

Kawasaki Heavy Industries, Subaru, Toyota, Mazda, and Yamaha Take on Challenge to Expand Options for Producing, Transporting, and Using Fuel Toward Achieving Carbon Neutrality





Going Beyond Electrification Initiatives to Provide Greater Choice for Using Internal Combustion Engines

Toward achieving carbon neutrality, the five companies announce a challenge to expand fuel options for using internal combustion engines.

- **Subaru, Toyota, and Mazda to use carbon-neutral fuel in the Super Taikyu Series**
- **Kawasaki Heavy Industries and Yamaha Motor to initiate consideration of the possibility of joint research for hydrogen engine development for two-wheeled and other vehicles**
- **Toyota’s hydrogen-engine vehicle to compete in the Super Taikyu Race in Okayama, with Fukuoka City joining the hydrogen supply effort**

Okayama, Japan, November 13, 2021—Kawasaki Heavy Industries, Ltd. (Kawasaki Heavy Industries), Subaru Corporation (Subaru), Toyota Motor Corporation (Toyota), Mazda Motor Corporation (Mazda), and Yamaha Motor Co., Ltd. (Yamaha Motor) jointly announced today that, toward the achievement of carbon neutrality, they will take on the challenge of expanding fuel options through the use of internal combustion engines at the (three-hour) Super Taikyu Race in Okayama on November 13–14.

Specifically, to further expand options for producing, transporting, and using fuel, the five companies intend to unite and pursue the three initiatives of 1) participating in races using carbon-neutral fuels, 2) exploring the use of hydrogen engines in two-wheeled and other vehicles, and 3) continuing to race using hydrogen engines. Toward achieving carbon neutrality, and in addition to advancing initiatives for electrification, by promoting further collaboration in producing, transporting, and using fuel in combination with internal combustion engines, the five companies aim to provide customers with greater choice.

1) Participating in races using carbon-neutral fuels	2) Exploring the use of hydrogen engines in two-wheeled and other vehicles	3) Continuing to race using hydrogen engines
<p>Mazda</p>  <p>Taking on the challenge of racing using a 1.5-liter SKYACTIV-D engine fueled with next-generation biodiesel</p> <hr/> <p>Subaru and Toyota</p>  <p>Taking on the challenge of racing in the Super Taikyu Series next year using biomass-derived synthetic fuel</p>	<p>Kawasaki Heavy Industries and Yamaha Motor</p>  <p>Initiating consideration of the possibility of joint research on hydrogen engine development</p>	<p>Toyota and Yamaha Motor</p>  <p>Entering a hydrogen-engine vehicle in the Super Taikyu Race in Okayama</p>

Three initiatives for expanding the options for producing, transporting, and using fuel

1) Participating in races using carbon-neutral fuels

Taking on the challenge of racing using a 1.5-liter SKYACTIV-D engine fueled with next-generation biodiesel (Mazda)

To achieve carbon neutrality, Mazda believes that it is important to provide customers with a variety of options. To do so, the company plans to expand its powertrain offerings by adding plug-in hybrid electric vehicle (PHEV) models to its current model lineup, which includes conventional hybrid electric vehicle (HEV), diesel engine, and battery electric vehicle (BEV) models. It also plans to enter the ST-Q class of the Super Taikyu Race in Okayama in its MAZDA SPIRIT RACING Bio concept DEMIO vehicle, which is equipped with a 1.5-liter SKYACTIV-D (diesel) engine that runs on 100 percent biomass-derived diesel fuel supplied by Euglena Co., Ltd. By repeatedly conducting verification tests in races, Mazda intends to increase the reliability of its technologies. Mazda intends to conduct verification tests in various environments and conditions to contribute to the expansion of the use of next-generation biodiesel fuel.



MAZDA SPIRIT RACING Bio concept DEMIO

■ Mazda Motor Corporation's related press release (on Mazda's official website)
<https://newsroom.mazda.com/en/publicity/release/2021/202111/211113b.html>

Taking on the challenge of racing in the Super Taikyu Series next year using biomass-derived synthetic fuel (Subaru and Toyota)

Toward the achievement of carbon neutrality, Subaru and Toyota are promoting efforts that include vehicle electrification, such as by introducing the jointly developed Subaru Solterra and Toyota bZ4X BEVs, which are scheduled for global launches in mid-2022.

To study new options, the two companies plan to enter and conduct verification tests of two new vehicles powered by carbon-neutral synthetic fuel derived from biomass in the ST-Q class of the 2022 season of the Super Taikyu Series. Specifically, Subaru intends to race in a Subaru BRZ-based vehicle and Toyota in a

Toyota GR86-based vehicle. By collaborating and competing together in racing, the two companies plan to accelerate the development of technologies for all options and take on the challenge of achieving carbon neutrality.

2) Exploring the use of hydrogen engines in two-wheeled and other vehicles

Initiating consideration of the possibility of joint research for hydrogen engine development (Kawasaki Heavy Industries and Yamaha Motor)

Since 2010, Kawasaki Heavy Industries has been focusing on hydrogen as a next-generation energy source and has been developing technologies for producing, transporting, and using hydrogen throughout the entire supply chain needed to support society. The company is currently conducting verification tests for transporting large-quantity, low-cost hydrogen to Japan produced from Australian lignite. By the end of fiscal 2021, it plans to transport hydrogen using its in-house-constructed, first-in-the-world purpose-built liquefied hydrogen carrier, the Suiso Frontier. Also, based on hydrogen combustion technologies cultivated through the creation of the world's first successful urban-area, 100 percent hydrogen-fueled gas turbine power generation technology for which it completed development in 2018, Kawasaki Heavy Industries is developing hydrogen-fueled engines for land, sea, and air mobility applications, such as for aircraft, ships, and two-wheeled vehicles.

Yamaha Motor is developing hydrogen engine technology for possible use in its two-wheeled vehicles, ROV (four-wheeled recreational off-highway vehicle) series, and other products. To accelerate this technology development, it is preparing to introduce new equipment and is strengthening its in-house development structure.

Kawasaki Heavy Industries and Yamaha Motor have started considerations toward the joint development of a hydrogen engine for possible use in two-wheeled vehicles. Going forward, they are planned to be joined by Honda Motor Co., Ltd. and Suzuki Motor Corporation, and the four companies intend to jointly explore the possibility of achieving carbon neutrality through the use of internal combustion engines in two-wheeled vehicles. To maintain a distinct line between cooperation and competition, they intend to proceed after establishing a framework that will clearly define areas of cooperation and collaborative research.

3) Continuing to race using hydrogen engines

Entering a hydrogen-engine vehicle in the Super Taikyu Race in Okayama (Toyota and Yamaha Motor)

Toyota has been working with Yamaha Motor, Denso Corporation (Denso), and other related parties to develop a hydrogen engine since 2016*. It has entered a vehicle equipped with an under-development hydrogen engine in three races: the Fuji Super TEC 24 Hours Race, the Super Taikyu Race in Autopolis, and the SUZUKA S-TAI, and it has been working with companies and local governments to expand the options for producing, transporting, and using hydrogen. Toyota plans to also compete in the Super Taikyu Race in Okayama through a vehicle entered by ORC ROOKIE Racing, with Toyota President and CEO Akio Toyoda taking stints at the wheel in his "Morizo" driver persona.

***Roles of Yamaha Motor and Denso in hydrogen engine development**

- Yamaha Motor is in charge of designing select engine components, in addition to providing support for engine prototyping, combustion considerations, power performance improvement, race homologation (type certification), and race endurance testing.
- Denso is in charge of the development of direct-injection injectors and spark plugs.



Hydrogen-engine vehicle during the SUZUKA S-TAI

i) The challenge of producing fuel

In addition to the companies and municipalities that have supplied hydrogen for Toyota's hydrogen-engine vehicle that has been competing in the Super Taikyu Series, Toyota is now collaborating with Fukuoka City, which is to supply Toyota hydrogen derived from sewage biogas. Since 2015 and as a world first, Fukuoka City has been taking on the challenge of producing and commercializing hydrogen from domestic wastewater sewage. The city is producing non-CO₂-increasing green hydrogen from biogas generated during sewage treatment at the Fukuoka City Chubu Water Treatment Center and has a daily hydrogen production capacity of 3,300 Nm³ (which is roughly equivalent to the daily amount of hydrogen used by 60 units of the Toyota Mirai hydrogen fuel cell electric vehicle, based on a per-unit daily hydrogen requirement of 55 Nm³). The city is also conducting verification tests with corporate partners, such as supplying green hydrogen to fuel cell-powered trucks, motorcycles, and power supply vehicles.



Fukuoka City hydrogen production facility

Companies and municipalities scheduled to supply hydrogen for the next Super Taikyu Series race and the types of hydrogen to be supplied

Entity name	Type of hydrogen
Obayashi Corporation	Hydrogen from geothermal power generation
Toyota Motor Kyushu, Inc.	Hydrogen from solar power generation
Fukuoka City	Hydrogen from sewage biogas
Namie Town, Fukushima Prefecture (FH2R)	Hydrogen from solar power generation

ii) The challenge of transporting fuel

For the Super Taikyu Race in Okayama, hydrogen is to be transported using large and midsize trucks of Toyota Transportation Co., Ltd. fueled by Euglena's next-generation biofuel. Also, Toyota and Commercial Japan Partnership Technologies (CJPT) have started considering how to solve the transportation efficiency challenges of small fuel cell-powered trucks as identified at the SUZUKA S-TAI.

Challenge 1: Metal tanks are heavy, limiting the number of tanks that can be loaded onto a small truck.
Challenge 2: Matters related to the allowable pressure of metal tanks limit the amount of hydrogen that can be filled per tank.

To overcome these challenges, Toyota and CJPT are employing CFRP (carbon fiber-reinforced plastic) tank resin-liner technologies developed through Toyota's experience with the Mirai, making lightweight, high-pressure transport of hydrogen possible. The two companies are on the verge of significantly improving transportation efficiency compared to when using conventional metal tanks, and they are advancing development and considerations that should enable them to actually transport hydrogen in the future.

iii) The challenge of using fuel

Toyota has advanced the speedy development of its hydrogen engine by competing in the harsh environment of motorsports in the form of the past three races of the Super Taikyu Series. Since the engine's first Super Taikyu Series race, which was the Fuji Super TEC 24 Hours Race, improvements have been made to it after each race. In the six months leading up to the Super Taikyu Race in Okayama, its output has been improved by about 20 percent and torque by about 30 percent, and in the two months since the SUZUKA S-Tai, its output and torque have been improved by five percent to 10 percent, giving it performance superior to that of a similarly-sized gasoline engine. Meanwhile, fuel economy has been kept the same. (If output were to be set the same as that at the time of the Fuji Super TEC 24-hour race, fuel economy would improve by about 20 percent.)

The engine's connected system, which was newly introduced during development before the SUZUKA S-Tai, has been improved to be able to process and analyze more data. Using the system in test runs further accelerated development, and increasing the pump pressure rating reduced hydrogen filling time to two minutes or less*.

*Time from connecting to disconnecting the nozzle of the hydrogen station pump to and from the vehicle

To expand the options for achieving carbon neutrality, and to contribute to the creation of a better society while protecting jobs and livelihoods, the five companies plan to continue to synergize their strengths, deepen their collaboration, and actively promote the generation of new colleagues across industries.

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