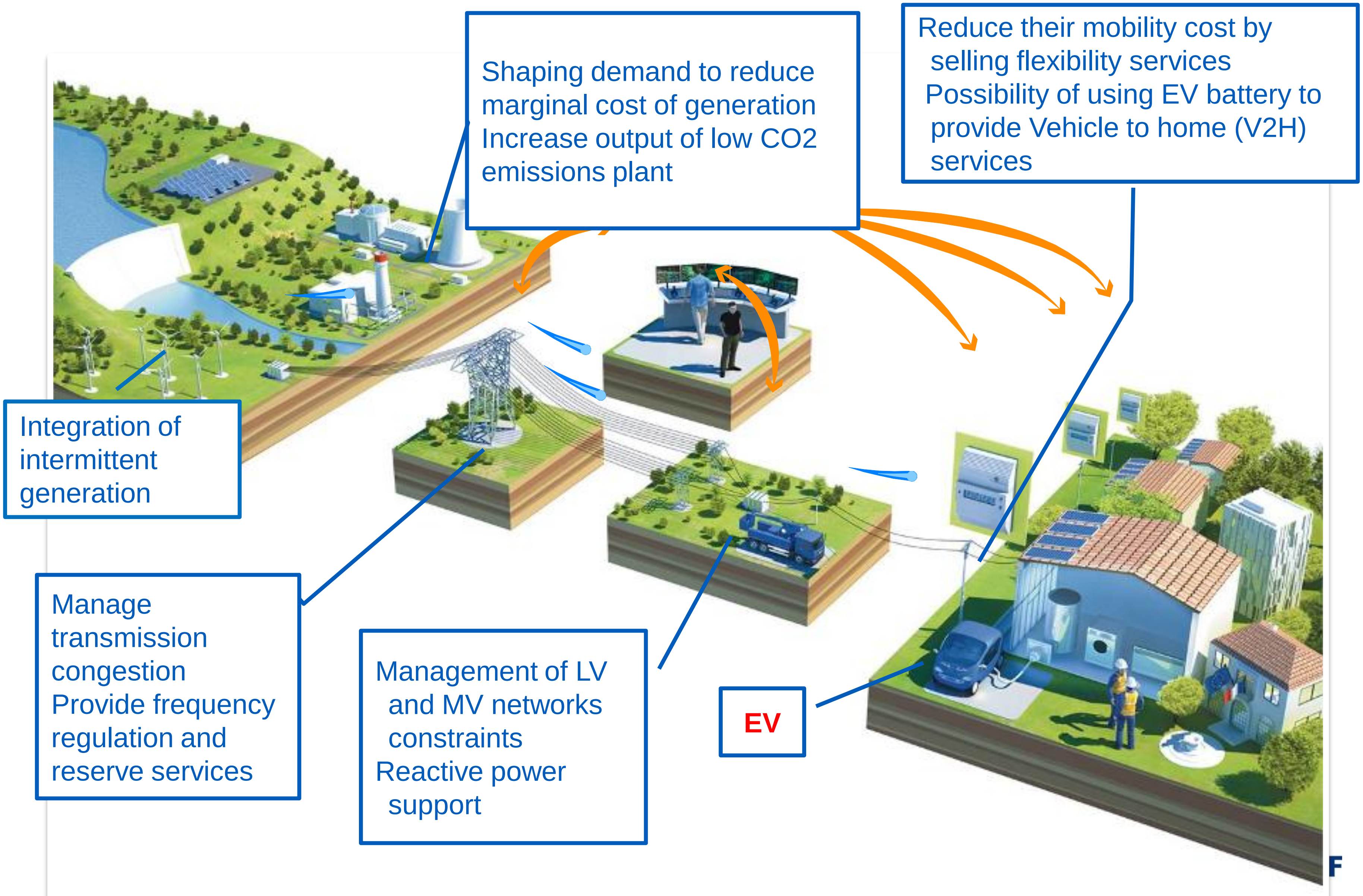



Source – Bilan prévisionnel RTE 2009

# Impacts of EV on electric power system operation



# Potential Benefits of using EV to support Power System Operation



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# Controlling EV Charge

**Controlling EV charge requires some interaction with the consumer**

**This can be done using:**

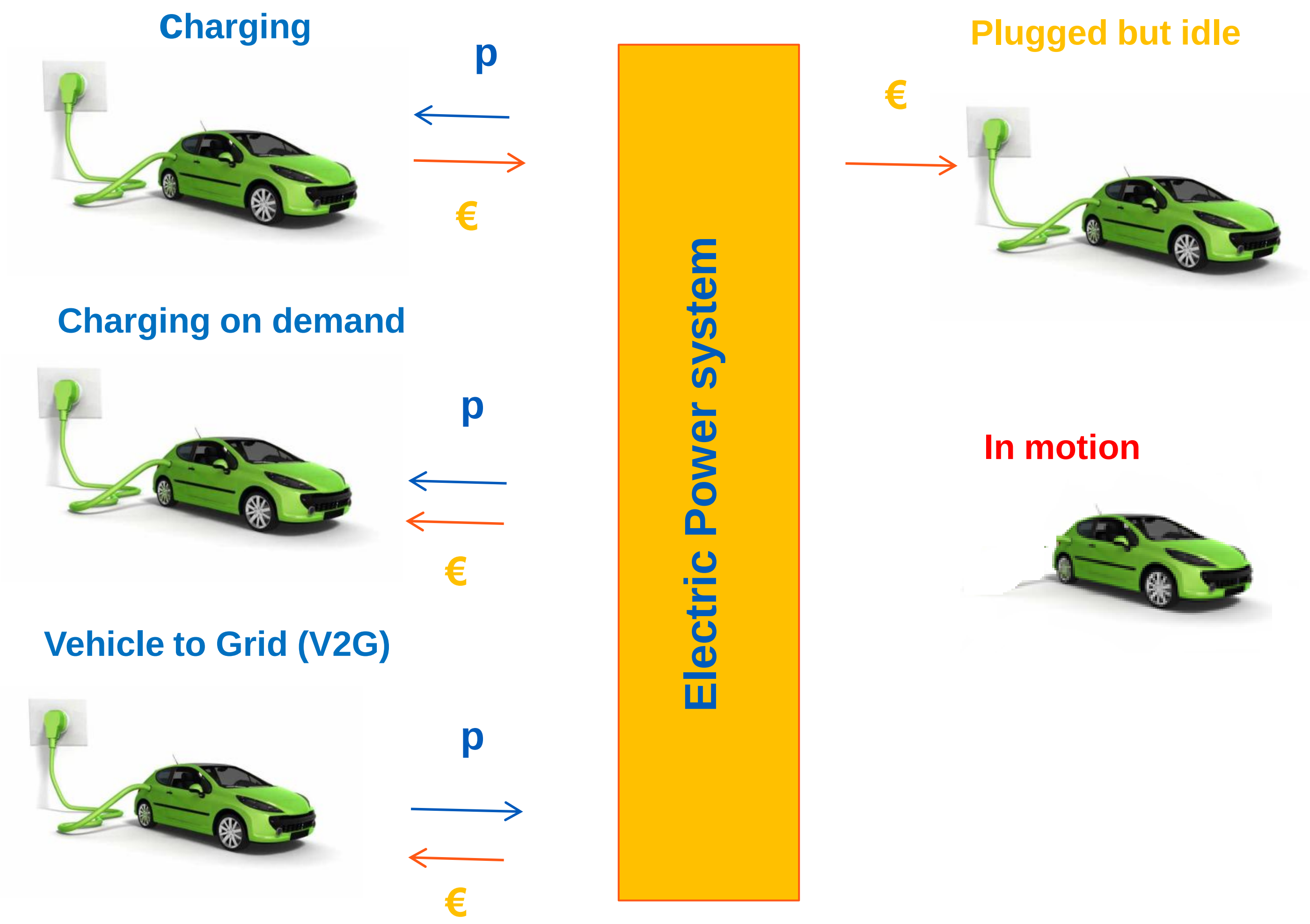
- **Tariff signals**: does not require advanced ICT **but** does not permit having a direct interaction nor having visibility of the EV status

- **Unidirectional signals**: can be done with simple systems **but** does not give visibility of the EV status

- **Bidirectional communication**: requires more complex ICT **but** permits direct interaction with the EV and gives full visibility of the EV status

**The choice of the adequate solution needs to be based on cost/benefit analysis of solutions with different levels of complexity for different scenarios of EV deployment**

# Electric Vehicle Operating Modes



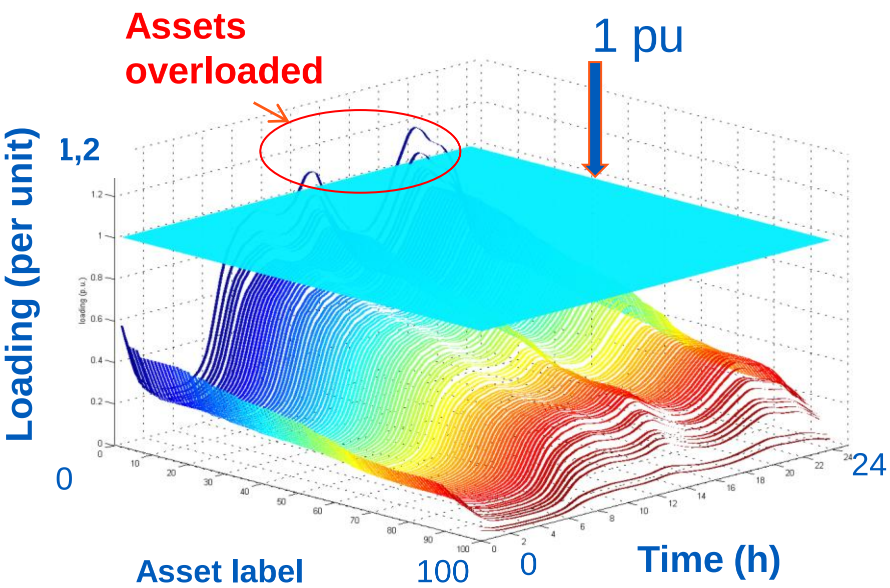
# Control Strategies to Deploy EV Flexibility

| Business as Usual (BAU) Strategies | Pragmatic Strategies | EV Flexibility Aggregation |
|---|---|---|
| Time varying tariffs | EV charging power is modulated to relieve distribution constraints | Optimized charge/discharge coordinated at aggregated level to provide various flexibility services |

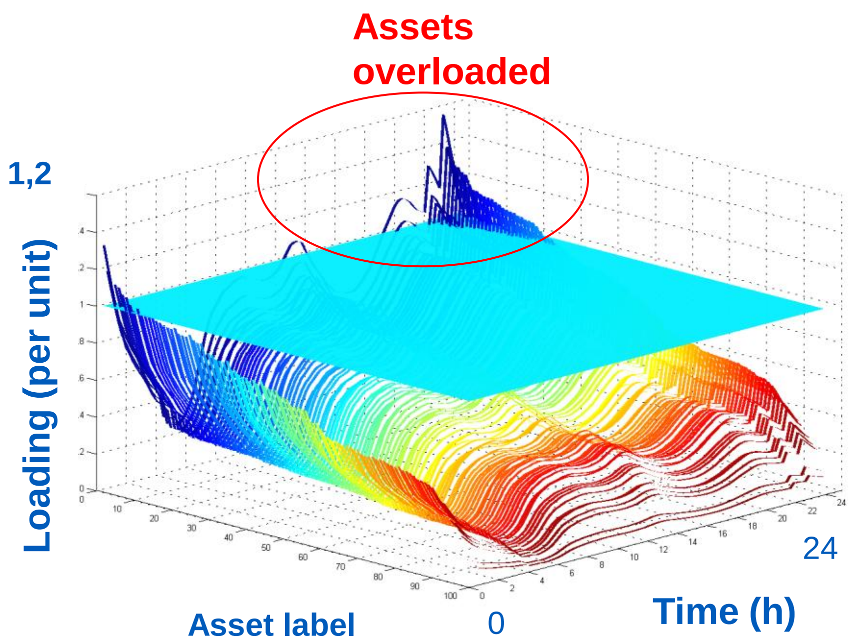


Source – Bilan prévisionnel RTE 2009

# Impact of BAU strategies on distribution networks asset overload




Uncontrolled charging – 35 % of cars in the system are EV

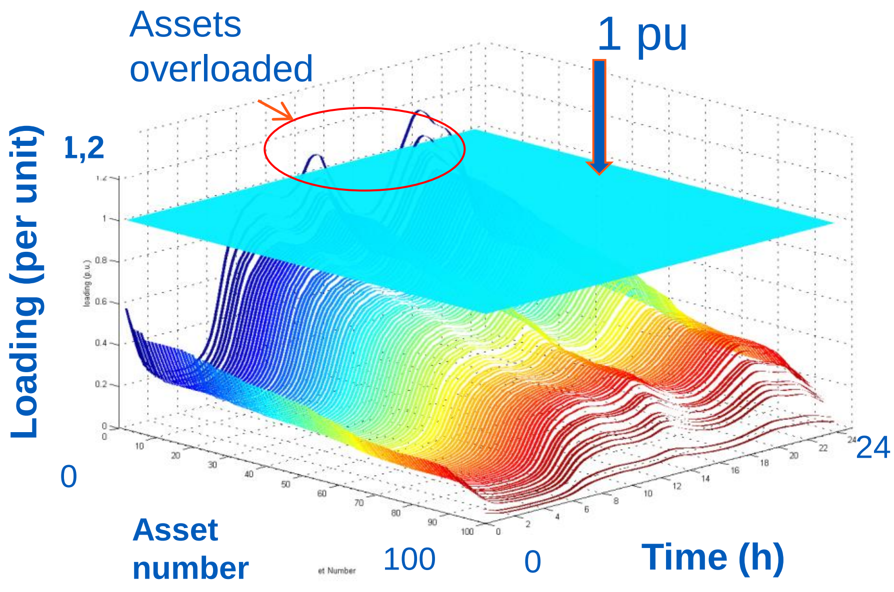



BAU Peak/Off peak tarrifs– 35 % of cars in the system are EV

BAU strategies without coordination at distribution system level can worsen the situation by disturbing demand diversity

Source – RWTH Aachen, 2011

# Impact of pragmatic strategies on distribution networks asset overload

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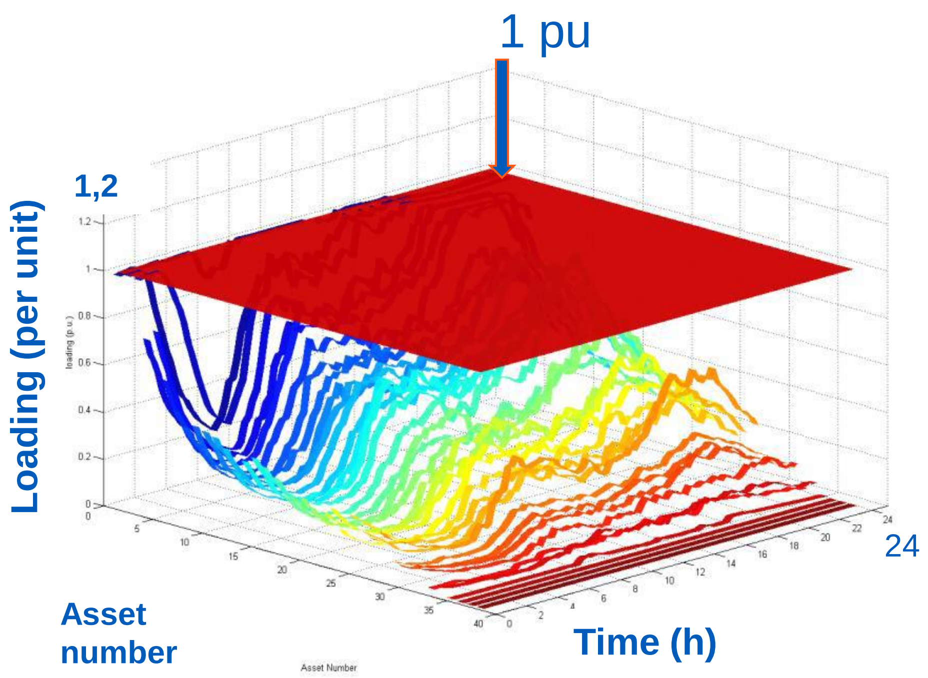


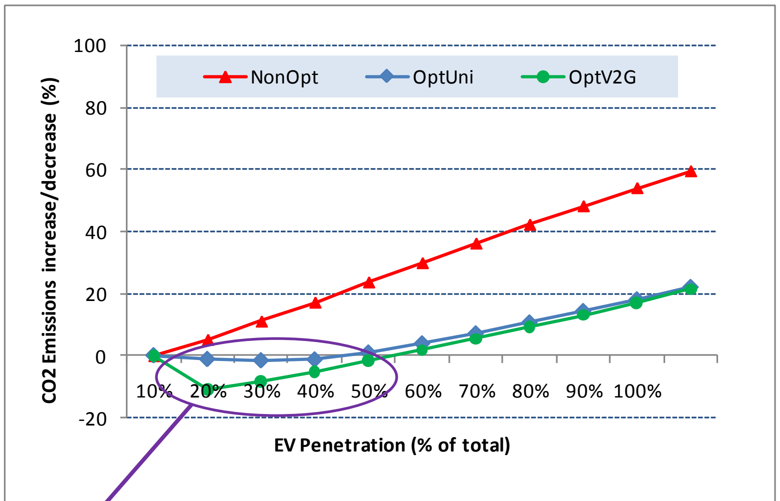

Pragmatic –35 % Evs with modulation of charging power

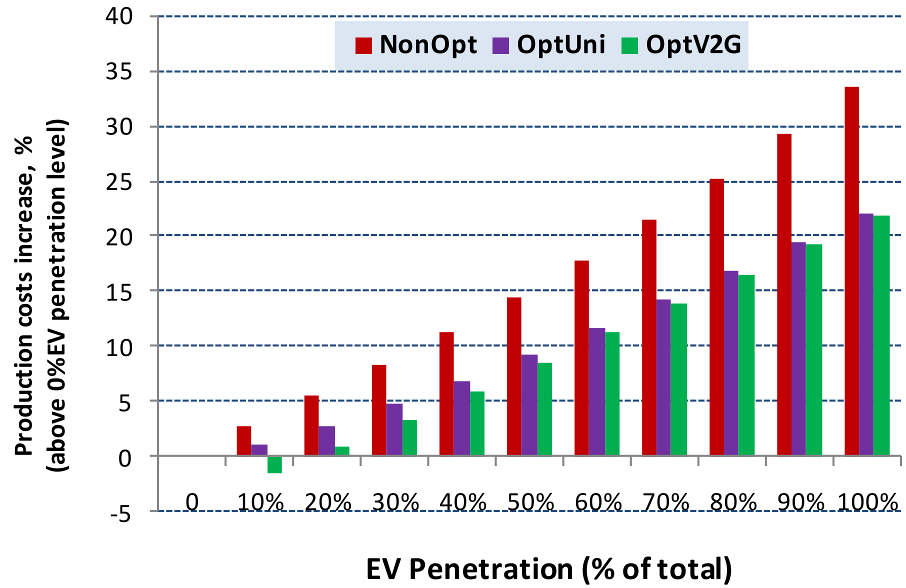
Pragmatic strategies can help in reducing network constraints at distribution network level

Source – RWTH Aachen, 2011

# Economic and environmental benefits of controlling electric vehicles at system level

Example: UK, 30% wind penetration in the system in the United Kingdom generation mix




**Drop in CO2 emissions if EV charging is controlled => greater use of wind energy**

Controlling EV charge reduces the cost of supplying EV

There is little value in using V2G when compared to shifting EV charge

Source – Aunedi, Shakoor & Strbac, Imperial College London, 2011

# First conclusions

**It is clear that if no control is performed there is a significant impact both at system and local level**

**How to control EV charge?**

- **At distribution level:**
  - **The design of the control strategies needs to ensure that to solve a problem we don't create another one**
  - **Pragmatic solutions can be used to solve congestion at local level**
- **At system level:**
  - **There are benefits from using electric vehicle flexibility**
  - **Individual EV flexibility needs to be aggregated to make up the energy volumes required to access centralized electricity markets**

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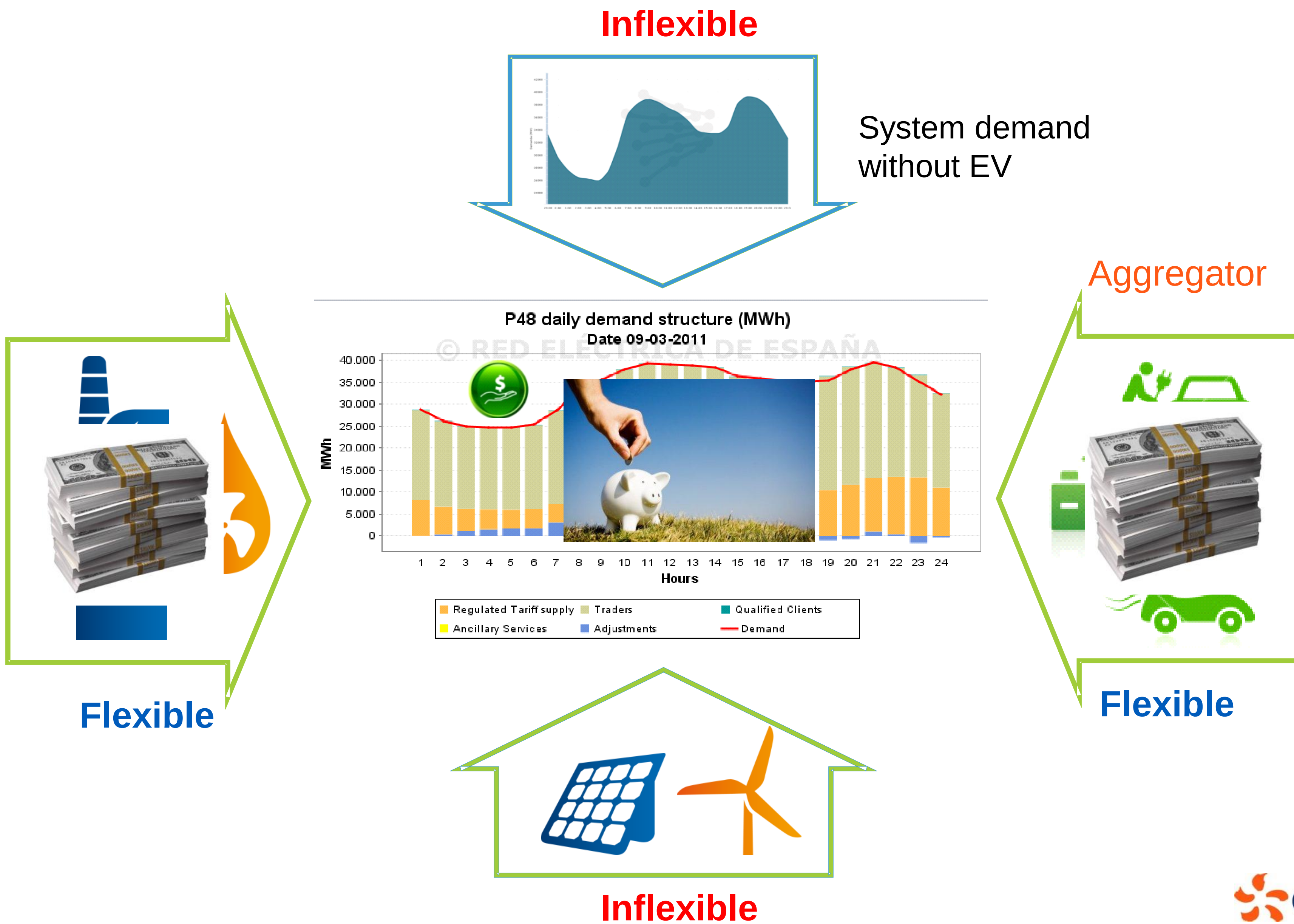
1. Impacts on and opportunities of EV integration into system operation
2. EV control strategies
3. EV flexibility services and aggregation function
4. Conclusions and Recommendations

# Aggregator as an Electricity Market Participant



# Flexibility Services from EV

- **The flexibility contracted from the EVs should be made available and deployable**

- **The aggregator will generate revenues from:**
  - **Energy deferral and V2G**
    - **The EV charges/discharges under favourable market conditions**
  - **Reserve capacity:**
    - **Aggregated EVs' spare capacity (from plugged but idle EVs)**
  - **Reserve capacity deployment:**
    - **The EV charges/discharges upon the request of the system operator**

# Optimisation of Aggregation Operation – System Level

The system operator (SO): schedules generation to meet electricity demand and keep some reserve to hedge the system against uncertainty

SO: **Minimise total operating costs** using generation and demand EV flexibility

**Subject to:** **Demand Generation Balance**

**Reserve requirement**

**Generation technical limits**

Aggregator: Schedules EV in order to **maximise revenues**

**Subject to:** **EV energy requirements for motion and V2G**

**Battery state of charge**

**Charging and Discharging rates**

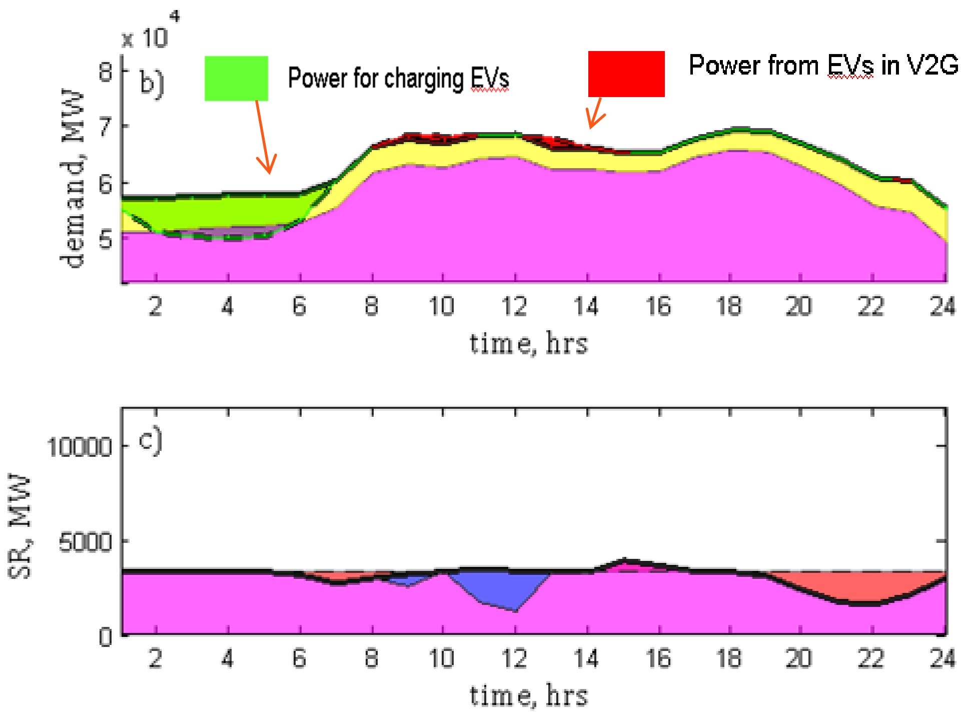
**EV status**



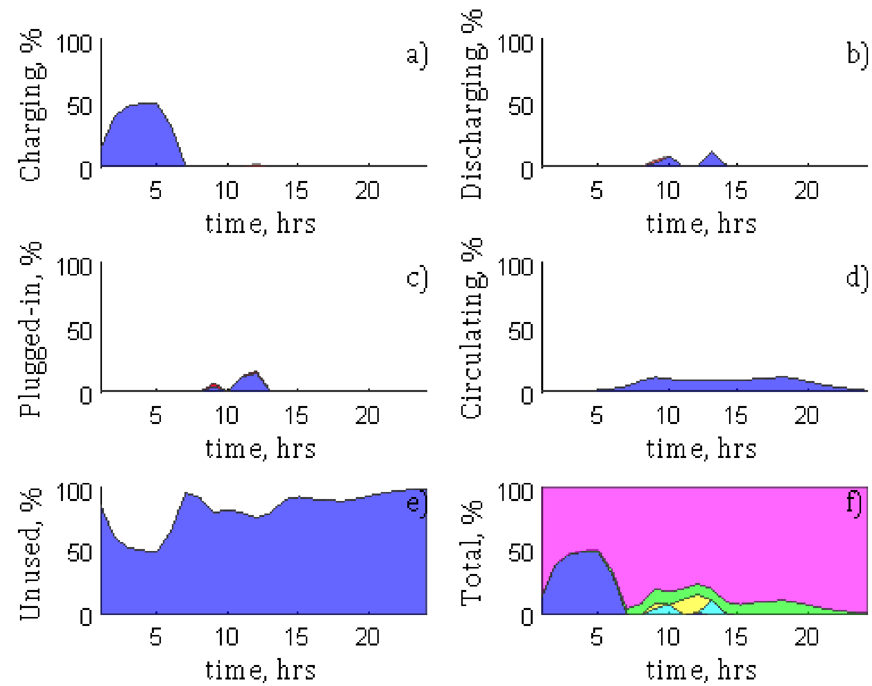
Ortega-Vazquez, Bouffard & Silva, 2011

# Generation and EV scheduling: Low EV Penetration

## 10% EV penetration




## EV operation mode




Power from Wind power generation

Power deployed from reserve

Power from Conventional generation

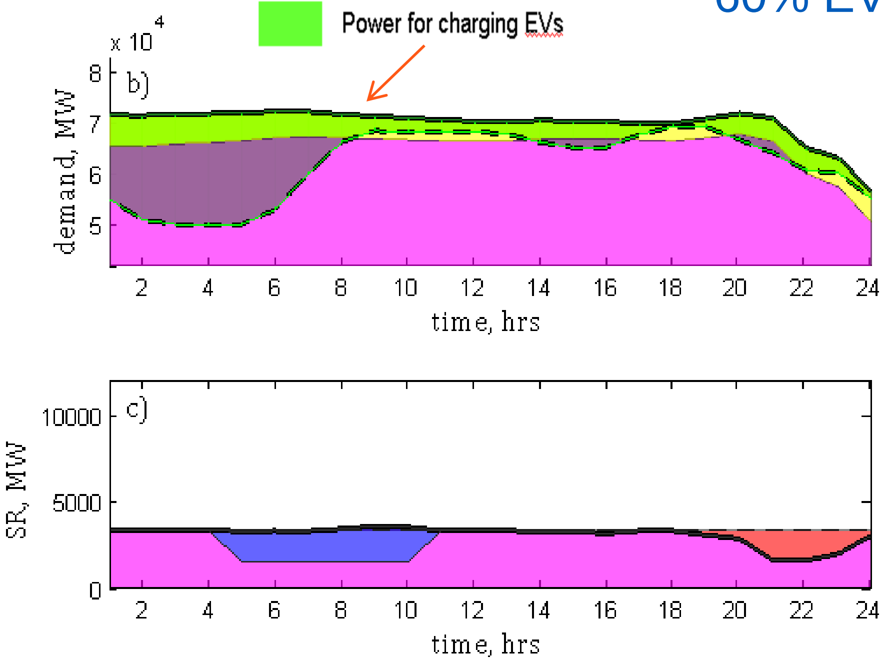
Power for reserve provision

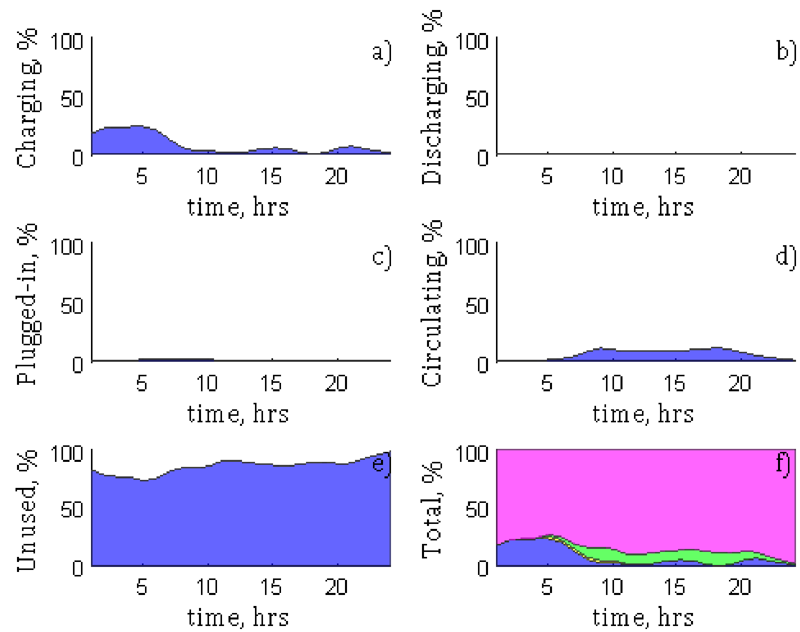
Aggregator bids competitive prices – all services are provided

Ortega-Vazquez, Bouffard & Silva, 2011

# Generation and EV scheduling: High EV Penetration

60% EV penetration




Power from Wind power generation

Power deployed from reserve

Power from Conventional generation

Power for reserve provision

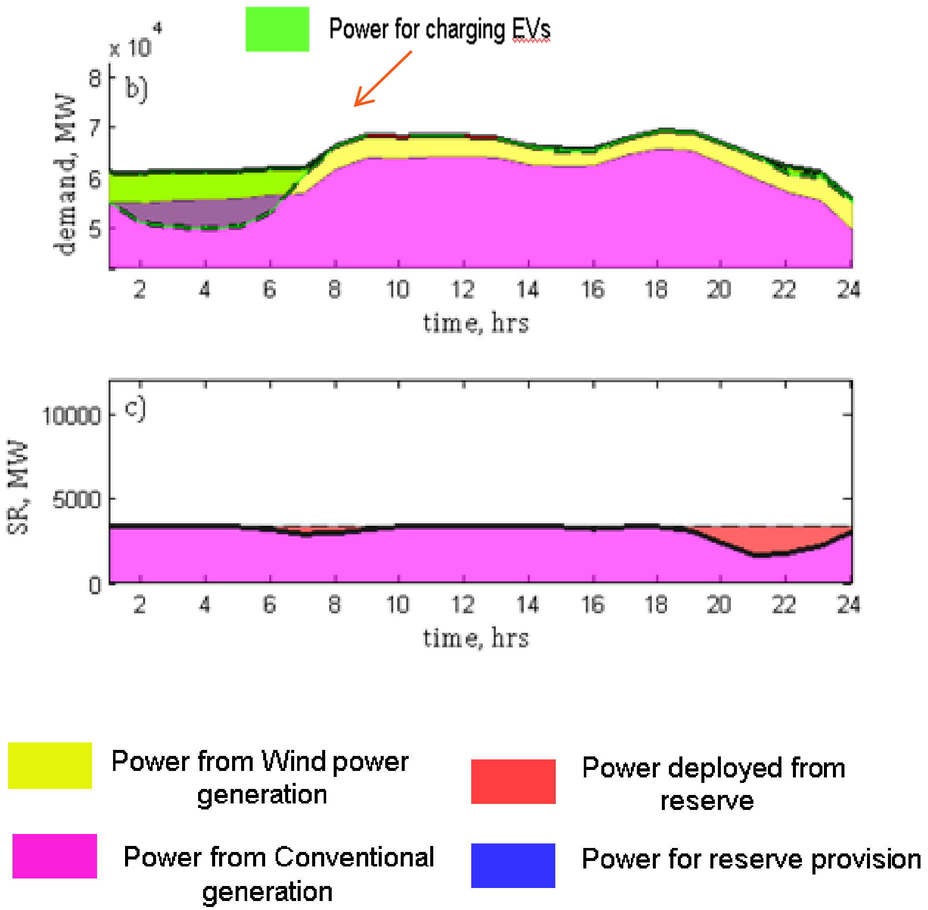
The reserve services are preferred since the wide demand has been increased and it is now “flat”

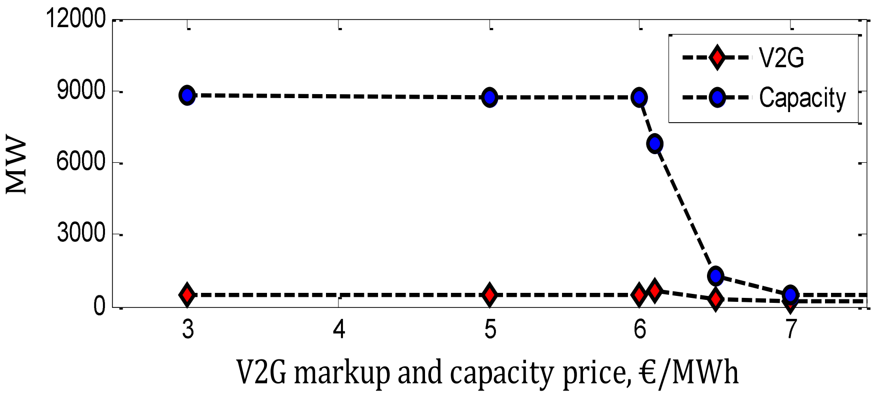


Ortega-Vazquez, Bouffard & Silva, 2011

G4V Grid for Vehicles EDF

# Generation and EV scheduling: High prices for EV services




The services offered by the aggregator will only be acquired if these are cheaper than those offered by conventional generation

# Economic Potential of EV Flexibility Services

- **Flexibility services** are contracted by the SO **only if competitive** when compared to existing technologies (conventional generation other flexible loads)

- **V2G services** are used whenever **their deployment is less expensive** than synchronizing or maintaining online conventional generation **but their value is low**

- **Key factors influencing the value of EV flexibility services:**
  - **System**: supply price curve, flexibility of the generation mix, penetration of intermittent generation
  - **Aggregator :** bidding strategies, operation cost of operating the EVs
  - **EV** : price/cost of the services, connection power, penetration of EV
  - **Consumer** : acceptance of control strategies, driving patterns (km/day),

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# Conclusions

- A cost effective deployment of EV should be done by controlling the EV charging

- EV control strategies should :
  - consider the needs and constraints of the electricity distribution networks
  - be implemented using upgradable solutions so that they can evolve together with the development of smart grid functionalities

- Advanced control strategies will be facilitated by the appearance of the function of aggregation that:
  - gathers disperse flexibilities from all EVs
  - trades different flexibility services in different electricity markets
  - operates the EVs in order to deploy this flexibility

# Challenges

- Further development of simulation models, economic analysis and social studies are required
- Standardization, lab testing and demonstration initiatives are needed before a large scale implementation of pragmatic and advanced control strategies

# Thank you for your attention!

**Colleagues involved in this work:**

Miguel Ortega-Vazquez, University of Washington, USA

Christophe Kieny, Luc Glorieux, EDF R&D, France

Joost Laarakkers , ECN, Netherlands

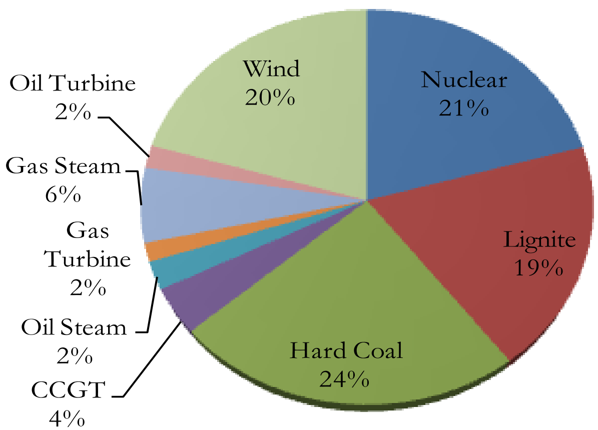
Details of this work can be found in the FP7 European Project G4V deliverables

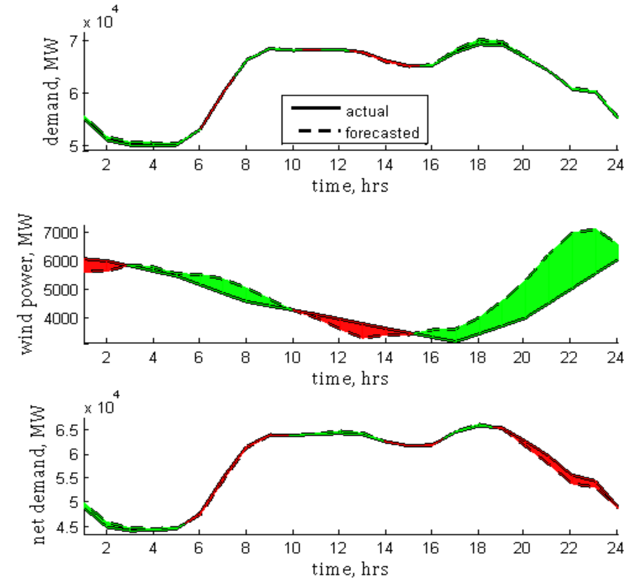
www.g4v.eu

# Aggregator: Case Study

## Generation and Demand Data

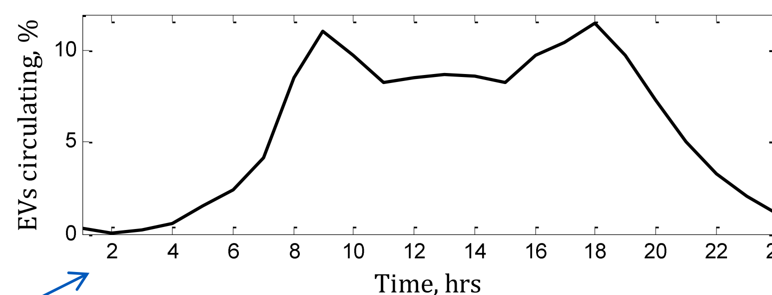
Generation Composition




## EV Data

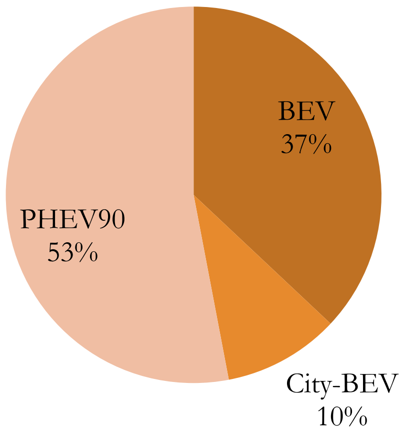
| | |
|---|---|
| Average EVs' range (km) | 125.5 |
| Average distance (km/day) | 40.0 |
| Energy consumption per day per car (kWh/day) | 7.680 |
| Slow charging/discharging power (kW/h) | 3.7 |
| Quick charging/discharging power (kW/h) | 11.0 |
| Fast charging/discharging power (kW/h) | 55.0 |
| **Number of vehicles in the system, (Millions)*** | **41** |

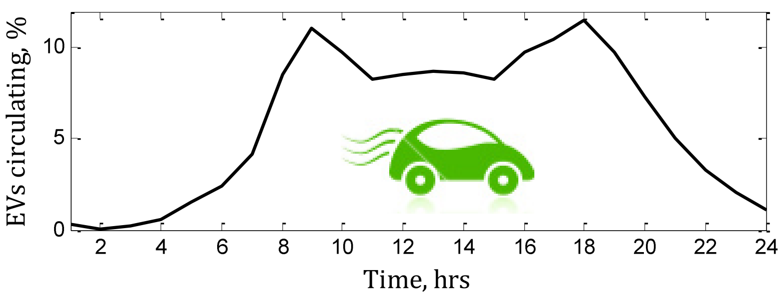


# EVs' characteristics

| EV's parameter | EV type | Value |
|---|---|---|
| EVs' composition (%) | BEV | 37 |
| | City-BEV | 10 |
| | PHEV90 | 53 |
| Battery Capacity (kWh) | BEV | 35.0 |
| | City-BEV | 16.0 |
| | PHEV90 | 18.0 |
| Average battery capacity (kWh) | | 24.1 |
| Energy consumption (kWh/km) | BEV | 0.20 |
| | City-BEV | 0.12 |
| | PHEV90 | 0.20 |
| Average energy consumption (kWh/km) | | 0.192 |

**EVs Composition**

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| Total number of vehicles in the system, (Millions)* | 41.019 |

*Statistisches Bundesamt Deuchland - Fahrzeugbestand*. Available [Online]: http://www.destatis.de/jetspeed/portal/cms/Sites/destatis/Internet/DE/Content/Statistiken/Verkehr/VerkehrsmittelbestandInfrastruktur/Tabellen/Content75/Fahrzeugbestand,templateId=renderPrint.psml