Energy Carriers

Becoming a New Energy Society

Leading the World in Hydrogen Energy Utilization; Creating a Low-carbon, Hydrogen-based Society

Reducing CO_2 emissions is a global issue. But for Japan, a country poor in energy resources, developing renewable energy and new eco-friendly sources of energy comparable to nuclear power is a critical factor to maintain our place as a leader in the international community. Hydrogen—which produces only safe, clean water after combustion—looks to be the best candidate for large-scale utilization as a new source of energy. Technology advancements have begun to offer answers to the issues of hydrogen production, transport, storage costs and safety. Now, we are beginning to see concrete results to the initiatives that will put Japan on the forefront as a low-carbon, hydrogen-based society.

Program Director

Shigeru Muraki

Tokyo Gas Co., Ltd.
Advisor

Profile

Shigeru Muraki joined Tokyo Gas Co, Ltd. in 1972. In 2000, he was named general manager of the Gas Resources Department, and in 2002, he was named executive officer and general manager of the Gas Resources Department. Mr. Muraki was subsequently promoted to senior executive officer and chief executive of the Tokyo Gas R&D Division in 2004, and then senior executive officer, chief executive of Energy Solution Division in 2007. In 2010, he was named executive vice president and chief executive of the Energy Solution Division. In 2014, Mr. Muraki was elected vice chairman of Tokyo Gas. He was later named Executive Advisor in 2015 and Advisor in 2017.

Research and Development Topics

1. Develop energy carriers and identify promising candidates

Advance the utilization of liquid hydrogen, organic hydrides, and ammonia as energy carriers for hydrogen production, transport and storage; structure a practical cost model to serve as a foundation for a hydrogen energy value chain.

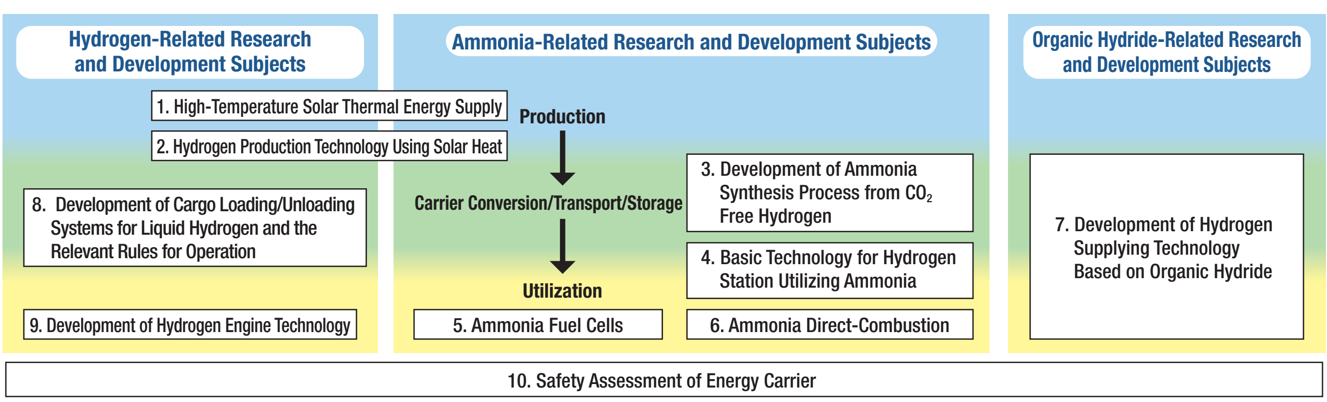
2. Develop peripheral technologies supporting a low-cost, highly efficient hydrogen value chain

Develop highly efficient hydrogen production technologies using renewable energy. Develop technologies for organic hydride and ammonia production, as well as hydrogen separation. Develop and demonstrate highly efficient technologies for fuel cells, turbines, and engines using hydrogen and energy carriers.

3. Conduct research and development linked to safety standards, deregulation for hydrogen transportation and use

Perform risk assessments for energy carriers, including spill accident simulation analysis and atmospheric diffusion modeling, to collect basic data for approvals and licensing, safety policies, and risk communication. Set safety policies for energy carriers; publicly disclose carrier assessment results and reflect these results in ongoing development work.

•Energy Carriers R&D Conceptual Overview



Exit Strategies

Promote wider adoption through technology assessment and standards (2017–)

Develop and test hydrogen carrier technologies. Evaluate tests based on economies, safety, and other factors to create safety standards for international acceptance, establishing a basis for worldwide hydrogen carrier use. Use the results of this work to study scenarios for utilizing hydrogen energy engaging in technological development driven by strategic investment allocation.

Prove research and development results in real-world applications (2018–)

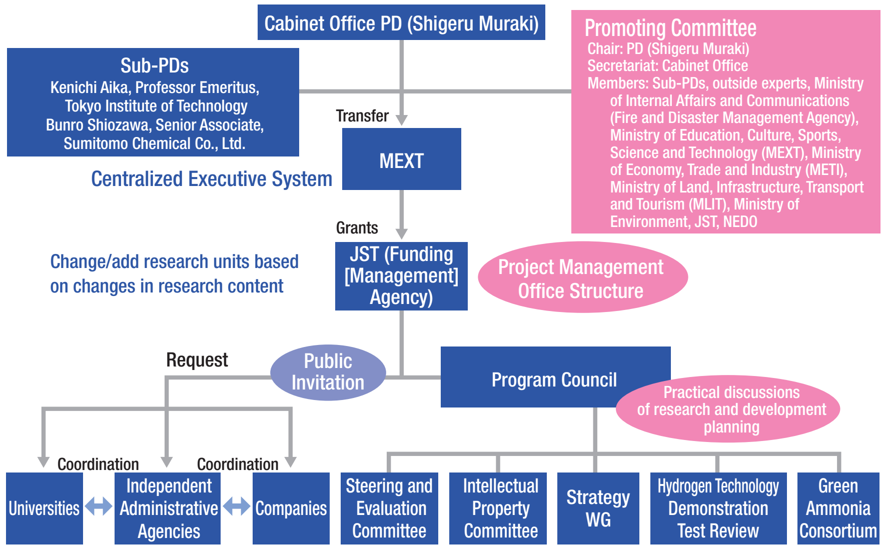
Demonstrate project successes in hydrogen stations, fuel cells, turbines and other technologies using energy carriers in locations where the 2020 Tokyo Olympic and Paralympic Games will be held. Introduce technologies for producing, transporting, storing, and using hydrogen; test hydrogen and energy carriers in practical electricity/heat production, vehicles, etc. in selected locations.

Promote international collaboration for using renewable energy overseas (2018–)

Promote international collaborative development of CO_2-free hydrogen and energy carrier production in overseas markets. Demonstrate systems ranging from hydrogen energy production to usage.

Implementation Structure

As a program director (PD), Shigeru Muraki is responsible for establishing and promoting research and development plans. The Promoting Committee is chaired by Mr. Muraki with the Cabinet Office serving as secretariat. The Committee is composed of relevant ministries, agencies, and experts who provide overall coordination. The Japan Science and Technology Agency (JST) exercises its authority as the management agency. Coordinating with other ministries, the program develops scenarios for the adoption of hydrogen to produce optimized research and development topics.



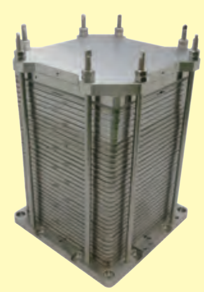
Progress to Date

Revolutionary progress in ammonia power generation

Ammonia is a hydrogen carrier successfully used in the generation of electricity. This success shows the potential of ammonia in practical use.

•The world's first success in a trial to co-firing ammonia at the existing coal power plant

This program succeeded in the world's first power generation trial by co-firing ammonia at the existing coal power station (rated output: 156MW). It was also verified that NOx can be processed using existing denitrification apparatus. This result has proved that ammonia has a potential for use in thermal power generation.



•Successful power generation using fuel cells directly fueled by ammonia

Successful power generation from the world's largest (1kW-class) solid oxide fuel cell (SOFC), fueled directly by ammonia. This is the beginning of systematization for practical use in small-scale power generation.

Program Director **Shigeru Muraki** Interview

Experiments Have Proven the Possibilities for Hydrogen in Full-scale Adoption; System Design Moving Forward for Development as an Energy Carrier

Energy carrier research and development is ongoing toward the creation of a CO_2-free hydrogen society. Certain areas of elemental technology research have progressed sufficiently to support systems design. The world's first success in generating power directly from ammonia has been one of a series of accomplishments to date.

Hydrogen is expected to play an important role as a source of energy that both fights global warming and improves energy security. Research and development under this program employs a view that spans the entire value chain, including hydrogen production, storage, transport and use. At present, we are moving from elemental technology development to the system design stage. At the same time, we are speeding efforts toward proof-of-concept demonstration tests.

Visions of Practical Utilization with the World's First Successful Test of Ammonia-based Direct Power Generation Technology

Mr. Shigeru Muraki, the director of this program, says, "We are seeing a number of specific successes in this program. Of those, research into ammonia-based power generation has produced results ahead of schedule." This program is ahead of those in other countries, having demonstrated power generation using methane-ammonia mixed-fuel combustion and ammonia single fuel combustion, both in a 50kW-class turbine. Taking these results, program engineers have started working on a demonstration test for a 2MW-class gas turbine. Studies have also been initiated for practical large-scale power generation with the cooperation of major national power companies.

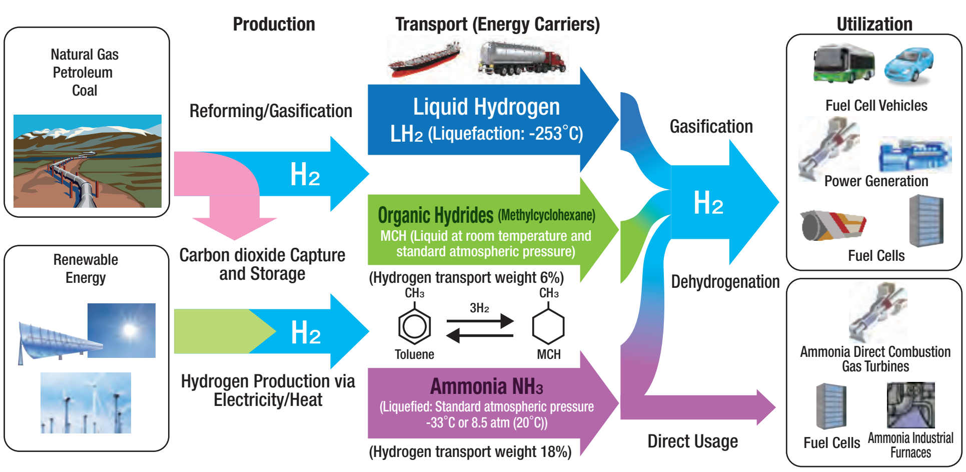
Following basic combustion tests using a pulverized coal burner for co-firing ammonia, the program succeeded in power generation trial by the co-firing at a power company's existing coal power station.

Our ammonia fuel cell research resulted in successful power generation for a 1kW-class SOFC stack, one of the largest in the world, and prototyping and design for system demonstration are currently underway. Mr. Muraki says, "Ammonia is distributed in great amounts throughout the world, and the cost of importing ammonia to Japan is clear. Advancing technology for use in gas turbines and fuel cells could gradually lead to CO2-free ammonia production."

The program has also made advancements in developing high-temperature solar thermal systems that could lead to CO2-free hydrogen and ammonia production. Now, program engineers are working on plans for practical demonstration tests, having narrowed research to light and heat collection systems and heating media.

The program continues to pursue the possibilities of creating a CO2-free hydrogen value chain, even after the completion of the SIP program.

•Hydrogen Production, Transportation and Usage



Steady Progress in Fuel Cell Vehicle Technological Development and Safety Assessment Research

Another important field of use for energy carriers is that of supplying hydrogen to fuel cell vehicles (FCV). This project focuses on organic hydrides and ammonia. However, dehydrogenation and high purity hydrogen purification technologies lie at the center of both.

Methylcyclohexane and hydrogenated toluene are used for organic hydride. After operational evaluations of 10Nm3/h dehydrogenation pilot systems, work has started to design 300Nm3/h dehydrogenation systems, which is a standard size for Japan's hydrogen stations.

The program is also developing practical carbon membrane modules as a low-cost hydrogen purification technique. At present, research has been completed for the elemental technologies required for ammonia-based dehydrogenation and purification. Now, work is progressing toward the design of 10Nm3/h dehydrogenation pilot systems.

In parallel, program engineers are conducting safety assessment research, while discussions related to hydrogen station facility performance requirements and social risks are bearing fruit. Mr. Muraki says, “We plan to be able to provide data between 2017 and 2018 that will contribute to studies on deregulation.”

Advancements in Hydrogen Utilization

Significant progress has been made in technology utilizing hydrogen. In hydrogen gas turbine power generation, the program has successfully developed a gas turbine combustor capable of low NOx combustion using 100% hydrogen, without using water or steam usually necessary for such a process. Based on these successes, the New Energy and Industrial Technology Development Organization (NEDO) began the development of hydrogen single-fuel combustion turbines in fiscal 2016.

NEDO is producing conceptual designs for systems necessary for the loading and unloading of liquefied hydrogen. At the same time, coordination is ongoing with related agencies for safe loading/unloading measures and procedures.

Focus on Results Toward Industry-academia-government Collaboration beyond SIP

Mr. Muraki says, “I think that it is difficult for our each projects to be completed during this program, but there are many with great potential for practical use. What we want to do is create an optimal scheme, while being flexible in reviewing our research content.”

As for the future of this research, he says, “A hydrogen-based society is a long-term challenge. We must build an even stronger framework for industry-academia-government collaboration with the help of NEDO and the Council for Science, Technology and Innovation, based on the currently effective implementation structure.” Even after the program finishes, close cooperation will be required for the long road ahead.

Future Plans

The schedule for research and development in each project current runs through fiscal 2018.

FY	2014	2015	2016	2017	2018
Hydrogen Production Using Solar Thermal Energy					
① High-Temperature Solar Heat Supply System	Component Technology Development (solar thermal receiver tubes, heat transfer fluid material, thermochemical energy storage system, etc.)				Feasibility Study
② Hydrogen Production via Heat	Component Technology Development (IS process, steam electrolysis)			Systemization/Improvement	Demonstration Evaluation
Ammonia Production/Usage Technologies					
③ Ammonia Using CO_2-Free Hydrogen	Component Technology Development, System Design			Systemization	System Demonstration
④ Ammonia Hydrogen Station Infrastructure Technology	Component Technology Development		Systemization		Feasibility Study
⑤ Ammonia Fuel Cells	SOFC Component Technology Development, Stack Prototype Evaluation		SOFC Module Prototyping/Systemization		System Demonstration
⑥ Ammonia-Based Direct-Combustion	Component Technology Development (heat transfer enhancement of the flame, low-NOx-emission, etc.)		Equipment Design, Prototyping, Improvement		System Demonstration
Organic Hydride Production/Usage					
⑦ Develop Hydrogen Supply Technology Using Organic Hydride	Component Technology Development			Optimization/Establishment of Mass Production Technology	
	Dehydrogenation Pilot Equipment Production/Operation Verification			Design of Commercial Prototype, Acquisition of Safety Data	Feasibility Study
Liquid Hydrogen Usage Technologies					
⑧ Develop Loading Systems and Rules for Liquefied Hydrogen	Basic Research into System, Specifications and Structure; Measures for Loading/Unloading Procedures		Production and Performance Testing, Accident Scenarios, Risk Assessment Studies, Development of Operational Conditions, etc.		System Demonstration, Making a Draft International Standards
⑨ Develop Hydrogen Engine Technologies	Component Technology Development (hydrogen spark plug, high-efficiency combustion technology, hydrogen injectors, etc.)				Model Demonstration
Development of Energy Carrier Safety Evaluation Systems					
⑩ Energy Carrier Safety Evaluation Research	Social Risk Assessment, Safety Assessment for Each Carrier, Database Construction			Safety Requirements and Countermeasures Study	Comprehensive Evaluation

Japan will continue in its unified efforts, coordinating between ministries and industry/academia/government entities. We will also conduct technological development with an eye toward international cooperation.