Mobility Innovation

February 19, 2018
Toyota Motor Corporation
Chairman of the Board of Directors
Takashi Uchiyamada
1. Toyota's Approach to Environmental Problems

2. Efforts to Realize a Hydrogen-based Society

3. On Mobility Innovation
1. Toyota's Approach to Environmental Problems

2. Efforts to Realize a Hydrogen-based Society

3. On Mobility Innovation
Environmental problems are becoming more serious
Toyota's Approach to Environmental Issues

Toyota Environmental Challenge 2050 was announced in October, 2015
# Three Challenges of Achieving Zero

<table>
<thead>
<tr>
<th>Challenges of achieving zero</th>
<th>(1) New vehicle zero CO2 emissions challenge</th>
<th>(2) Lifecycle zero CO2 emissions challenge</th>
<th>(3) Plant zero CO2 emissions challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>90% reduction by 2050</td>
<td>Environmental friendly design, from materials to disposal</td>
<td>Achieving zero by 2050</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>(4) Challenge of minimizing and optimizing water usage</th>
<th>Thoroughly reduce usage Clean thoroughly and return</th>
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<tbody>
<tr>
<td>(5) Challenge of establishing a recycling-based society and systems</td>
<td>Deploy resource recycling systems globally</td>
</tr>
<tr>
<td>(6) Challenge of establishing a future society in harmony with nature</td>
<td>All-Toyota group activities connecting society and the world</td>
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</tbody>
</table>
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Clean Energy Source Usage Among Large Overseas Companies

Announced September 2016
By 2050, switch to clean energy for 100% of energy consumption

Announced November 2017
2020 target: Use clean energy for all power needs

Source: General Motors’ website

Source: Response.jp website, November 17, 2017

Clean energy usage is a global trend

START YOUR IMPOSSIBLE
How to Achieve the 3 Zero Challenges

Industry initiatives

Clean energy
Pursue innovation aimed at further adoption

Particular attention must be given to:

- Economic Efficiency
- Energy Security

The slow speed of clean energy adoption must be resolved
Picture of a Hydrogen-Based Society Using Clean Energy

- Clean energy
- Solar power
- Wind power
- Biomass
- Wastewater treatment

- Electric vehicles and plug-in hybrids
- Power storage equipment
- Thermal power generation
- Industrial usage
- Power grid
- Cities and homes
- Power generation units
- Chemical plants

- Hydrogen to power conversion
- Water electrolysis
- Hydrogen tanks
- Cities and homes
- Vehicle fuel
- Fuel cell vehicles
- Fuel cell buses

- High-capacity, long-term storage
Characteristics of Hydrogen

- Zero CO2 emissions in hydrogen use
- Can be produced from a range of primary energy sources
- Japanese Hydrogen technology Leads the world
- Store & Transport capability
- Offset clean energy fluctuation
Characteristics of Hydrogen

- Use as energy
- Zero CO2 emissions in hydrogen use
- Can be produced from a range of primary energy sources
- Japanese Hydrogen technology leads the world
- Store & Transport capability
Japan is home to many of the world’s leading materials and parts manufacturers. Developing and deploying hydrogen applications in Japan will strongly impact international competitiveness, industry growth, and the creation of jobs.
The Japanese Government's Scenario for Basic Hydrogen Strategy

<table>
<thead>
<tr>
<th>Supply</th>
<th>Use</th>
<th>Mobility</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Fossil fuel-based</td>
<td></td>
<td></td>
<td>(~100 yen/Nm³) (hydrogen station price)</td>
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<tr>
<td>hydrogen (by-product hydrogen, natural gas reformation)</td>
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<tr>
<td></td>
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<td>(Present) 200 t to (2020) 4,000 t</td>
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<td></td>
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<td></td>
<td>Supply chain development and demonstration, scale-up</td>
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<tr>
<td>Fossil fuel-based</td>
<td></td>
<td></td>
<td>300,000 t (commercial supply chain capacity)</td>
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<tr>
<td>hydrogen (by-product hydrogen, natural gas reformation)</td>
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<td>(2030) 10 million t + a (depending heavily on consumption for power generation)</td>
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<td></td>
<td>Scale-up Substantial cost cuts</td>
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**Present picture**

- Developing international hydrogen supply chains
- Establishing technologies for renewable-based hydrogen production in Japan

**Target future picture**

- CO2-free hydrogen (Brown coal combined with CCS, utilizing renewable energy)

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: ~100 yen/Nm³ (hydrogen station price)
  - **Use**: ~100 yen/Nm³ (hydrogen station price)
  - **Mobility**: ~100 yen/Nm³ (hydrogen station price)

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: 30 yen/Nm³ (1/3 or less)
  - **Use**: 30 yen/Nm³ (1/3 or less)
  - **Mobility**: 30 yen/Nm³ (1/3 or less)

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: 17 yen/kWh (Commercial operation stage)
  - **Use**: 17 yen/kWh (Commercial operation stage)
  - **Mobility**: 17 yen/kWh (Commercial operation stage)

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: 12 yen/kWh (Replacing gas power generation)
  - **Use**: 12 yen/kWh (Replacing gas power generation)
  - **Mobility**: 12 yen/kWh (Replacing gas power generation)

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Profitability improvement will allow hydrogen stations to replace gas stations
  - **Use**: Profitability improvement will allow hydrogen stations to replace gas stations
  - **Mobility**: Profitability improvement will allow hydrogen stations to replace gas stations

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Introducing large FCVs
  - **Use**: Introducing large FCVs
  - **Mobility**: Introducing large FCVs

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Natural gas imports: 85 million t/y
  - **Use**: Natural gas imports: 85 million t/y
  - **Mobility**: Natural gas imports: 85 million t/y

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Natural gas import price: 16 yen/Nm³
  - **Use**: Natural gas import price: 16 yen/Nm³
  - **Mobility**: Natural gas import price: 16 yen/Nm³

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: *Conversion based on hydrogen’s calorific value
  - **Use**: *Conversion based on hydrogen’s calorific value
  - **Mobility**: *Conversion based on hydrogen’s calorific value

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Unit LNG power generation cost: 12 yen/kWh
  - **Use**: Unit LNG power generation cost: 12 yen/kWh
  - **Mobility**: Unit LNG power generation cost: 12 yen/kWh

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Fossil power generation capacity: 132 GW
  - **Use**: Fossil power generation capacity: 132 GW
  - **Mobility**: Fossil power generation capacity: 132 GW

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Number of gas station: 31,500
  - **Use**: Number of gas station: 31,500
  - **Mobility**: Number of gas station: 31,500

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Number of passenger cars: 62 million
  - **Use**: Number of passenger cars: 62 million
  - **Mobility**: Number of passenger cars: 62 million

### Fossil fuel-based hydrogen

- **Supply**: Developing international hydrogen supply chains; Establishing technologies for renewable-based hydrogen production in Japan
  - **Cost**: Number of households: 53 million
  - **Use**: Number of households: 53 million
  - **Mobility**: Number of households: 53 million
1. Toyota's Approach to Environmental Problems

2. Efforts to Achieve a Hydrogen Economy

3. On Mobility Innovation
New vehicles in 2050 emit 90% less CO2 (compared to 2010)
Reducing CO2 Emissions

Mobility Electrification is essential
**Other Countries**

**France**
Gasoline/diesel car sales to be prohibited by 2040

**UK**
Gasoline/diesel car sales to be prohibited by 2040

**Other Companies**

**Volkswagen**
Will introduce 50 EV models by 2025

**Volvo**
All vehicles to be EV or HV by 2019

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**Tones to EV Adoption Intent in Other Countries/Companies**

**UK**
Gasoline/diesel car sales to be prohibited by 2040

- **Nihon Keizai Shimbun, July 7, 2017**
  - UK: Gasoline/diesel car sales to be prohibited by 2040

**Europe**
Fuel efficiency regulations

- **Nihon Keizai Shimbun, July 26, 2017**
  - Europe: Fuel efficiency regulations

**Other Countries**

**Other Companies**

**France**
Gasoline/diesel car sales to be prohibited by 2040

- **Nihon Keizai Shimbun, July 7, 2017**
  - France: Gasoline/diesel car sales to be prohibited by 2040

**Volkswagen**
Will introduce 50 EV models by 2025

- **Nihon Keizai Shimbun, September 12, 2017**
  - Volkswagen: Will introduce 50 EV models by 2025

**Volvo**
All vehicles to be EV or HV by 2019

- **Nihon Keizai Shimbun, July 5, 2017**
  - Volvo: All vehicles to be EV or HV by 2019

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**START YOUR IMPOSSIBLE**
Electrified Vehicles

- HV, PHV, EV, FCV

Electric Vehicles

- EV

Vehicles that run on stored power from the grid
One of electrified vehicles
What Determines the Needs of Vehicle Feature?

"Customers" and "Markets"

There's more than one option to choose from with electrified vehicles.
Toyota Electrified Vehicle Sales

More than 11M vehicles sold since 1997 (20 years)

- Sold in more than 90 countries and regions
- Roughly 4,500 staff in electrified vehicle development
- Roughly 1.52M annual electrified vehicle sales (2017, a record high)
What Toyota's Electrified Vehicle Sales Mean

Vehicles sold to date
More than 11M

- Customers choose vehicles based on environmental performance
- We have supplied products that enhance customer convenience
Global Electrified Vehicle Market (2016)

3.23M units

HV
2.41M units

EV
490K units

PHV
330K units

FCV
2K units

TOYOTA

HV + PHV + FCV
1.4M units

Market share
43%

We are the electrified vehicle market leader
We will continue to provide electrified vehicles that fit customer and market needs
Motors, Batteries, and Inverters: Core Electrification Technologies

- Motor
- Battery
- Inverter (PCU)
- Engine
- Fuel Cell
- Hydrogen Tank
- Charging

HV → PHV → EV → FCV

Core vehicle electrification technologies Can be used in all electrified vehicles
EV Issues

- Vehicle weight
- High battery costs
- Battery durability
  - Difficult to procure battery resources
- Short cruising range
- Long charging times
- Need to develop charging infrastructure
- Lack of battery re-use & recycling systems

There are still many issues to resolve
EVs Use High-Capacity Batteries

- **HV**
  - Prius: 0.75 kWh

- **EV**
  - Other makers' EVs: 40 kWh
Since its founding, Toyota has pursued perfection in battery development with an understanding of the importance of batteries.
Next-Generation Battery Development

- **All-solid-state batteries**
  - Power density (W/L)
  - Energy density (Wh/L)
  - Now (Research)
  - Goal

- **Lithium-ion batteries** (High-capacity models)
  - High-output

- **Groundbreaking batteries** (Metal-air batteries, etc.)
  - Goal

- **Sakichi battery**
  - Long EV cruising range

Develop the next-generation batteries crucial to widespread electrified vehicle usage

**Start Your Impossible**

ToYota
In order to solve EV issues

- Develop and produce globally-competitive batteries with Panasonic.

Developing and stably supply market-leading automotive prismatic batteries

Contribute to the deployment of electrified vehicles from Toyota as well as a wide range of automakers.
Zero emissions

- Zero emissions when in operation

Ease of use

- Cruising range similar to that of gasoline cars
- Hydrogen filling time (about 3 mins)

Energy diversification

- Hydrogen can be produced from a range of primary energy sources

Driving enjoyment

- Smooth ride and quietness unique to motor-driven vehicles
- Good acceleration up to low- and mid-range speeds

Emergency power supply

- High supply capacity
Increasing costs

<Total cost of ownership>
Vehicle purchase cost, fuel costs, maintenance costs, etc.

Large EV batteries enable long cruising ranges but consequently hurt carrying capacity, resulting in worse cost performance.
Toyota will upgrade and expand its lineup of passenger and commercial vehicles in the 2020s.
As a volume manufacture of approx. 10 million vehicles globally, to provide its customers diversified electrified vehicles...

Toyota's All-encompassing strategies

- Products
- Technologies
- Social infrastructure

All-encompassing approach to products, technologies, social infrastructure
Vehicle Electrification Milestones

- **Vehicles with engines**
  - 1990
  - 2000
  - 2010
  - 2020
  - 2030
  - 2040
  - 2050

- **1997** World’s first mass-produced HV
- **2010** HVs/PHVs: At least 4.5M units
- **2014** EVs/FCVs: At least 1M units
- **2020** EVs
- **2020: BEV rollout in earnest**
- **2030** HVs/PHVs: At least 4.5M units
- **2040** EVs/FCVs: At least 1M units
- **2050** Zero CO2 emissions challenge

**From around 2025:** Electrified version available for all vehicle models

**1990 - 2050**

**HVs**

**PHVs**

**FCVs**

**EVs**

**START YOUR IMPOSSIBLE**
Future Electrified Vehicle Positioning (image of popularization)

Greater diversification is needed for HVs, PHVs, EVs, and FCVs alike.
Motors, Batteries, and Inverters: Core Electrification Technologies

Core vehicle electrification technologies

- Motor
- Battery
- Inverter (PCU)

Can be used in all electrified vehicles

- Engine
- Engine
- Engine
- Fuel Cell
- Hydrogen Tank

HV
PHV
EV
FCV

START YOUR IMPOSSIBLE
Develop next-generation power semiconductors

- Target: 10% fuel performance increase
- Silicon (now)
- SiC (future)

- PCU miniaturization
  (Target: reduce size by 80%)

We aim to improve fuel efficiency by 10% and shrink sizes by 80%

Power modules

Power semiconductors

Transistors

Diodes

Power control units (PCUs)
Evolution of the Automotive Power Semiconductor

Silicon performance improves with structural advancements.

Next-generation power semiconductor performance improves with new materials.

SiC public road test car

Future devices
We hope for further support through government-let industrial policies.
Energy-Saving Effects of Autonomous Driving

Traffic flow improvement by the Autonomous vehicle proliferation will lead the energy saving.
Ex.) Traffic congestion improvement around the Sag area*

*The turning point from downslope to upslope

Cover the deceleration by the change in terrain

Cover the deceleration by the driver caring too much for the distance with the front car.

Realize the smooth traffic movement by supporting the appropriate vehicle speed control

Traffic congestion by conventional cars

After Autonomous vehicles popularization (Image)
For achieving “Sustainable Society”, “Customers’ Smiles”