Nissan Electric Vehicle and Future Vision

JULY 20th, 2016
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Nissan Technical Center
Contents

- EV Customer Expectation
- Technical Breakthrough of EV
  - Battery
  - E-Powertrain
  - Charging
- Summary
EV customers expectation

Range: Mileage per Charge

Drivability: Driving Performance

Charging: Easy to Charge

Cost: Vehicle Price
Technology Trend: Driving Range

- Double driving range in the near future

<table>
<thead>
<tr>
<th>Year</th>
<th>Range (mile)</th>
<th>Battery (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>73</td>
<td>24</td>
</tr>
<tr>
<td>2013</td>
<td>84</td>
<td>24</td>
</tr>
<tr>
<td>2016</td>
<td>107</td>
<td>30</td>
</tr>
<tr>
<td>2017 - 2020</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

< EPA label >
Technology Trend: Drivability

- Increased motor power, plus AWD
Technology Trend: Charging

- QC power increase with Battery capacity

Benchmarking of Quick charge performance

Charged Power in 30 min [KWh]

<table>
<thead>
<tr>
<th>Battery Capacity [KWh]</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC 150KW</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>QC 120KW</td>
<td></td>
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<tr>
<td>QC 100KW</td>
<td></td>
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<tr>
<td>QC 50KW</td>
<td></td>
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</tbody>
</table>

MAX Power of Quick charger

- EV-01
- EV-02
- EV-03
- EV-04
- EV-05
- EV-06 (Announce)

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# Technical breakthrough of EV

<table>
<thead>
<tr>
<th>Key Technology</th>
<th>Battery</th>
<th>e Power-Train</th>
<th>Charging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>High capacity</td>
<td>High power</td>
<td>N/A</td>
</tr>
<tr>
<td>Drivability</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Charging</td>
<td></td>
<td></td>
<td>High power</td>
</tr>
<tr>
<td>Cost</td>
<td>High capacity</td>
<td></td>
<td>High power</td>
</tr>
</tbody>
</table>

- **Battery**
  - New material
  - Pack design
- **e Power-Train**
  - Semiconductor
  - Magnetic material
- **Charging**
  - High power
  - Wireless

- **Cost**
  - High capacity
  - High power

- **Impact**

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## Technical breakthrough of EV

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<p>| | | | |</p>
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<tr>
<th></th>
<th></th>
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<th></th>
</tr>
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<tbody>
<tr>
<td>Range</td>
<td>★★★</td>
<td>★</td>
<td>★</td>
</tr>
<tr>
<td>Drivability</td>
<td>★</td>
<td>★★★</td>
<td>N/A</td>
</tr>
<tr>
<td>Charging</td>
<td>★</td>
<td>N/A</td>
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<td>★★★</td>
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Battery technology

Autonomy range expansion
Further acceleration performance
Flexibility for various vehicles

High energy density  High power density
※Maintain Safety and Reliability

Dense packaging technologies
～Module, Stack, Pack～
1) High density
2) Low resistance connection
3) Flexible packaging

Materials
～Anode, Cathode, Separator, electrolyte～
1) Energy density, 2) Power density, 3) Safety
**Cell material and module innovation**

- Improve chemical structure
- Increase the number of cell-stacking (High density stacking)

<table>
<thead>
<tr>
<th>Cell material and module innovation</th>
<th>24kWh Current</th>
<th>Future materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrodes &amp; Cell</td>
<td>Cathode</td>
<td>Manganese (M)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nickel (N)</td>
</tr>
<tr>
<td>Anode</td>
<td></td>
<td>Cobalt (C)</td>
</tr>
<tr>
<td>Stack /Module</td>
<td></td>
<td>Graphite (Gr)</td>
</tr>
<tr>
<td>4cell module</td>
<td>Packaging efficiency improvement</td>
<td>Multiple cell In High density stack</td>
</tr>
<tr>
<td>Li amount increase</td>
<td>Li acceptance improve</td>
<td></td>
</tr>
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</table>
Packaging innovation

- More than 2 times the battery capacity within the same size constraints as the current one

24-30 kWh Pack
(LEAF Current model)

Larger capacity battery

Today

Tomorrow

Module

New stack

Current cell

High capacity cell
Packaging innovation
## Technical breakthrough of EV

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<td>Semiconductor</td>
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</tr>
<tr>
<td>Magnetic material</td>
<td></td>
<td>Wireless</td>
</tr>
</tbody>
</table>

| Range       | ★★★ | ★ | ★ |
| Drivability | ★ | ★★★ | N/A |
| Charging    | ★ | N/A | ★★★ |
| Cost        | ★★★ | ★★★ | ★★★ |

*Note: The ★ symbols represent the level of development or achievement for each category.*
e-PT technology

Further autonomy range expansion
Further acceleration performance
Flexibility for various vehicles

- Efficiency
- Power
- Size
- Cost

- Cooling
- Integration
- Integration
- High voltage components
- New magnet (Rare earth reduction)
- New structure, WBG devices

Magnet
Magnetic Steel
Capacitor, etc
Power Module

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Magnet innovation

- Reduced Dy contents in the magnet by 40%, applying the grain boundary diffusion magnet technology
- Towards 2020, further Dy reduction and/or Zero to be expected
Electromagnetic steel innovation

- Used Silicon steel (Electromagnetic steel sheet) of less than 0.35 mm in thickness
- The thin iron plate expected small Iron loss and high-efficiency

**Trend of the Silicon steel**

- Magnetic flux density $B_{50}$ [T]
- High frequency iron loss $W_{10/400}$ [W/Kg]

**Key Points**

- **Today**
  - Magnetic flux density: less than 0.35 mm ($t=0.2 \sim 0.3$ mm)
  - High frequency iron loss

- **Tomorrow**
  - Magnetic flux density: 0.35 mm
  - High frequency iron loss

**Legend**

- High performance
- Upper grade
- Standard
Power Semiconductor innovation

- Wide Band Gap technologies expected for System-level improvement

Low-loss

- Power Loss
  - Si
  - GaN, SiC
  - ~40% down

- Benefits:
  - Autonomy range extension
  - Cooling cost reduction

High-frequency Switching

- ~75% down

- Benefits:
  - Parts size (cost) reduction

Wide Band Gap (WBG) materials (GaN, SiC) promise significant improvements in efficiency and cost reduction for power semiconductor applications.
Power Semiconductor innovation

- 2 directions for SiC / GaN application

![Diagram showing switching frequency vs. power with categories like Power Grid, Train, EV drive, EV charger, Home appliance, Si, and GaN.]
Electric drive enables high power models

- Game change of high power models by common EV assets + dedicated PF
- High power performance with disruptive MSRP thanks to the architecture

e.g. AWD EV w/ 3 motors (360kW)
## Technical breakthrough of EV

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</tr>
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<table>
<thead>
<tr>
<th>Feature</th>
<th>Battery</th>
<th>e Power</th>
<th>Charging</th>
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</thead>
<tbody>
<tr>
<td>Range</td>
<td>3 stars</td>
<td>1 star</td>
<td>1 star</td>
</tr>
<tr>
<td>Drivability</td>
<td>1 star</td>
<td>3 stars</td>
<td>N/A</td>
</tr>
<tr>
<td>Charging</td>
<td>1 star</td>
<td>N/A</td>
<td>3 stars</td>
</tr>
<tr>
<td>Cost</td>
<td>3 stars</td>
<td>3 stars</td>
<td>3 stars</td>
</tr>
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High-power quick charge

- Widening standard and developing technology are needed for infrastructure and vehicles, as well as batteries.

Current maximum power 50kW ➜ over 100kW

- Charging gun for high power
- User friendly charging cable
- Small relay on board
- Battery pack capability
- Battery pack
Wireless Charging System

Coil (Vehicle side)

Power Unit

Remote auto parking

Coil (Road side)

Prototype

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Summary
Focus on customer expectations and the future of EV development

Nissan continues to lead Zero Emission Vehicle development and implementation

Future development of EV performance:
- Battery: Higher density, higher power output
- e-PT: Efficiency improvement, acceleration performance
- Charging: High power, wireless
Thank you for your attention!