

# TOYOTA

## Fuel Cell Technology



**Fuel cell vehicles (FCVs) are ideal clean cars that offer solutions to energy and emissions issues.**

FCVs are powered by fuel cells that generate electricity from hydrogen, a fuel which is environment-friendly and can be produced using a variety of readily available raw and renewable materials.

This makes fuel cell vehicles ideal for achieving sustainable mobility, and it's why Toyota, with its strong track record in fuel cell development, is striving to make this vehicle technology widely available as soon as possible.

Toyota has been leasing fuel cell vehicles since 2002, when the "Toyota FCHV" (fuel cell hybrid vehicle), based on the "Highlander" SUV, was made available for lease in the U.S. and Japan.

In 2015, Toyota plans to launch a fuel cell sedan for sale to the general market.

Setting the next 100 years in motion

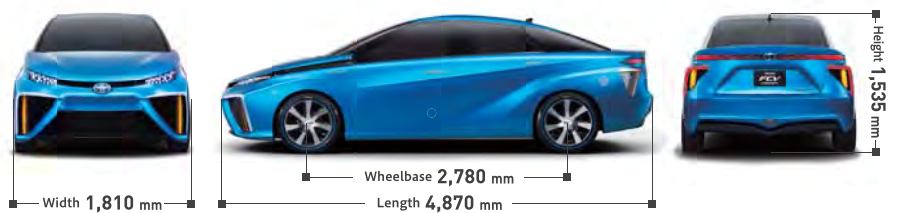
# Toyota FCV Concept

World premiere at the 2013 Tokyo Motor Show



## Point 01 | Extraordinary packaging

The FCV Concept's packaging represents a significant step forward in Toyota's development of fuel cell vehicles: the FC system is smaller and lighter, thanks to Toyota's newly developed proprietary FC stack and two 70 MPa high-pressure hydrogen tanks. Furthermore, the placement of the tanks beneath the specially designed sedan body allows the FCV Concept to accommodate four occupants.



## POINT 02 | Unique exterior design



The vehicle's exterior design evokes two key characteristics of a fuel cell vehicle: the transformation of air into water as the system produces electricity, and the powerful acceleration enabled by the electric drive motor.

The bold front view features pronounced air intakes, while the sleek side view conveys the air-to-water transformation with its flowing-liquid door profile and wave-motif fuel cap. The theme carries to the rear view, which conveys a catamaran's stern and the flow of water behind.



# On track for a 2015 launch, Toyota's small, light-weight fuel cell stack is more efficient than ever.

## A new fuel cell stack, with more than twice the power output density

Toyota's new fuel cell stack has an output of at least 100 kW and a power output density of 3.0 kW/L (more than twice the power output density of the FC stack in the Toyota FCHV-adv). In addition, the new FC system is equipped with Toyota's high-efficiency boost converter. Increasing the voltage has made it possible to reduce the size of the motor and the number of fuel cells, leading to a smaller system offering enhanced performance at reduced cost.

## Driving range of about 700 km

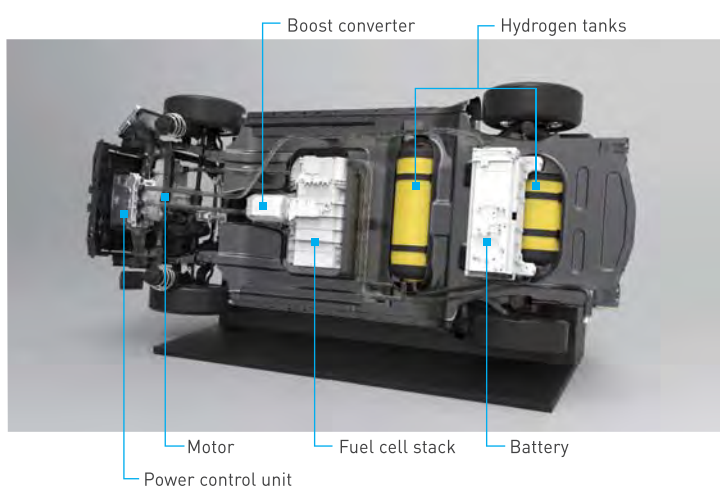
The vehicle has a driving range of approximately 700 km (under the Japanese MLIT JC08 test cycle; based on in-house calculations). Refueling time is as low as three minutes, roughly the same as for a gasoline vehicle.



Fuel cell stack

Toyota's fuel cell stack no longer requires a humidifier to supply moisture from a source outside the stack. Instead, water produced during power generation is recirculated inside the fuel cells themselves. In addition to simplifying the structure of the fuel cell system, this improves reliability and reduces size, weight and cost.

## Toyota FCV Concept: System configuration



## From four hydrogen tanks to two

Toyota's new FCV sedan is spacious enough to seat four, thanks to the under-seat placement of two proprietary 70 MPa high-pressure hydrogen tanks (as opposed to the four tanks on board the FCHV-adv).

## Main Specifications

	Name	Toyota FCV Concept
Vehicle	Overall length / Width / Height	4,870 mm / 1,810 mm / 1,535 mm
	Seating capacity	4
	Max cruising range	Approx. 700 km (JC08 Mode, in-house measurements)
	Maximum speed	More than 170 km/h
	Vehicle system efficiency	65% (LA#4 mode, in-house measurements)
	Fuel Cell stack	Type
Output power density		3.0 kW/L
Output		More than 100 kW
Cold start capability		-30 °C
Hydrogen tank	Storage type	High pressure tank (2 units)
	Storage pressure	70 MPa
	Storage density*	5.7 wt%

\*Hydrogen storage per unit tank weight

# Toyota's fuel cell stack: Providing world-leading performance

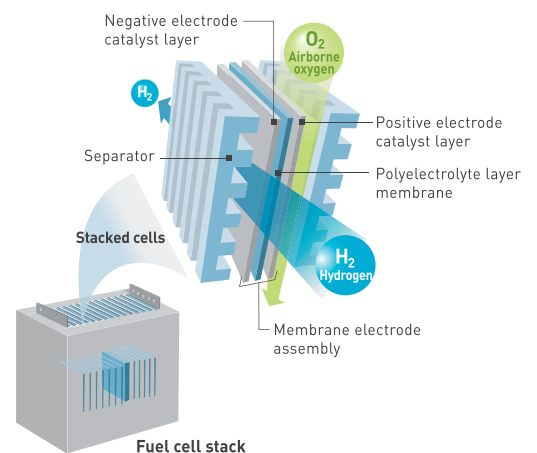


## Using hundreds of individual fuel cells to make a fuel cell “stack”

Fuel cell vehicles are powered by electricity generated through a chemical reaction between hydrogen and oxygen. Inside each individual fuel cell in the stack, a polyelectrolyte layer membrane sits between an anode (negative side) and cathode (positive side). The anode, cathode, and polyelectrolyte membrane together form the MEA (membrane electrode assembly), a polymer electrolyte membrane with catalyst layers applied, which is positioned between two separators. As each individual cell can only yield less than one volt, hundreds of cells are connected in series to increase the voltage. This combined body of cells is called a fuel cell stack (FC stack), also commonly referred to as a fuel cell unit.

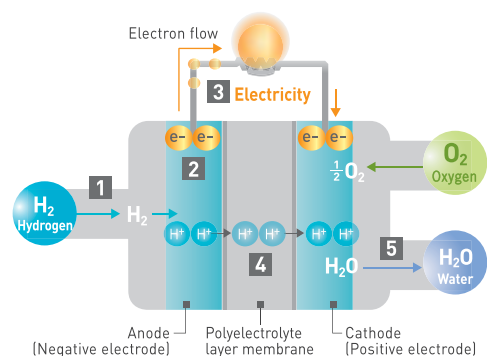
Toyota's philosophy is to develop key technologies in-house, and its proprietary FC stack is a worldwide performance leader among vehicular fuel cell stacks.

Fuel cell vehicles are remarkably efficient, as they generate electricity directly from hydrogen. A fuel cell vehicle can convert 83 percent of hydrogen's energy into usable power—about twice the efficiency possible with current gasoline engines.



## Making electricity from hydrogen and oxygen—how it works

- 1 Hydrogen (H<sub>2</sub>) is supplied to the anode
- 2 Hydrogen molecules activated by the anode release electrons (e<sup>-</sup>)
- 3 The electrons released from hydrogen travel from the anode to the cathode, creating an electrical current
- 4 Hydrogen molecules that released electrons become hydrogen ions (H<sup>+</sup>) and move through the polymer electrolyte membrane to the cathode (positive) side
- 5 Hydrogen ions bond with airborne oxygen and electrons on the cathode to form water (H<sub>2</sub>O)



# Toyota fuel cell technology: Not limited to cars

Besides passenger cars, Toyota's fuel cell technology is being used in a wide variety of applications. In addition to the FCV sedan planned for launch in 2015, Toyota and Hino Motors plan to launch the co-developed FC Bus in 2016. Toyota is also working with Toyota Industries on a fuel cell forklift and with Aisin Seiki on a residential fuel cell cogeneration system that was launched in 2012.

**Cars**

FCV

**Buses**

FC Bus

**Industrial & residential applications**

Fuel cell forklift

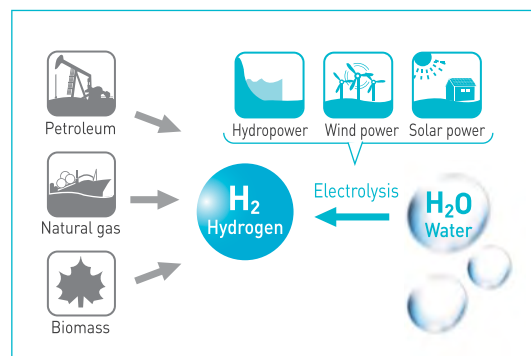
Residential fuel cell cogeneration system

Toyota fuel cell technology

# A world that runs on hydrogen

## Hydrogen as energy

Hydrogen is the lightest element in the periodic table. It is colorless, odorless, tasteless and non-toxic. Unlike carbon dioxide, hydrogen allows infrared rays to penetrate, which means it does not contribute to global warming. When burned, it combines with oxygen to form water. Hydrogen can be obtained from a wide variety of materials ranging from petroleum and natural gas to biomass. It can also be produced by the electrolysis of water. If electricity for electrolysis is obtained from renewable energy sources such as solar power, wind power or hydropower, we can make hydrogen without emitting significant amounts of CO<sub>2</sub>. Hydrogen has a higher energy density than batteries, and it is easy to store, making it a strong candidate as a source of energy in the future.

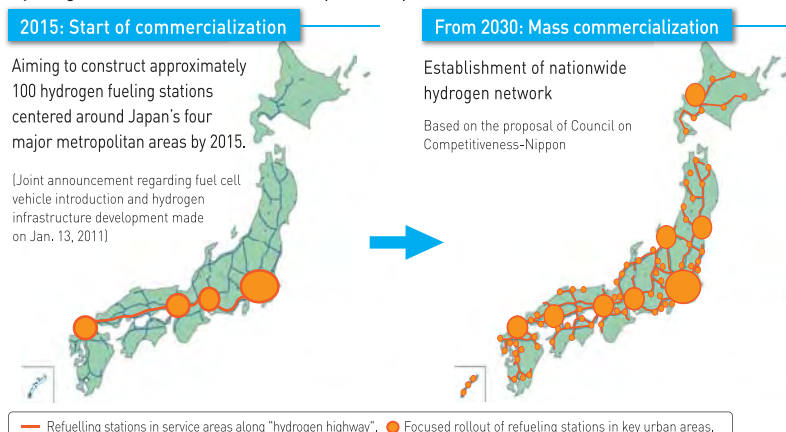


## Ensuring hydrogen safety in FCVs

Hydrogen only combusts if it accumulates in a confined space. If it leaks, its density rapidly falls below its flammable range\*. Toyota's approach to hydrogen safety for FCVs focuses on the key need to prevent hydrogen from leaking. If any leakage is detected, it must be stopped instantly and leaked hydrogen must not be allowed to collect.

\*Flammable range indicates the level of concentration in air necessary for combustion of a substance to occur. The flammable range of hydrogen is between 4% and 75%.

### Hydrogen station establishment plan: Japan



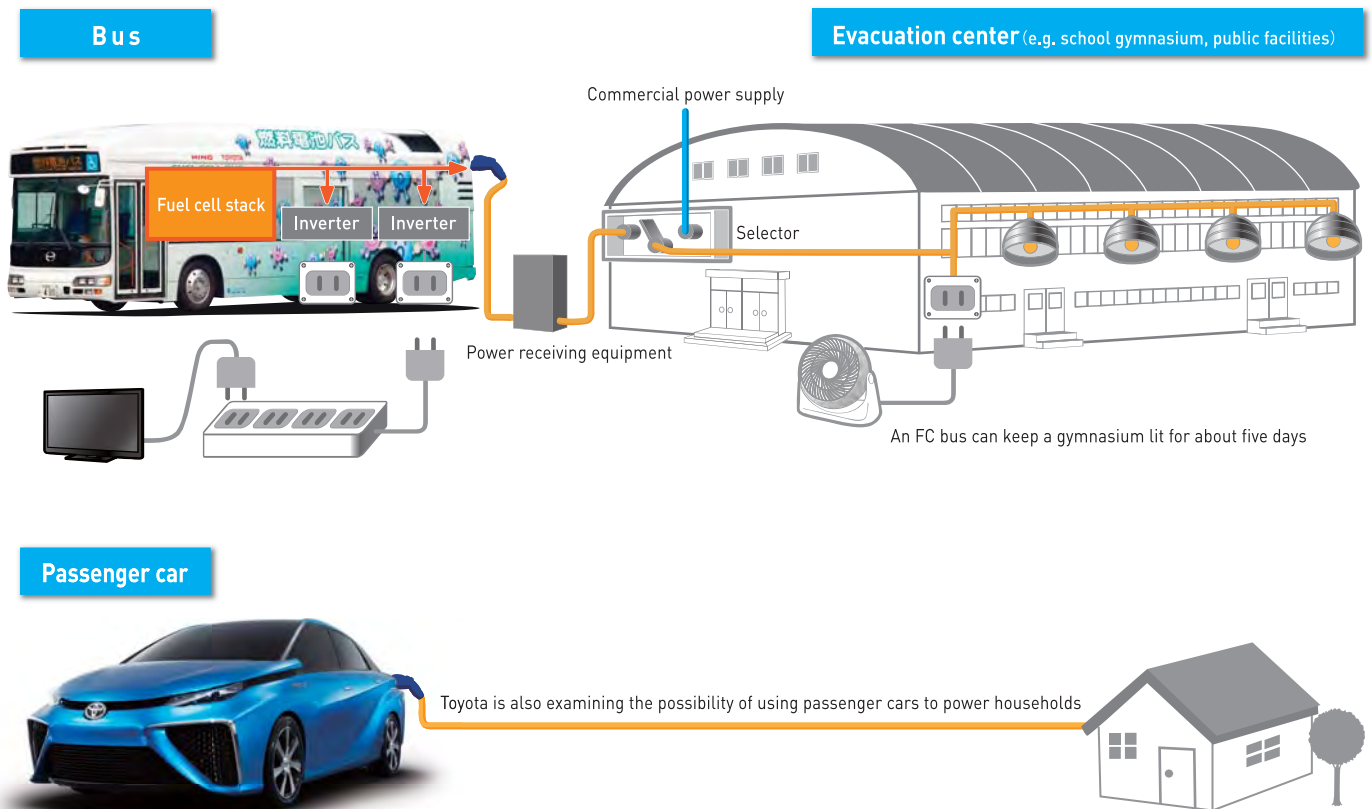
### Commercial hydrogen stations currently in Japan

Name	Toyota Ecoful Town Hydrogen Station (Toyota City, Aichi Prefecture)	Kaminokura Hydrogen Station (Nagoya City, Aichi Prefecture)	Ebina Central Hydrogen Station (Ebina City, Kanagawa Prefecture)
Raw material	City gas	LPG	Compressed hydrogen
Characteristics	Direct charging Able to fuel large capacity tanks	Installed at gasoline station 80MPa CFRP containers	Installed at gasoline station 80MPa CFRP containers
Loading pressure	70/35 MPa	70 MPa	70 MPa

# FCVs and society

## External power supply system

Considering their extraordinarily high power output density, we believe that FCVs have a great deal of potential as mobile power supply units. They could be particularly useful in the event of a natural disaster, when there is limited access to electricity by conventional means. We hope that this potential additional function of FCVs will increase their utility and provide significant value to society.



# Toyota fuel cell vehicle development history

