Flexibility of EV charging: Use-Cases, actors and technologies
Bruno Robisson

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The project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 857484
AGENDA

• Panorama of the french full electric vehicles (EV) market
• Charging an EV
  • Modes
  • The plug and socket zoo
  • Wallbox and Charging stations
  • The french charging infrastructure
• Smart charging an EV
  • Use Case 1: Charging stations for employees within the company
    • Smart charging need: max power reduction
    • Principle and setup
  • Use Case 2: Charging commercial vehicles in depots
    • Smart charging need: energy cost reduction
    • Principle and setup
  • Use Case 3: Charging stations at home
    • Smart charging need: Autoconsumption increase
    • Principle and setup
  • Use Case 4: "Opportunist’ charging stations
PANORAMA OF THE FRENCH EV MARKET

Sales of full Electric Vehicles (EV) in France [1]

Sells of full EV cars in France

Total: ~ 276485 EV from 2010

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# TOP TEN SALES – FRANCE 2020

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Model</th>
<th>Capacity kWh</th>
<th>Autonomy Km (WLTP)</th>
<th>Charging power AC (kW)</th>
<th>DC(kW)</th>
<th>#units</th>
<th>Price €</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renault</td>
<td>Zoé</td>
<td>52</td>
<td>395</td>
<td>22</td>
<td>0-50</td>
<td>37409</td>
<td>(33.7%)</td>
</tr>
<tr>
<td>Peugeot</td>
<td>E-208</td>
<td>46</td>
<td>340</td>
<td>7-11</td>
<td>100</td>
<td>16557</td>
<td>(14,9%)</td>
</tr>
<tr>
<td>Tesla</td>
<td>Model-3</td>
<td>50-75</td>
<td>448-580</td>
<td>11</td>
<td>250</td>
<td>6477</td>
<td>(5,8%)</td>
</tr>
<tr>
<td>Hyundai</td>
<td>Kona</td>
<td>40-64</td>
<td>289-482</td>
<td>7</td>
<td>77</td>
<td>5156</td>
<td>(4,7%)</td>
</tr>
<tr>
<td>Kia</td>
<td>E-Niro</td>
<td>40-64</td>
<td>289-455</td>
<td>7</td>
<td>77</td>
<td>5089</td>
<td>(4,6%)</td>
</tr>
<tr>
<td>Volkswagen</td>
<td>Id3</td>
<td>45 58-77</td>
<td>350 424-549</td>
<td>11</td>
<td>11</td>
<td>50</td>
<td>4187</td>
</tr>
<tr>
<td>Nissan</td>
<td>Leaf</td>
<td>40-62</td>
<td>273-385</td>
<td>6</td>
<td>50-100</td>
<td>3395</td>
<td>(3,1%)</td>
</tr>
<tr>
<td>Peugeot</td>
<td>E-2008</td>
<td>46</td>
<td>320</td>
<td>7-11</td>
<td>100</td>
<td>2933</td>
<td>(2,6%)</td>
</tr>
<tr>
<td>DS</td>
<td>DS3</td>
<td>50</td>
<td>320</td>
<td>7-11</td>
<td>100</td>
<td>2710</td>
<td>(2,4%)</td>
</tr>
<tr>
<td>Mini</td>
<td>Cooper</td>
<td>33</td>
<td>234</td>
<td>11</td>
<td>50</td>
<td>2481</td>
<td>(2,2%)</td>
</tr>
</tbody>
</table>

Total: 110900 EV (6.7%)  
Source: [1]  

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• Panorama of the french full electric vehicles (EV) market

**Charging an EV**

• Modes
• The plug and socket zoo
• Wallbox and Charging stations
• The french charging infrastructure

**Smart charging an EV**

• Use Case 1: Charging stations for employees within the company
  • Smart charging need: max power reduction
  • Principle and setup
• Use Case 2: Charging commercial vehicles in depots
  • Smart charging need: energy cost reduction
  • Principle and setup
• Use Case 3: Charging stations at home
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  • Principle and setup
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CHARGING MODE (IEC 61851 STANDARD)

On board charging, also called « AC charging »
From 3kW to 22kW (and even 43kW for Zoé first generation)

Off-board charging, also called « DC charging »
From 20kW to 150kW (and even 350kW)

MODE 4: DC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

Source: [2]
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AC CHARGING MODE: MODE 3

MODE 3-B: AC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

MODE 3-C: AC connexion to dedicated Electric Vehicle Supply Equipment (EVSE)

Source: [2]
THE PLUG AND SOCKET ZOO – MODE 2

- **Blue**: « camping » socket Mono-ρ 230V
- **Red**: Industrial socket Tri-ρ 400V

**plug – grid side**

- AC
- **IC-CPD**
- Grid

**EV-side coupler**

- AC
- **on board Charger**
- **Battery**
- DC

- **Tesla coupler**
- **Type 1 coupler**
- **Type 2 coupler**

« Green-up » : type E (CEE 7/17) Mono-ρ 230V

Source: [2,3]
THE PLUG AND SOCKET ZOO – MODE 3

Type 2 outlet
Type 3 outlet (out of date)

AC

plug – EVSE - side

EVSE

AC

Grid

Tesla coupler
Type 1 coupler
Type 2 coupler

Source: [2,3]
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**FRENCH VEHICLE CHARGING INFRASTRUCTURE DEFINITIONS**

Charging points speed range

- **« Own » scale**
  - Slow
  - Standard
  - Accelerated
  - Fast
  - Very Fast
  - Ultra Fast

- **« Avere » scale [4]**
  - <11kW
    - Normal
  - 14-22kW
    - Accelerated
  - 24-50kW
    - Fast
  - >50kW
    - Very fast
Number of station: 1
Number of Charging Points: 5
2*22 kW AC Type 2
+ 50 kW DC CHAdeMo
+ 50 kW DC CCS2
+ 43 kW AC Type2
Installed Power (sum (on each charging point) of the max power): 187 kW

106 Avenue de Compiègne 02200 Soissons

Source: [5]
Public charging points

<table>
<thead>
<tr>
<th>InstalledPowerCPO MW</th>
<th>NumberOfStation Units</th>
<th>NumberOfCP Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>533.91</td>
<td>9260</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Own classification</th>
<th>Slow 0-4</th>
<th>Standard 4-14</th>
<th>Accelerated 14-24</th>
<th>Fast 24-51</th>
<th>Veryfast 51-151</th>
<th>Ultrafast &gt;151</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>1886</td>
<td>348</td>
<td>16431</td>
<td>1438</td>
<td>28</td>
<td>344</td>
<td>20475</td>
</tr>
<tr>
<td>%</td>
<td>9.21</td>
<td>1.70</td>
<td>80.25</td>
<td>7.02</td>
<td>0.14</td>
<td>1.68</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avere classification</th>
<th>Normal 0-14</th>
<th>Accelerated 14-24</th>
<th>Fast 24-51</th>
<th>Very fast &gt;51</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>2234</td>
<td>16431</td>
<td>1438</td>
<td>372</td>
<td></td>
</tr>
<tr>
<td>In pourcents</td>
<td>10.91</td>
<td>80.25</td>
<td>7.02</td>
<td>1.82</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Avere Data</th>
<th>Units</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7093</td>
<td>24.52</td>
</tr>
<tr>
<td></td>
<td>19959</td>
<td>69.00</td>
</tr>
<tr>
<td></td>
<td>1102</td>
<td>3.81</td>
</tr>
<tr>
<td></td>
<td>774</td>
<td>2.68</td>
</tr>
</tbody>
</table>

*Without Tesla charging points ~500 DC very fast chargers

Predominance of “accelerated” charging points (i.e. 22kW AC)
Few fast, very fast and ultra fast charging points
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USE - CASE 1 - CHARGING STATIONS FOR EMPLOYEES WITHIN THE COMPANY [7]

- The charging points are used, during the working hours, for the vehicles of employees which commutes.
- The charging points are generally "normal" or "accelerated" and located in the company parking lot.

Examples:

**SAP Labs / Mougins Sophia-Antipolis + Caen + Paris**
- 85 CP @ AC
- 2 CP @ 50 kW DC
- 1 CP @ 150 kW DC
- ~250 EV users [8]

**CEA / Marcoule + Saclay + Cadarache**
- 22 CP @ 3kW AC
- 40 CP @ 7kW AC
- 16 CP @ 11kW AC
- 80 CP @ 22kW AC
- ~400 EV users

source [8]
How to reduce the max power bill due to the EV charging?

\[ \sum \text{individual peak loads} = 22 \times 80 = 1.76 \text{MW} \]
\[ \sum \text{Aggregated loads} \approx 300 \text{kW} \]

Diversity factor \( \approx 6 \)

Power max Bill:

- 300kW \( \approx 12000 \text{€/year} \)

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USE - CASE 1 – SMART CHARGING 1 – MAX POWER REDUCTION - PRINCIPLE

Without max power management: 13 EV Max @ 22kW charging during 8:00 and 10:00

EV arrivals

kW

13 Evs

300*kW

EV departures

0:00 6:00 12:00 18:00 24:00

2 hours @22kW ~40kWh

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USE - CASE 2 - CHARGING COMMERCIAL VEHICLES IN DEPOTS [7]

- The charging points are used, the night, for the fleets of utility vehicles (used by delivery people, postmen, repairers, bus drivers, etc.) providing their service during the day.
- The charging points are generally slow and located in the company depot.

Enedis:
1880 EV [10]

EDF / Bugey nuclear plant:
276 charging points
110 EV (Renault Zoé) [11]

La Poste:
300 establishments
7000 light commercial EV (mostly Renault Kangoo) [12]
USE - CASE 2 – SMART CHARGING 2 – ENERGY COST REDUCTION

Electricity provider

Energy Bill Wh

Max Power Bill W

Consumer

EVRI manager

Electric network

TSO/DSO

(Wh,W)

×20

3kW

3kW

MyRenault application

Cloud ‘Renault’

Remote EV Service

How to reduce the energy bill due to the EV charging?

+At lowest cost

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**USE - CASE 2 – SMART CHARGING 2 – ENERGY COST REDUCTION - PRINCIPLE**

Postman’ round from 6AM to 12AM: 120km / day / EV (~20kWh / day / EV)

<table>
<thead>
<tr>
<th>Time</th>
<th>Charging cost</th>
<th>Price/€/kWh</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:00</td>
<td>3€</td>
<td>15c€/kWh</td>
</tr>
<tr>
<td>12:00</td>
<td>Charge without management</td>
<td>3€</td>
</tr>
<tr>
<td>18:00</td>
<td>Charge with management</td>
<td>2€</td>
</tr>
<tr>
<td>24:00</td>
<td>Charge without management</td>
<td>3€</td>
</tr>
<tr>
<td>6:00</td>
<td>Charge with management</td>
<td>2€</td>
</tr>
</tbody>
</table>

Potential Savings with **peak / off-peak hours option**

Price(peak)-Price(off-peak) ~5 c€/kWh

i.e. 1 € / day /EV

For 20 EV working 260 days/Years -> ~5000€/year
Charge management:
Off-board via MyRenault App or manually « on board »

Electricity provider

Energy Bill Wh
Max Power Bill W

TSO/DSO

Electric network

(Wh,W) ×20

TSO/DSO

Electric network

Cloud ‘Renault’

MyRenault application

EVRI manager

Consumer

peak / off-peak hours

3kW

3kW

3kW

In collaboration with

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**USE - CASE 2 – SMART CHARGING 2 – ENERGY COST REDUCTION – SETUP 2**

Charge management:
Via Linky and an electric contactor
Cost of a $ n$ electric contactor

**Electricity provider**

**Energy Bill**
Wh

**Max Power Bill**
W
peak / off-peak hours option

**TSO/DSO**

**Electric network**

<table>
<thead>
<tr>
<th>Linky</th>
<th>3kW</th>
<th>Linky</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak</td>
<td>ON/OFF</td>
<td>Peak</td>
</tr>
<tr>
<td>3kW</td>
<td>3kW</td>
<td></td>
</tr>
</tbody>
</table>

Electric contactor (~60€ / unit)
USE - CASE 3 - CHARGING STATIONS AT HOME [7]

- The charging points are used for recharging the EV used for commuting during the working week.
- The charging points are generally slow or accelerated and located in the garage, next the house or in the parking lot of a collective dwelling.
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Cost Price (network) ~ 15 c€/kWh
Cost Price (PV) ~ 10 c€/kWh
Sell Price (PV surplus) ~ 10 c€/kWh
PV production: 24kW
Consumption without EV: 20kWh

### Period kWh Price (c€/kWh) Cost (c€) Sell (c€)
<table>
<thead>
<tr>
<th>Period</th>
<th>kWh</th>
<th>Price (c€/kWh)</th>
<th>Cost (c€)</th>
<th>Sell (c€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>4</td>
<td>15</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>MidDay</td>
<td>8</td>
<td>10</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>MidDay (Surplus)</td>
<td>16</td>
<td>10</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Evening</td>
<td>8</td>
<td>15</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>420</strong></td>
<td><strong>160</strong></td>
</tr>
</tbody>
</table>

PV production

4kWh @ 15c€/kWh
8kWh @ 10c€/kWh
16kWh @ 10-10=0c€/kWh
8kWh @ 15c€/kWh

Consumption without EV Charging
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### USE - CASE 3 – SMART CHARGING 3 – ENERGY COST REDUCTION - PRINCIPLE

**Consumption of EV:**  
50 km/day → 10 kWh/day

<table>
<thead>
<tr>
<th>Period</th>
<th>kWh</th>
<th>Price (c€/kWh)</th>
<th>Cost c€</th>
<th>Sell c€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>4</td>
<td>15</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>MidDay</td>
<td>8</td>
<td>10</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>MidDay (Surplus)</td>
<td>16</td>
<td>10</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Evening</td>
<td>8+10</td>
<td>15</td>
<td>120</td>
<td>+150</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>570</td>
<td>160</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>260</td>
<td>+150=410</td>
</tr>
</tbody>
</table>

**With EV Charging**  
Without smart charging

- 4 kWh 15c€/kWh
- 8 kWh @10c€/kWh
- 16 kWh @10c€/kWh  
- 18 kWh @15c€/kWh

+ increase subscription ~6kW
USE - CASE 3 – SMART CHARGING 3 – ENERGY COST REDUCTION - PRINCIPLE

<table>
<thead>
<tr>
<th>Period</th>
<th>kWh</th>
<th>Price (c€/kWh)</th>
<th>Cost c€</th>
<th>Sell c€</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morning</td>
<td>4</td>
<td>15</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>MidDay</td>
<td>8+10</td>
<td>10</td>
<td>80+100</td>
<td></td>
</tr>
<tr>
<td>MidDay (Surplus)</td>
<td>16-10</td>
<td>10</td>
<td>160-100</td>
<td>160-100</td>
</tr>
<tr>
<td>Evening</td>
<td>8</td>
<td>15</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>420</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>360</td>
<td></td>
</tr>
</tbody>
</table>

Expected savings:
Subscription 9+3=12kW instead of 9+6=15kW ~30€ /year
If 1 EV used 250 days/years : 3/5 of solar charge -> ~75€/year
~100€ /year

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USE - CASE 4 - "OPPORTUNISTIC" USE [7]

- These stations are used on an “ad hoc” and “opportunistic” basis by passing electric vehicles.
- These charging stations are normal, accelerated or fast and are installed on public roads, in car parks of shops or shopping centers or on motorway service areas.

Owners: shops
- Lidl: 900 charging points

Owners: territorial collectivity
- LaRecharge (Aix-Marseille Metropole)
  - 174 charging points (22kW AC)

Owners: charge point operator
- Ionity: 350 charging points (>50kW DC)
Nowadays, various smart charging solutions can be setup with commercial equipments and solutions.

There exist cheap solutions but also very expensive ones.

Other « smarter » solutions exist, based on complex information systems and off-site control of the EV charges.
  - For example, smart charging of EVs @ CEA Cadarache.

To setup smart charging solutions, the charging needs of the users have to be precisely studied.

CONCLUSION
REFERENCES / SOURCES


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