ZOE Battery Durability, Field Experience and Future Vision

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World EV Market

Alliance Cumulated EV sales:
- >350k:
  - ~250k for NISSAN
  - ~100k for RENAULT

2016 Alliance EV sale:
- ~100k for the Alliance

2016 Word wide EV Sales:
- ~500k (~250k for China)
Installation in the Renault ZOE
ZOE Electric Drive Components

ZOE made in Flins (France)
Driving Range
400km (NEDC)

E-Powertrain made in Cleon (France)
65kW, 220Nm
22kW AC integrated charger

Battery assembled in Flins (France)
Usable energy
41 kWh
Voltage: 240V-403V DC
### Battery Pack for ZOE

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usable Energy</td>
<td>41kWh</td>
</tr>
<tr>
<td>Maximum power</td>
<td>80kW</td>
</tr>
<tr>
<td>Nominal voltage</td>
<td>360V</td>
</tr>
<tr>
<td>Pack weight</td>
<td>300kg (+21kg)</td>
</tr>
</tbody>
</table>

- **12 modules inside**
- **Cooling air interface**: (1 inlet / 2 outlets)
- **Service Disconnect Switch**
- **High voltage connector**

- **No pack modification to reach 400km (NEDC)**
- **Only module and BMS SW evolution**
ZOE NEDC range evolution since 2013

NEDC Range (km)

Year


210km E-powertrain R240

240km ZE40

400km New Battery
How to go from 240 to 400km based on cell energy density improvements?

- Improvements mainly based on cell design

Improvements mainly based on cell design
Driving range evolution

Range (NEDC km)

> 2020

<table>
<thead>
<tr>
<th>Year</th>
<th>Range (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>210</td>
</tr>
<tr>
<td>2013-16</td>
<td>240</td>
</tr>
<tr>
<td>2016</td>
<td>400</td>
</tr>
<tr>
<td>&gt; 2020</td>
<td>~600</td>
</tr>
</tbody>
</table>
Cell performance evolution

Cell Energy Density (Wh/l), (Wh/kg)

- 300 Wh/l
- 160 Wh/kg

Year:
- 2010
- 2015
- 2020
- 2025
- 2030
- 2035
Cell performance evolution

Cell Energy Density (Wh/l), (Wh/kg)

Year

- 160 Wh/kg
- 240 Wh/kg
- 300 Wh/l
- 500 Wh/l
Cell performance evolution

- **Li-ion Technology**
  - 2010: 160 Wh/kg
  - 2015: 240 Wh/kg
  - 2020: 300 Wh/l
  - 2025: 500 Wh/l
  - 2030: ~800 Wh/l
  - 2035: ~350 Wh/kg
Cell performance evolution

**Li-ion Technology**
- 160 Wh/kg
- 240 Wh/kg
- ~350 Wh/kg
- 500 Wh/kg
- ~800 Wh/l
- 5000 Wh/kg
- 1000 Wh/l

**Post Li-ion?**
Cell performance evolution

- How to go from 500 to 800Wh/l cell energy density?

500Wh/l → 800Wh/l

- Ni-rich
- Si-based
- Electrolyte
- Additives

- Cell Chemistry
- Cell design

- Space optimization
- Thinner foils
- High loading
- Separator

- “New” chemistries needed for reaching 800Wh/l
Requirements Roadmap for EV

Cycle life requirement estimation

Usage 1 < Usage 2 < Usage 3

City → Highway

Total pack energy (kWh)

Cycle number
Requirements Roadmap for EV

Cycle life requirement estimation

- Usage 1 < Usage 2 < Usage 3
- City → Highway

Total pack energy (kWh) vs. Cycle number

2013

- Usage 1
- Usage 2
- Usage 3
Requirements Roadmap for EV

Cycle life requirement estimation

- Usage 1 < Usage 2 < Usage 3
- City < Highway
Requirements Roadmap for EV

Cycle life requirement estimation

Cycle life requirement will not decrease... (too much)
Customers’ usages need to be mastered for better battery design
ZOE ZE22 Battery: Feedback on T°C distribution

-10°C < T°C < 40°C

Cumulated driving events (%)

Temperature (°C)

Average T°C~15°C
ZOÉ ZE22 Battery: Feedback on mileage distribution

- Daily usage for short distance (Average ~40km/day)

Average customer: 9123 km/year
ZOÉ ZE22 Battery: Feedback on mileage distribution

- **Average customer:** 9123 km/year

- **Daily usage for short distance (Average ~40km/day)**

![Graph showing mileage distribution]

- Mild driving range

<table>
<thead>
<tr>
<th>Driving range (km per year)</th>
<th>Customer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2k</td>
<td>3</td>
</tr>
<tr>
<td>2k-4k</td>
<td>4</td>
</tr>
<tr>
<td>4k-6k</td>
<td>9</td>
</tr>
<tr>
<td>6k-8k</td>
<td>10</td>
</tr>
<tr>
<td>8k-10k</td>
<td>14</td>
</tr>
<tr>
<td>10k-12k</td>
<td>12</td>
</tr>
<tr>
<td>12k-14k</td>
<td>8</td>
</tr>
<tr>
<td>14k-16k</td>
<td>6</td>
</tr>
<tr>
<td>16k-18k</td>
<td>5</td>
</tr>
<tr>
<td>18k-20k</td>
<td>3</td>
</tr>
<tr>
<td>20k-22k</td>
<td>2</td>
</tr>
<tr>
<td>22k-24k</td>
<td>1</td>
</tr>
<tr>
<td>24k-26k</td>
<td>1</td>
</tr>
<tr>
<td>26k-28k</td>
<td>1</td>
</tr>
<tr>
<td>28k-30k</td>
<td>0</td>
</tr>
<tr>
<td>30k-32k</td>
<td>0</td>
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<tr>
<td>32k-34k</td>
<td>0</td>
</tr>
<tr>
<td>34k-36k</td>
<td>0</td>
</tr>
<tr>
<td>36k-38k</td>
<td>0</td>
</tr>
<tr>
<td>38k-40k</td>
<td>0</td>
</tr>
<tr>
<td>&gt;40k</td>
<td>0</td>
</tr>
</tbody>
</table>
ZOE ZE22 Battery: Feedback on mileage distribution

- **Daily usage for short distance (Average ~40km/day)**

  - **Mild**
  - **Average**

  - **Average customer:** 9123 km/year

  - Driving range (km per year):
    - 0-2k
    - 2k-4k
    - 4k-6k
    - 6k-8k
    - 8k-10k
    - 10k-12k
    - 12k-14k
    - 14k-16k
    - 16k-18k
    - 18k-20k
    - 20k-22k
    - 22k-24k
    - 24k-26k
    - 26k-28k
    - 28k-30k
    - 30k-32k
    - 32k-34k
    - 34k-36k
    - 36k-38k
    - 38k-40k
    - >40k

  - Customer (%) distribution for different ranges.
ZOE ZE22 Battery: Feedback on mileage distribution

Mild

Average customer: 9123 km/year

Severe

Daily usage for short distance (Average ~ 40 km/day)
Expected durability is achieved and confirmed by our life estimation model.
CONCLUSIONS

- RENAULT succeed to increase the driving range from 240km* (ZE22) to 400km* (ZE40) without modifying the pack architecture.

- Renault will adapt this new chemistry to others vehicles (i.e. Kangoo ZE, Master ZE,...)

- ZE22 Battery life has been confirmed through field data analysis and life estimation model.

- For achieving higher energy density, “new” chemistries are needed (i.e. Si-based anode, Ni-rich, Electrolyte, Additives...)

*NEDC cycle
RENAULT ZE VEHICLES

Twizy

ZOE ZE40

Fluence/SM3 ZE

Kangoo ZE

http://www.renault-ze.com/
RENault ZE Vehicles to be launched

Master ZE

200km (NEDC)

New Kangoo ZE

270km (NEDC)
Thank you for your attention