Towards Sustainability

The current status and future outlook of fuel cell vehicles in Toyota

18/02/2018
World Leaders Agreement – COP21 Paris
Forecast International Climate Change

Annual greenhouse gas emissions (1,000 Tg CO₂ Eq./year)

Source: From the IPCC Working Group III 5th Assessment Report (2014)

Regarding GHG emissions, there is no time to lose
European Challenge 2050
Cut Green House Gases emission to 80% compared to 1990 levels

-20% Greenhouse Gas Emissions
20% Renewable Energy
20% Energy Efficiency

-40% Greenhouse Gas Emissions
>27%* Renewable Energy
27%* Energy Efficiency

* To be reviewed by 2020, having in mind an EU level of 30%
European Challenge 2050
Cut Green House Gases emission to 80% compared to 1990 levels
To go beyond zero environmental impact and achieve a net positive impact, Toyota has set itself six challenges. All these challenges, whether in climate change or resource and water recycling, are beset with difficulties, however we are committed to continuing toward the year 2050 with steady initiatives in order to realize sustainable development together with society.
Toyota 2050 Challenge

Zero Environmental Impact Challenge

Challenge 1: New Vehicle Zero CO₂ Emissions Challenge

Challenge 2: Life Cycle Zero CO₂ Emissions Challenge

Challenge 3: Plant Zero CO₂ Emissions Challenge

Challenge 4: Challenge of Minimizing and Optimizing Water Usage

Challenge 5: Challenge of Establishing a Recycling-based Society and Systems

Challenge 6: Challenge of Establishing a Future Society in Harmony with Nature

Net Positive Impact Challenge

Challenge of Achieving Zero
Challenge 1: New Vehicle Zero CO₂ Emissions Challenge

90% reduction of new vehicle CO₂ emissions by 2050 compared to 2010
Mix of powertrains required to achieve 90% CO2 reduction.

Electrification (including BEV and FCEV) will increase dramatically after 2020.
FCEVs are essential for decarbonising transport

Bubble size represents relative annual energy consumption of this type in 2013

1 Battery-hydrogen hybrid to ensure sufficient power

2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Hydrogen Council
Future Vision: HyGrid (Hybrid Hydrogen – Electricity Grid)

- Renewable Energy
  - Wind power
  - Photovoltaic generation
- Biomass
- Wastewater
- Fossil fuels
- EV/PHEV storage facilities
- Urban/residential
- Hydrogen Grid
  - High-volume, long-term storage
  - Electrolysis
  - Power generation units
  - Thermal power generation
- Hydrogen - Electricity Conversion
- Electricity Grid
- Urban/residential
- Automotive fuel
- FCEV
- FC bus

Source: HyGrid Study Group HP
Using Hydrogen as a Storage for Renewables

Energy storage capacities in Denmark

If all current vehicles in Denmark would be BEV and connected to smart grid at the same time.
Using Hydrogen as a Storage for Renewables

Tesla Grid Storage Facility (Southern California)
Can store 80 MWh

Liquid hydrogen trailer:
3500 kg $\text{H}_2 = 117$ MWh

2,500 m$^3$ of $\text{LH}_2 = 5.9$ GWh
Using Hydrogen as a storage for renewables

and even further....

1MW Solar Power to Gas installation

Underground storage of up to 6100 tonnes of Hydrogen or 240 GWh
Using Hydrogen as a Storage for Renewables

Hydrogen is most promising for long-term and carbon-free seasonal storage

1 IEA data updated due to recent developments in building numerous 1MW hydrogen storage tanks

Mirai is not a car, it’s a symbol
Mirai is not a car, it’s a symbol

The Toyota Way

“Contribution to society through Monozokuri.”
Developing Hydrogen FCEV for 20 years

- 1992: FCHV-3 Fuel
  - Hydrogen (adsorbing alloy)

- 1996: FCEV Fuel
  - H₂ stored in adsorbing alloy

- 1999: FCHV-4 Fuel
  - Hydrogen stored in high-pressure tanks

- 2001: FCHV
  - Toyota-made tanks, 1st FCEV homologated

- 2002: FCHV-adv Fuel
  - New stack, stainless steel cells

- 2005: FCHV
  - Hydrogen generated on-board by reforming on gasoline

- 2009: FCHV-adv Fuel
  - New stack, stainless steel cells

- 2011: Mirai
  - Revolutionary Titanium stack, 3.1 kW/L world record

- 2015: FCEV-R Fuel
  - Mirai precursor
Mirai

= “Future” in Japanese
Toyota’s Answer – Mirai, the obvious next step

We had a kind of feeling that “we could do it with the HYBRID, why not the FUEL CELL VEHICLE?”

Akio Toyoda
Hybrid Global Sales

5.5 Million/year as of 2030
(1M Zero Emission Vehicles)

10 million

MARCH 2018

tons of CO₂ saved vs comparable petrol engines

1 M

5 M


93M

2000000
4000000
6000000
8000000
10000000
12000000
14000000

1 M Zero Emission Vehicles

5.5 Million/year

37x472

Hybrid Global Sales

0 2000000 4000000 6000000 8000000 10000000 12000000 14000000

93M

MARCH 2018

tons of CO₂ saved vs comparable petrol engines

1 M

5 M

Toyota FCEV sales plan in 2020

GLOBALTARGET: More than 30,000 FC-stacks per year as of 2020

- 2015: 700 vehicles/year
- 2016: ~2,000 vehicles/year
- 2017: ~3,000 vehicles/year
- 2018: ~3,000 vehicles/year
- 2019: ~3,000 vehicles/year
December 2018:

- Japan: 2710
- USA: 5038
- EU: 345
- TOTAL: 7748
## Hydrogen Refuelling Infrastructure

![Map of Hydrogen Refuelling Infrastructure in Europe](http://h2.live/en)

<table>
<thead>
<tr>
<th>Country</th>
<th>2018 ACTUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>60</td>
</tr>
<tr>
<td>UK</td>
<td>10</td>
</tr>
<tr>
<td>Denmark</td>
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</tr>
<tr>
<td>Norway</td>
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<td>Austria</td>
<td>5</td>
</tr>
<tr>
<td>Switzerland</td>
<td>1</td>
</tr>
<tr>
<td>Latvia</td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>105</strong></td>
</tr>
</tbody>
</table>

**END 2019**

200 public 700 bar HRS
Public hydrogen refuelling stations (700 bar public)

Source: FCH JU KM data collection file, 20/09/2017, public stations
USA-DoE & CaFCP, Japan-HySUT
To date ca. S1 2017

December 2018
UNITED STATES: 39
JAPAN: 115
EUROPE: 105
# Toyota shares patents to accelerate the spread of FCEVs

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NUMBER OF PATENTS TO BE FREE</th>
<th>FREE USE PERIOD</th>
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</thead>
<tbody>
<tr>
<td>FC stack</td>
<td>Approx. 1,970</td>
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<tr>
<td>High-pressure hydrogen tanks</td>
<td>Approx. 290</td>
<td>Until the end of 2020</td>
</tr>
<tr>
<td>FC system control</td>
<td>Approx. 3,350</td>
<td></td>
</tr>
<tr>
<td>Hydrogen station</td>
<td>Approx. 70</td>
<td>No expiration</td>
</tr>
</tbody>
</table>
Other developments

Caetano Fuel Cell Bus
Sora Fuel Cell Bus
Tundra Fuel Cell Pizza delivery
Project Portal Fuel Cell Truck
Toyota Fuel Cell Truck
Toyota Fuel Cell Forklift
Hydrogen Council Roadmap

1. Power generation
   - Forklifts
   - Medium and large cars
   - City buses
   - Vans
   - Coaches
   - Trucks
   - Trams and railways
   - Small cars
   - Minibuses
   - Passenger ships
   - Synfuel for freight ships and airplanes

2. Transportation
   - In renewables-constrained countries
   - In other countries

3. Industrial energy
   - High-grade industry heat
   - Medium-/low industry heat

4. Building heat and power
   - Blended hydrogen heating
   - Pure hydrogen heating

5. Industry feedstock
   - Refining
   - Production of methanol, olefins and BTX using H₂ and captured carbon
   - Ammonia, methanol
   - Decarbonization of feedstock
   - Steel

Today

2020

25

30

35

40

2045
Pioneering Technology – Hybrid to Hydrogen < 20 year development

Using hybrid technology for Plug-In, EV and Fuel Cell

- **HYBRID**
  - Engine
  - Motor
  - Battery
  - Fuel Tank

- **PLUG-IN HYBRID**
  - Engine
  - Motor
  - Battery
  - Fuel Tank

- **ELECTRIC**
  - Motor
  - Battery

- **FUEL CELL**
  - Motor
  - FC Stack
  - H₂ Tank
  - Battery
Huge potential for cost reduction

Costs down to 1/20 of 2008 Model costs (2015)

Further cost reductions

Limited sales  Market entry  Widespread use
Fuel-cell components

- Ni-Mh Battery
- Hydrogen tanks
- Fuel Cell Stack
- Power Control Unit
- Motor
- Converter
**Fuel Cell Components**

**FC stack**
- Innovative flow channel structure and Electrodes of cells for higher output
  - Output/volume: 3.1kW/L

**Humidifier less**
- Internal circulation

**High pressure hydrogen tank**
- The light weight structure of carbon fiber reinforced plastic enabled
  - Storage: 5.7 wt%*

**FC boost converter**
- Reduced number of cells in FC stack
- Common use of hybrid units

*Hydrogen mass/Tank mass

**FC main components developed in-house to achieve world leading performance**

*TOYOTA*
Warranty Period like any other Toyota hybrid

3 years / 100,000 km
Standard warranty for all general parts and components

5 years / 100,000 km
Extended warranty for all hydrogen and high voltage parts

- Fuel tank
- FC stack
- HV battery
- Drive motor
- HV Inverter
- HV booster
Thank you

Vincent.mattelaer@toyota-europe.com
Backup slides
Hydrogen Tanks

Tank designers and inspectors run a load of harsh tests in laboratories:
- Burst test
- Cycling test
- Bonfire tests
- Crush test @150 tons force (Powertech)
- Cold weather tests
- Impact test (CEA/France hypactor.eu)
- Gunfire test (tested@Powertech)
Durable under intense EU driving style

**Challenge:**
clocking up 200,000 kilometres in just over 250 days

**Driving style:**
City traffic (Hamburg)
High speed driving (Germany)
Cold conditions down to -20°C (Norway)
Uphill-downhill in summer up to +37°C (Alps)

The Mirai operated with 100% reliability.

**Meaning for Europe:**
Records like this brought by OEMs can build confidence and customer satisfaction.

**Excellent H₂ Quality**
ISO 14687-2
EN 17124
We ensure **safety** on board

**Toyota FC stack**
Steel frame and aircraft grade fibre-reinforced plastic used in protect the FC Stack

**Impact safety structure**
Protects the FC Stack and Hydrogen tanks in the event of an accident

**Hydrogen sensors**
Provide warnings and can shut off tank main stop valves

**High pressure Hydrogen tank**
Made from reinforced carbon of the highest quality

**Hydrogen related parts**
Located outside the cabin
FCEV Benefits for our Customers

- Zero tailpipe CO₂ emissions
- Fun to drive with powerful acceleration
- Smooth, quiet driving (electric motor)
- 3-5 min refueling
- 500km* range

*Depending on driving style