

Our Efforts toward the Creation of a Hydrogen-Based Society

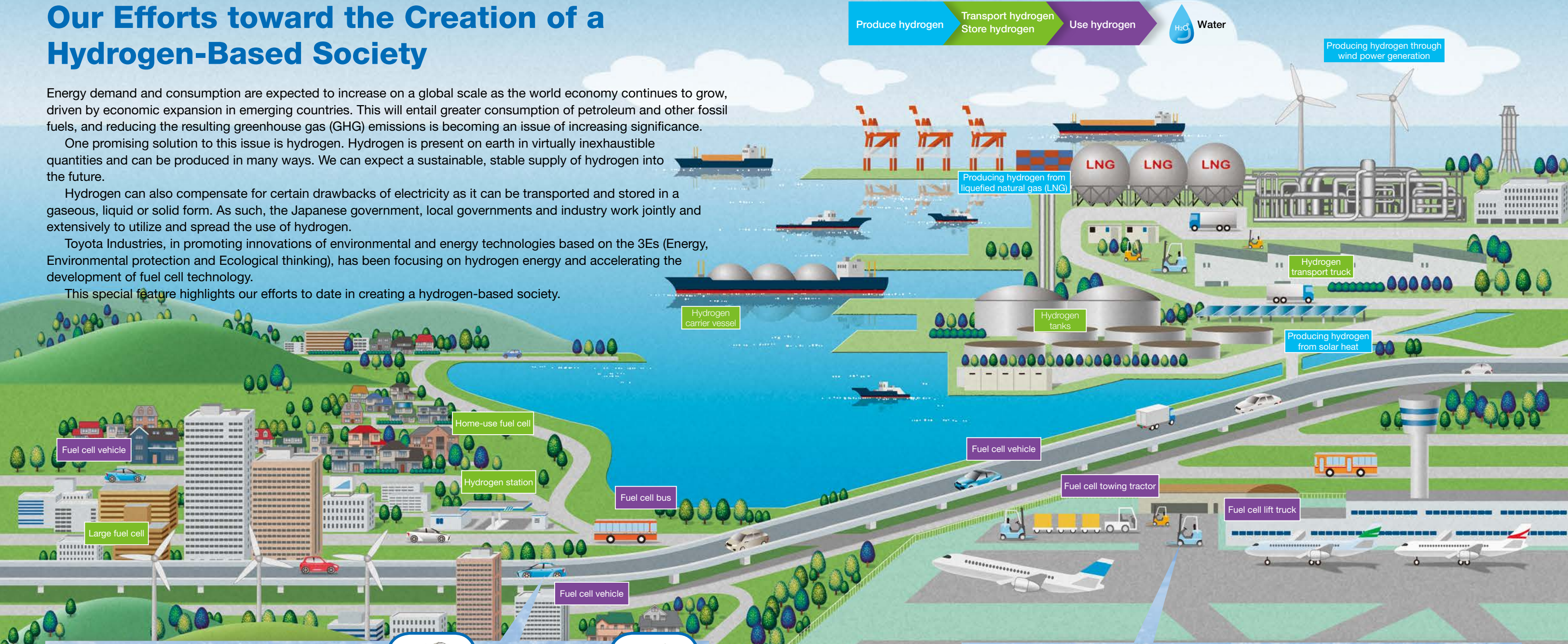
Energy demand and consumption are expected to increase on a global scale as the world economy continues to grow, driven by economic expansion in emerging countries. This will entail greater consumption of petroleum and other fossil fuels, and reducing the resulting greenhouse gas (GHG) emissions is becoming an issue of increasing significance.

One promising solution to this issue is hydrogen. Hydrogen is present on earth in virtually inexhaustible quantities and can be produced in many ways. We can expect a sustainable, stable supply of hydrogen into the future.

Hydrogen can also compensate for certain drawbacks of electricity as it can be transported and stored in a gaseous, liquid or solid form. As such, the Japanese government, local governments and industry work jointly and extensively to utilize and spread the use of hydrogen.

Toyota Industries, in promoting innovations of environmental and energy technologies based on the 3Es (Energy, Environmental protection and Ecological thinking), has been focusing on hydrogen energy and accelerating the development of fuel cell technology.

This special feature highlights our efforts to date in creating a hydrogen-based society.



Our Products to Support “MIRAI,” the World’s First Mass-Produced Fuel Cell Vehicle

The MIRAI is the world’s first mass-produced fuel cell vehicle (FCV) released by Toyota Motor Corporation (TMC). It has drawn much public attention as an ultimate eco car that emits only water and no CO₂ while in motion. At its core are components developed by Toyota Industries, such as an oxygen-supplying air compressor and a hydrogen circulation pump, playing crucial roles and supporting the driving performance of this next-generation vehicle. (See page 28 for details.)



Use of Fuel Cell Technology in Lift Trucks

Many lift trucks operate at various logistics sites across the world, including factories, airports, seaports, warehouses and market sites. Now, these trucks are also required to demonstrate greater environmental performance along with improved functionality and operability. Our fuel cell (FC) lift trucks currently under development hold great promise as next-generation lift trucks that can satisfy both of these requirements. (See page 29 for details.)



FC lift truck operating outdoors at Kansai International Airport (feasibility test)

Oxygen-Supplying Air Compressor and Other Toyota Industries Products Used in the MIRAI

Development of Crucial Components to Support the Fuel Cell System, an FCV Core

The Toyota FCV MIRAI runs on electricity generated from hydrogen and oxygen and produces no exhaust emissions or CO₂ when driven. This next-generation vehicle, which delivers both superior environmental performance and the pleasure of driving, has been equipped with crucial components developed by Toyota Industries.

Oxygen-Supplying Air Compressor to Support Driving Pleasure

The MIRAI offers smooth driving performance, excellent acceleration from startup and a cruising range of approximately 650 km in one hydrogen charge. These features are supported by our oxygen-supplying air compressor, which takes in and compresses air and feeds oxygen required to generate electricity into the fuel cell. Based on a range of technologies we have cultivated in the development of car air-conditioning compressors, we adopted the world's first six-lobe helical root-type rotor and attained high air compression efficiency in the idling period and during acceleration.

An FCV is a type of electric vehicle that runs on electricity generated using hydrogen as fuel, and a high level of operational quietness is required for its components when the vehicle is in motion. Our development efforts thus concentrated on achieving exceptionally high operational quietness while at the same time creating sound that evokes the stirring takeoff of acceleration. We have contributed to the delivery of driving exhilaration, going a step beyond simply offering an environmentally excellent vehicle.



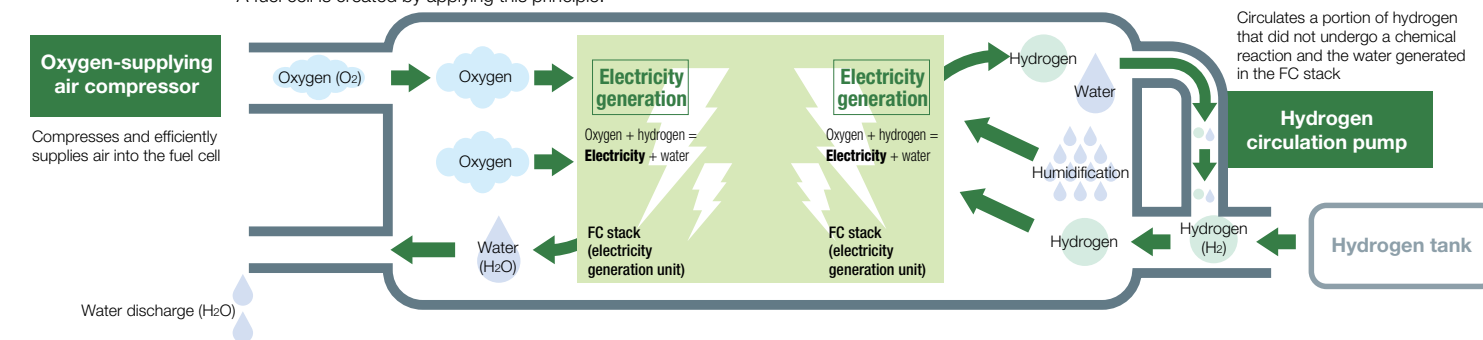
Oxygen-supplying air compressor

Newly Developed Hydrogen Circulation Pump to Help Reduce Size and Weight of the Fuel Cell System

Toyota Industries' hydrogen circulation pump contributes to the reduced size and weight and greater efficiency of the fuel cell system.

The FC stack, a unit to generate electricity, produces electricity more efficiently in a wet condition. For this reason, a humidifier was installed in a conventional fuel cell system, making size reduction difficult. In order to remove the humidifier from the system, we decided to shift its role to a hydrogen circulation pump, which circulates a portion of hydrogen that did not undergo a chemical reaction as well

How a Fuel Cell Works Under a certain condition, hydrogen and oxygen react together and generate electricity and water. A fuel cell is created by applying this principle.



as the water generated in the FC stack. However, increasing the amount of water to be circulated by the pump means a larger quantity of water remains within the pump when the vehicle comes to a stop. This water freezes at extremely low temperatures and hinders the start of the electricity generation process. We modified the internal structure of the pump to improve the system's ability to start operation at lower temperatures and contributed to the elimination of a humidifier.



Hydrogen circulation pump

For Achieving Even Greater FCV Performance

Our excellence stems from our compression-related expertise accumulated in the Car Air-Conditioning Compressor Business and from our technological capabilities for size and weight reductions, fuel savings and machining. Based on this technical superiority and our total strengths resulting from our involvement in a diverse range of businesses, we closely collaborated with the Electronics Division and succeeded in developing crucial components for FCVs.

Looking ahead, we will accelerate development of fuel cell technology to contribute to the enhancement of the product appeal of FCVs.

Accelerating Development of FC Lift Trucks to Enable Eco-Friendly Logistics Operations

Initiatives for Achieving Practical Application of Fuel Cell Technology in Lift Trucks

In the Materials Handling Equipment Business as well, we are engaging in development of next-generation lift trucks that can simultaneously offer high environmental and economic performance, while continuing to seek higher environmental performance in internal-combustion and electric lift trucks.

Improving Reliability of FC Lift Trucks through Feasibility Tests

We have been conducting feasibility tests in order to raise the reliability of FC lift trucks and achieve their early application in practical fields.

We participated in the Kitakyushu Smart Community Project jointly undertaken by the Ministry of Economy, Trade and Industry and Kitakyushu City and carried out a feasibility test of our FC lift trucks for two years from 2012. During the test, we operated FC lift trucks equipped with a compact and highly efficient lift truck fuel cell system jointly developed with TMC at the Kitakyushu Plant of Toyoda Gosei Co., Ltd. and worked to reduce CO₂ emissions and attain the leveling of energy consumption.

In addition, we have been participating in the "Hydrogen Grid Project" taking place at Kansai International Airport. In 2015, we started collecting data on the operations and effectiveness of "Well to Wheel*" CO₂ emissions reduction by operating the same FC lift truck used in the Kitakyushu project under different usage conditions. Moreover, we have developed a new practical-use lift truck model fitted with the same fuel cell used in the Toyota MIRAI FCV as a means to achieve better reliability and durability as well as lower costs.

* From extraction of fuel raw materials to operation of lift trucks



FC lift truck operating in a warehouse (feasibility test)



Refueling with hydrogen

Growing Potential of FC Lift Trucks

Lift trucks are used not only outdoors but also in such indoor logistics sites as warehouses and factories. Their indoor use makes superior environmental performance and quieter operation all the more important. Leveraging the technologies and know-how accumulated in the field of lift trucks, we are carrying out R&D of FC lift trucks that offer high environmental as well as economic performance.

We believe that such FC lift trucks have the potential to generate a range of benefits as follows.

- 1) FC lift trucks realize excellent environmental performance, as their operation only generates water but emits no CO₂ or substances of concern, thereby contributing to a cleaner and more comfortable logistics environment.
- 2) Hydrogen refueling just takes about three minutes, allowing longer continuous uptime without battery charging or replacement and thus enabling a significant improvement in operational efficiency.
- 3) Not having to replace the battery eliminates the need for a storage space and charging equipment, thereby saving indoor space.
- 4) Equipped with external power supply functionality, FC lift trucks can be used as a mobile electricity generator to power electric tools during ordinary times and as an emergency power source in case of a disaster-induced power outages.

Working from Indoor Logistics toward the Creation of a Hydrogen-Based Society

Creating a hydrogen-based society requires an appropriate infrastructure, including hydrogen stations. Such an infrastructure is easier to set up for lift trucks than FCVs because lift trucks usually operate within a limited area, such as in a factory. Through the development and use of FC lift trucks, we aim to promote the establishment of the required infrastructure within an airport or a factory and contribute to the creation of a hydrogen-based society by capitalizing on our experience in the field of indoor logistics.

Accelerating Efforts for the Creation of a Hydrogen-Based Society

As a technology to reduce CO₂ emissions and respond to energy diversification, the use of fuel cells has been expanding in automobiles as well as for residential applications (ENE-FARM fuel cell system). However, there are still a number of issues to overcome before their practical use can spread on a full-fledged basis, which include reducing costs, improving reliability, establishing an infrastructure and lowering retail prices of hydrogen fuel.

Toyota Industries, with its total strengths spanning diverse business fields, will accelerate its efforts toward the creation of a hydrogen-based society by making maximum use of resources available within the Toyota Industries Group and capitalizing on a pool of technology and experience accumulated to date.