Technology development and future vision of Nissan's Electric Vehicle

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Nissan Motor Co., Ltd.
SVP Minoru SHINOHARA

1. Background on the Electric Powertrain
2. Development of Nissan’s EV
3. Preparation for Widespread EV Adoption
4. Approach to Future Mobility
Nissan Green Program (NGP) 2010

CO2 Reduction
In 2050 vs. 2000: -90% (estimation)

Short-term: Evolution of engine technologies including HEV
Long-term: Expanding Zero-emission vehicles

Cleaner Emissions
Atmosphere-level emission
Expanding SU-LEVs
Cube (SU-LEV)

Recycling resources
Recycling rate: over 95%
Resource recovery rate: 100%

Environment: Electric powertrain for CO2 reduction
- Ultimate goal of Zero-emission vehicles and clean energy

New car's CO2 emissions (Well To Wheel) (%)
Energy: Electricity for powertrains

- Electricity is a highly efficient use of energy
- Electric energy can be generated from various sources
- Electric energy is essential for securing energy and lessening dependence on oil

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LEAF unveiled in August 2009

- Launch Nissan’s original EV in Japan, US and Europe in FY10
- Expand globally in 2012

LEAF overview

- Seating capacity: 4-5 adults
- Cruising range: over 160km (US LA4)
- Motor: 80kW, 280Nm
- Battery: 24kWh Li-ion (produced by AESC)
### LEAF overview

- **EV dedicated IT support system**

### Various merits of EV

<table>
<thead>
<tr>
<th>ICE</th>
<th>EV</th>
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<tbody>
<tr>
<td>Exhaust gas</td>
<td>Zero-emission</td>
</tr>
<tr>
<td>Gas station</td>
<td>Sustainable mobility society</td>
</tr>
<tr>
<td>Noise</td>
<td>Filled-up every morning</td>
</tr>
<tr>
<td>Gasoline cost 6,000 yen/mth (20 km/L, 1,000 km/mth driving)</td>
<td>Charge at home</td>
</tr>
<tr>
<td>Quiet, for you and your neighbors</td>
<td>Quietness from start-up to high-speed</td>
</tr>
<tr>
<td>Electricity cost 1,200 yen/mth (Charge using nighttime electricity, 1,000 km/mth driving)</td>
<td>Equivalent gasoline cost of 100 km/L</td>
</tr>
<tr>
<td>EV unique dynamic performance</td>
<td>Stimulating acceleration Smooth start</td>
</tr>
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</table>
**LEAF acceleration**

- Quick acceleration with equal performance to 3L gasoline vehicle

![Graph showing LEAF acceleration compared to a 3L gasoline vehicle](image)

- LEAF
- 3L gasoline vehicle

- Hypermini
- LEAF
- FUGA

- 10m
- 20m
- 30m

**Quietness at all speeds**

- Total silence with no engine sound from start-up to acceleration
- Wind noise at high speeds is minimized by diverting airflow

![Graph showing noise levels with TEANA 2.5L and LEAF](image)

Position and style of headlights can reduce wind noise from the door mirrors
Cruising range sufficient for daily use

- Cruising range for a fully charged Nissan EV is over 160km (US LA4)
- Covers daily commute for most major cities in urban areas

Cruising range test mode of US LA4

- Based on driving conditions in Los Angeles suburbs
- Similar to actual use including start-up in cold cycle to frequent acceleration and deceleration

<table>
<thead>
<tr>
<th></th>
<th>Average speed</th>
<th>Top speed</th>
<th>Engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>US LA4</td>
<td>31.5km/h</td>
<td>approx. 80km/h</td>
<td>Cold cycle + Hot cycle</td>
</tr>
</tbody>
</table>

Average speed | Top speed | Engine
---|---|---
US LA4 | 31.5km/h | approx. 80km/h | Cold cycle + Hot cycle

Cold cycle | Soak | Hot cycle
---|---|---
0 | 500 | 1000 | 1500 | 2000 | 2500 (s)

60 | 40 | 20

60 | 40 | 20 | 0 | 500 | 1000 | 1500 | 2000 | 2500 (s)
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Newly developed dedicated EV platform

- Front mounted high performance powertrain
- Laminated Lithium ion batteries are installed under the floor
- High body stiffness achieved by the dedicated flame with battery and inverter

High response motor and inverter are mounted on the front

Comfortable cabin space, quiet and lively driving

Laminated Lithium ion batteries are installed under the floor

Structure of Li-ion battery pack

- Laminated cell are housed in the battery module
- Assembled modules are combined to form battery pack, which is then installed in EV
Battery’s role for EV

- Battery not only stores energy but also generates power
- Battery performance defines main values of EV, such as cruising range, acceleration and cabin space

<table>
<thead>
<tr>
<th>Energy storage</th>
<th>Generate power</th>
<th>Shift gears</th>
<th>Drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel tank</td>
<td>Engine</td>
<td>Transmission</td>
<td>Drive</td>
</tr>
</tbody>
</table>

General ICE vehicle vs. EV

<table>
<thead>
<tr>
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<th>General ICE vehicle</th>
<th>EV</th>
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</thead>
<tbody>
<tr>
<td>Battery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverter</td>
<td></td>
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</table>

Performance of laminated Li-ion battery

- Nissan was the first to believe in the potential of Li-ion batteries for automotive applications and began development in 1992
- Developed a commercially viable automotive battery with high performance and reliability

Twice the power

- > 2.5kW/kg*
- Cylindrical (2000) vs. Laminated

Twice the energy

- 140Wh/kg*
- Cylindrical (2000) vs. Laminated

Halved size and flexible packaging

- ½ the Size
- Cylindrical vs. Laminated

High reliability

- Stable crystal structure material
- Higher cooling efficiency by laminated structure
**Evolution of vehicle**

- Advanced battery installed under vehicle floor, which results in improved cabin space

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<table>
<thead>
<tr>
<th>Year 2000</th>
<th>Current</th>
</tr>
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<tbody>
<tr>
<td>Lead-acid battery</td>
<td>Li-ion battery</td>
</tr>
</tbody>
</table>

1600L

eg) Capacity for storing 20kwh of energy

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**Feature and potential of Li-ion battery**

- Principally high potential and durability/reliability.
- Higher energy density with high theoretical capacity compared to other batteries.
- To achieve higher power output for automotive, due to optimized design of electrode structure.

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<table>
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<tr>
<th>Mechanism of Li-ion</th>
<th>Energy density</th>
<th>Electrode model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge/discharge mechanism without chemical change</td>
<td>More than twice energy performance</td>
<td>Optimizing capacity and power output by electrode structure</td>
</tr>
</tbody>
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Furthermore future potential of technical innovation due to material design flexibility.
Battery management on EV

- Battery management is necessary in order to maximize battery performance
- Control temperature and manage driving conditions

<table>
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<tr>
<th>Battery management through vehicle</th>
<th>Factors for changing battery performance</th>
</tr>
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<tbody>
<tr>
<td>Temperature control</td>
<td>Temperature</td>
</tr>
<tr>
<td></td>
<td>• Deterioration with heat</td>
</tr>
<tr>
<td></td>
<td>• Low power with cold</td>
</tr>
<tr>
<td>Battery's driving condition</td>
<td>SOC* (remaining of battery)</td>
</tr>
<tr>
<td>management</td>
<td>• Deterioration with over discharge</td>
</tr>
<tr>
<td></td>
<td>• Deterioration with full charge</td>
</tr>
</tbody>
</table>

Charging condition
- Deterioration with charging frequency and quick charging

*SOC: State of Charge

Electric parts on the EV

- All major components of the EV are electric, including the powertrain, power steering and air-conditioner
EV’s ability to meet global market needs

For global markets, acceptance of the EV requires reliability under various conditions and comparable performance to current vehicles.

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Basic concept of charging infrastructure

- **Charging network**
  - **EV uses**
    - Short distance
    - Short / middle distance
    - Long distance
  - **Charging methods**
    - Ordinary charge
    - Choose ordinary or quick charge depending on how long stay
    - Quick charging

- **Charging type**
  - **Type**
    - Ordinary charge
    - Quick charging
  - **Power source**
    - Single-phase 100V
    - Single-phase 200V
    - Three-phase 200V
  - **Charging time**
    - ~15A 16h
    - ~20A 8h
    - 30min

Ex: Infrastructure in Kanagawa Prefecture

- **Nissan is developing a network of charging points with multiple partners**
  - As of March 2009

<table>
<thead>
<tr>
<th>Number of public charging facilities in Kanagawa pref.</th>
<th>Today</th>
<th>2010 Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick charger</td>
<td>23 (current)</td>
<td>100</td>
</tr>
<tr>
<td>Ordinary charger</td>
<td>160 (planned)</td>
<td>1000 (〜2014)</td>
</tr>
</tbody>
</table>

Explain: Infrastructure in Kanagawa Prefecture
Estimate for EV demand

- Currently, there are many views on the future EV market

**Estimate on future global EV market**
(from various public data)

- **A**
- **B**
- **C**
- **D**

**EV Market: Potential demand of 100 million units in urban areas**

- Initial customers are users in urban areas, with a daily commutes within the charging station network
- Approximately 100 million units or 15% of the global automobile market is in urban areas

*Number of automobiles counts only the city holds over 1 million units of passenger vehicle (CY2006)*
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New businesses surrounding EV

- To expand EV, consider wide range of views on energy supply, power storage and optimization of mobility

introduction of clean energy

• power production
  - nuclear
  - wind

• power network

• charge network

power supply stabilization peak shaving

storage of energy

EV battery

optimization of mobility

• urban mobility
  - car sharing
  - park & ride
  - ITS support

battery reuse
Effective utilization of clean energy: smart house

- Resulting in ultimate energy savings for the household, possible to deliver more clean energy through solar power and EV battery

Effective utilization of clean energy: solar power generation

- Ministry introduced subsidy for solar power generation (budget: 20 billion yen, cases: 84,000, subsidy: 70,000yen/1kW)
- Various governments introduced measures at local levels

(excerpt from J-PEC HP)
### Introduction scenario for smart grid

- **Evolution to smart house, smart community and smart grid**

**Smart House**
- Increase facilities and houses with high energy self-sufficient rate

**Smart Community**
- Power sharing among facilities and network

**Smart Grid**
- Connection with clean power basement
  - Mega solar
  - Wind

### Solar electric charging station demonstration

**(started 2009)**

- Created battery storage facility through EV located on parking area
- Integrated solar electric generation for emergency power and quick charging station

**Battery Storage**
- 168kWh
  - (EV on parking area)

**Quick Charge**
- 50kW
For the most suitable mobility:

**YOKOHAMA mobility “Project ZERO”**

- Began examination that aims for a model low carbon city
- Divided areas in order to provide suitable mobility and reduce the city’s overall CO2 levels

![Image of Low Carbon, Spread of eco-driving, Improvement of traffic jam, Zero Carbon, Popularization of EV]

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**Approach for “Zero Carbon”: EV expansion**

- Considering various measures to introduce and spread EV use

**Infrastructure development**

- more charging systems at public parking areas
- support for private businesses

**EV expansion**

- preferential purchasing
- preferential use
  - parking with charge
  - express highway

**Urban area mobility**

- EV car sharing
- personal mobility
- effect of reducing CO2
Governmental support for EV usage

- Active support through resources for charging infrastructure and purchasing incentives

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<th>Germany</th>
<th>France</th>
<th>United Kingdom</th>
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</thead>
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<tr>
<td><strong>Target volume</strong></td>
<td>1 million units (~2020)</td>
<td>2 millions units (~2020)</td>
<td>1.2 million units (~2020)</td>
</tr>
<tr>
<td><strong>Scale of budget</strong></td>
<td>500 millions € (Federal government)</td>
<td>4 billions € (1.5 billion € : Invest for charging infrastructure)</td>
<td>2.3 billions £ (20 m £ : Invest for charging infrastructure)</td>
</tr>
<tr>
<td><strong>Purchasing incentive</strong></td>
<td>3,000 - 5,000€ subvention for initial 100,000 units (2012-2014)</td>
<td>5,000€ subvention for 100,000 units of EV/PHEV (~2012)</td>
<td>2,000~5,000€ subvention for EV/PHEV (scale of budget : 250 millions £)</td>
</tr>
</tbody>
</table>

Global partnership for EV popularization

- Approximately 30 partnerships announced worldwide

(As of the end of August, 2009)