Innovative Powertrains for a sustainable mobility

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Innovative Powertrains for a sustainable mobility

Contents

- Challenges for future powertrain systems
- Reducing the CO2-footprint of Automobiles
- Future Powertrain technology by Honda
  - New Turbo GDI engine series
  - Hybrid powertrain of Honda NSX
  - Plug-In Hybrid Technology
  - New Fuel Cell Vehicle „Clarity“
- Summary
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- Summary
Megatrends in the area of powertrain

- Tailpipe emission reduction
- CO$_2$ reduction & Performance
- Electrification
Electrification is on the way

Honda CEO Hachigo-san


Two-Thirds Of 2030 Hondas Will Be Electrified Or Zero Emission

Honda CEO Shifts Focus to Electric Vehicles
Powertrain Strategy towards zero emission impact

CO2 (g/km)

- FCX クラリティ
- FIT EV
- 新 FCV
- ZEV
- PHEV
- HYBRID
- ICE
- VTEC TURBO
- CVT シリーズ

Present (2016) 2010 2020 2030

Thermal efficiency improvement
- ICE
- CVT シリーズ

Electric efficiency improvement
- PHEV
- HYBRID
- SPORT HYBRID i-MMD

ZERO Emission
- ZEV
- FIT EV

CO2 (g/km) 0

Present (2016)
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In current policy framework, road transport sector will reduce TTW emissions by ~29% vs. 2005 – Almost achieving aspired 2030 levels

1) Fleet emissions of passenger cars and commercial vehicles, excluding two-wheelers, biofuels considered TTW carbon-neutral
2) Scenario A: low oil price, high battery cost
3) Based on EU 2030 Climate & Energy Framework (2014) reduction aspiration for non-ETS sectors

Source: Roland Berger

Vehicles built since 2015
Vehicles built before 2015

GHG emission reduction aspiration road transport 2030
Hybrid technology and sustainable, CO2-neutral fuels are economic options for further GHG reduction

1) Compared to optimized Gasoline powertrain 2030 using E5, all technologies with 250,000 km lifetime mileage
2) 30% e-driving, higher e-driving share reduces abatement costs
3) Large range between scenarios driven by decoupling effect of natural gas price
4) Risk of higher abatement costs due to need of second battery over lifetime,
5) Diesel fuel with 7% FAME and 26% HVO
6) Abatement cost in existing vehicle: -67 EUR/ton CO2 (high oil price), 7 EUR/ton CO2 (low oil price)

Source: Roland Berger
By increased application of hybrid technology and sustainable biofuels it is possible to reduce GHG emissions by further 34 Mton CO2e.

- Under current regulation, the transport sector will significantly reduce GHG emissions to 862 Mton CO2e.
- Additional measures (biofuels, HEVs, new truck concepts) allow additional reduction to 828 Mton CO2e.
- Advanced biofuel measures:
  - Full coverage of E10
  - Introduce E20 on fuel and vehicle
  - Increase HVO drop-in share
- Hybridization:
  - Increase MH uptake in new passenger car sales (assuming ~40% sales share in new car sales 2030)
  - Increase FH uptake in new passenger car sales (assuming ~20% sales share in new car sales 2030)
- Non-powertrain measures for HD CV:
  - increased vehicle length/weight (assuming 5% share in new truck sales 2030)

Source: Roland Berger

1) In reference case a 36% E10 coverage is assumed
2) Assuming full E20 compatibility from MY 2025 onwards, 7% cap for conv. biofuel remains
3) In reference case full B7 coverage is assumed, assumed feedstock restriction 4% advanced HVO drop in ("R11")
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New Gasoline Engine line-up

- 3.5L TWIN TURBO
- 2.0L TURBO
- 1.5L TURBO
- 1.0L TURBO
- NA gasoline engines

Further performance evolution

Efficiency
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**1.0L Gasoline turbo engine**

**FUN**
- DI DOHC VTEC
- High-efficiency turbo charger

**Environment Performance**
- Competitors’ gasoline turbo
- Newly-developed 1.0L turbo engine
- Fuel Economy
- Displacement

**2.0L Gasoline turbo engine**

**Overwhelming dynamic performance**

CIVIC TYPE-R (Announcement in Mar. 2015)

**1.5L Gasoline turbo engine**

**Excellent balance between FUN and fuel economy**

JADE (Announcement in May 2015)
1.0L Gasoline turbo engine

Compact & High-efficiency
New Technology of 1.0l Turbo-GDI engine

- Timing belt in Oil
- Dual VTC system with Centre OCV
- Active electric thermostat
- Fleece impactor mist separator
- Narrow journal crankshaft
- Variable oil pump
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2.0L Gasoline turbo engine
Overwhelming dynamic performance
CIVIC TYPE-R (Announcement in Mar. 2015)

1.5L Gasoline turbo engine
Excellent balance between FUN and fuel economy
JADE (Announcement in May 2015)
Combustion concept

- Down-sizing Turbo
- High efficiency
  - High load operation
- Rapid combustion
  - Knocking relief

- High tumble port
- Sodium-filled exhaust valve
- Multi-hole direct injector
- Shallow dish piston
LSPI (Low Speed Pre-Ignition)

Typical LSPI pressure wave

Example of damage by LSPI
Hardware measures against LSPI

Piston ring attacked by high frequency peak, connecting rod only by damped pressure

Previous Conventional Forging

Developed Controlled Forging

- Cross-section area: 25% reduction
- Weight: 15% reduction
- Reinforced area

2nd land height
5mm → 6mm
Software measures against LSPI

Knock Control
- Ignition timing control

Detection (Signal treatment)

Knock sensor signal

Detection (Signal treatment)

LSPI Protection
- Fuel enrichment / Boosting pressure control

Heavy Knock

Knock sensor signal

LSPI (Super Knock)

Knock sensor signal

Fuel enrichment is required to suppress LSPI

1900rpm
260Nm
with No oil mist

enrichment

A/F[-]
Low Ca-content in engine oil is desirable to improve LSPI

LSPI influence of Ca in oil

Ca-based additives in automotive gasoline engine oil, global market samples

<table>
<thead>
<tr>
<th>Ca in oil</th>
<th>1900ppm</th>
<th>3000ppm</th>
<th>3000ppm</th>
<th>1400ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil mist in Breathing</td>
<td>&lt; 0.5 cm³/h</td>
<td>5 cm³/h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Current average  Worst case  GF-6 Assumption
Soot generation mechanism of DI engine

**Piston wetting at cold start**

- Spray to cold piston → liquid film

**Injector nozzle wetting**

- Injector spray interference dripping

**Injector Pocket wetting**

- Splay deflection by tumble flow → pocket wetting
GDI PN reduction methods

**Engine management**
(e.g. Benz B-Class 1.6L)

**GDI + PFI**
(e.g. Honda NSX)

**GPF**

Multiple injection by Piezo Injector

... and advanced fuels !!!
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Expansion of Hybrid portfolio for driving fun and efficiency
Honda NSX Powertrain

Intelligent Power Unit (IPU)

Power Drive Unit (PDU)

Twin Motor Unit (TMU)

Twin-turbo DOHC V6

Direct Drive Electric Motor

9-Speed DCT
Rear Power Unit

3.5L V6 DOHC twin turbo ENG

High output

- Electric wastegate actuator
- Dual-VTC (intake + exhaust)
- Direct injection & port injection
- High compression ratio

Max power
373 kW (507 PS) / 6000 – 7500 rpm

Max torque
550 Nm / 2000 – 6000 rpm
As an exclusive sports car engine

Power performance and a low center of gravity and compact package

**High power**

- Highly responsive twin turbocharger
- Dual VTC
- Efficiently cooled cylinder head
- Pistons with cooling galleries
- High-compression-ratio combustion chamber

Fuel system features in-cylinder direct injection and port injection

- Increased power realized by wide-range fuel flow
- Increased combustion efficiency realized by refinement of fuel droplet diameter

**373kW / 550Nm**

**Low center of gravity/compact**

- 75° V-bank
- Compact cylinder head

Fe spray-coated cylinder bore

- Reduced weight
- Enhanced cooling for greater knock resistance

Dry sump system

Road surface (Dry sump)  Road surface (Wet sump)

Wet sump oil pan

61mm
Rear Power Unit

- Direct, high output and high torque
- Linear acceleration performance
- Instant start

Max power
35 kw (48 PS) / 3000 rpm
Max Torque
148 Nm / 500 - 2000 rpm
Rear Power Unit

9-Speed Dual Clutch Transmission

Wide gear ratio

- 1st gear for launch acceleration
- 2nd – 8th gears with close-ratio
- 9th gear for cruising

Circuit performance

Power peak is maintained at circuit driving
Front Power Unit

- Image of Torque vectoring

On Rails Cornering

- Inner wheel: Torque
- Outer wheel: Torque

Transfer the energy of inner wheel to outer wheel.

- One-Way Clutch
- Double-pinion Gear Deceleration Mechanism
- Motor 1
- Motor 2
- Brake

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Max power
427 kW (581 PS)

Max torque
646 Nm

New Sports eXperience
Instant acceleration

V6 DOHC twin turbo engine

Twin Motor Unit

direct drive motor
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Accord PHEV system

Front Unit

- Electric A/C (Compressor and water heater)
- 2.0L DOHC i-VTEC Atkinson Cycle Engine
- High efficiency Two Motor Hybrid System (Electric-coupled CVT)

Intelligent Power Unit

- Exclusive high capacity Li-Ion Battery (6.7kWh)
- Onboard charger
- DC-DC converter

Power Control Unit
- Inverter
- Voltage control unit
- Motor control unit
### 3 drive modes of PHEV

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EV Drive</strong></td>
<td>Use electric energy from battery to drive motor.</td>
</tr>
<tr>
<td><strong>Hybrid Drive</strong></td>
<td>Use electric energy from engine generator to drive motor, with assistance from battery.</td>
</tr>
<tr>
<td><strong>Engine Drive</strong></td>
<td>Use engine to directly drive wheels.</td>
</tr>
</tbody>
</table>
Operation strategy for high fuel efficiency

- **Hybrid Drive (without battery charge/assist)**
- **Engine Drive (without battery charge/assist)**

BSFC: Good
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Ultimate clean performance – Honda Fuel Cell vehicles
MM Concept: Fuel Cell Sedan Package

- High-efficiency package with the fuel cell powertrain mounted inside the front hood
- Optimal positioning of battery and hydrogen tank realizes comfortable sedan passenger space
- Largest luggage space in a fuel cell vehicle
Evolution of fuel cell stack

Volume-power density (kW/L) vs. Weight-power density (kW/kg)

- 1999: 1.0 kW/L, 0.0 kW/kg
- 2001: 1.0 kW/L, 0.0 kW/kg
- 2003: 2.0 kW/L, 0.0 kW/kg
- 2006: 2.0 kW/L, 0.0 kW/kg
- 2013: 3.1 kW/L, 2.0 kW/kg

3.1 kW/L
Powertrain package

Fuel Cell Stack System

FCVCU
Boosts the stack voltage to drive the motor at high voltage. Use of a SiC high power module achieves high power with a compact size.

MOT
The motor is based on the compact coaxial motor used in the CLARITY, and the torque, power and quietness have been increased.

PCU (Power Control Unit)
Integration of the motor PDU and the battery VCU
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"Generate – Use – Get connected" concept by Honda

Original Honda technology

Technologies to realize FCV sedan

Synergy between automobile and general-purpose product technologies

Generate Hydrogen

Use Hydrogen

Get connected with Hydrogen

- Small-scale self-contained hydrogen stations
- High-voltage electrolysis system

- External power supply inverter

- Five-passenger sedan
- Smaller stack → Fitted under hood

- External power supply inverter

- Single-phase three-wire 200V 6kVA

- Power supply to home appliances

AC 100V 30A 3-system

- Power supply to home appliances

Emergency power supply

Small-scale self-contained hydrogen stations

High-voltage electrolysis system

Power supply to home appliances

AC 100V 30A 3-system

Power supply to home appliances

Single-phase three-wire 200V 6kVA

Emergency power supply

Emergency power supply

Single-phase three-wire 200V 6kVA

Power supply to home appliances

Emergency power supply
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Summary

- Future powertrains must provide a strong contribution to GHG emission reduction
  - CO2 neutral, sustainable fuels are key to keep ICE competitive

- Air quality problems in the cities require zero, or even sub-zero tailpipe emissions
  - Advanced Fuels play a crucial role for a clean combustion

- Advanced gasoline engines must avoid fuel enrichment for component protection or LSPI prevention
  - Tailor made fuels and lubricants can contribute to knocking prevention

- Electric and fuel cell vehicles are making big progress and sales are increasing
  - Sustainable, advanced fuels are required to keep ICE competitive
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HONDA
The Power of Dreams