Leading the World in Hydrogen Energy Usage; 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 new eco-friendly sources of energy to replace fossil fuels and nuclear power is a critical factor to maintain our place as a leader in the international community. Hydrogen—which only produces safe, clean water after combustion—looks to be the best candidate for large-scale adoption 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 looking toward initiatives that will put Japan on the forefront as a low-carbon, hydrogen-based society.

Energy Carriers

Becoming a New Energy Society

Program Director

Shigeru Muraki

Executive Advisor
Tokyo Gas Co., Ltd

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. 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, Muraki was elected vice chairman of Tokyo Gas, and in 2015 he was named Executive Advisor.

The Foundation of a Hydrogen-Based Society: R&D throughout the Entire Value Chain

After the March 11 disaster in northeastern Japan, our nation's energy policies underwent a fundamental shift. While the country had been on a long path away from fossil fuels, now we struggled with questions about expanding our reliance on nuclear power. Despite expectations for the future of renewable, low-impact energy, natural energy sources have yet to prove themselves on economic and practical levels. Where should we turn for highly efficient, low-cost, scalable, environmentally friendly energy now? It seems that hydrogen may be an answer.

Hydrogen has been viewed as a potentially ideal source of clean energy for the past several decades. Unfortunately, we have yet to find a way to use hydrogen in practical applications. Japan leads the world in technical development of residential fuel cell systems, and also introduced the first mass-market hydrogen-based vehicle to the world at the end of 2014. However, there are still numerous issues to address if we are to truly become a low-carbon, hydrogen-based society.

Of course, the number one issue is cost. Despite the advancements made in using hydrogen for space development and industrial uses, we only see hydrogen in a few, small-scale applications in general society. To develop hydrogen into a mass-scale energy source that replaces thermal and nuclear power, we have to develop more advanced technologies for highly efficient, low-cost production, transport, storage, usage, and all the other processes involved.

"The goal of our program is to draw a blueprint—a script for hydrogen use, if you will—across the hydrogen value chain, from production to transport to usage," explains program director Shigeru Murakami. "For hydrogen to become a mainstream power source, we need it to be part of a large-scale power generation mechanism.

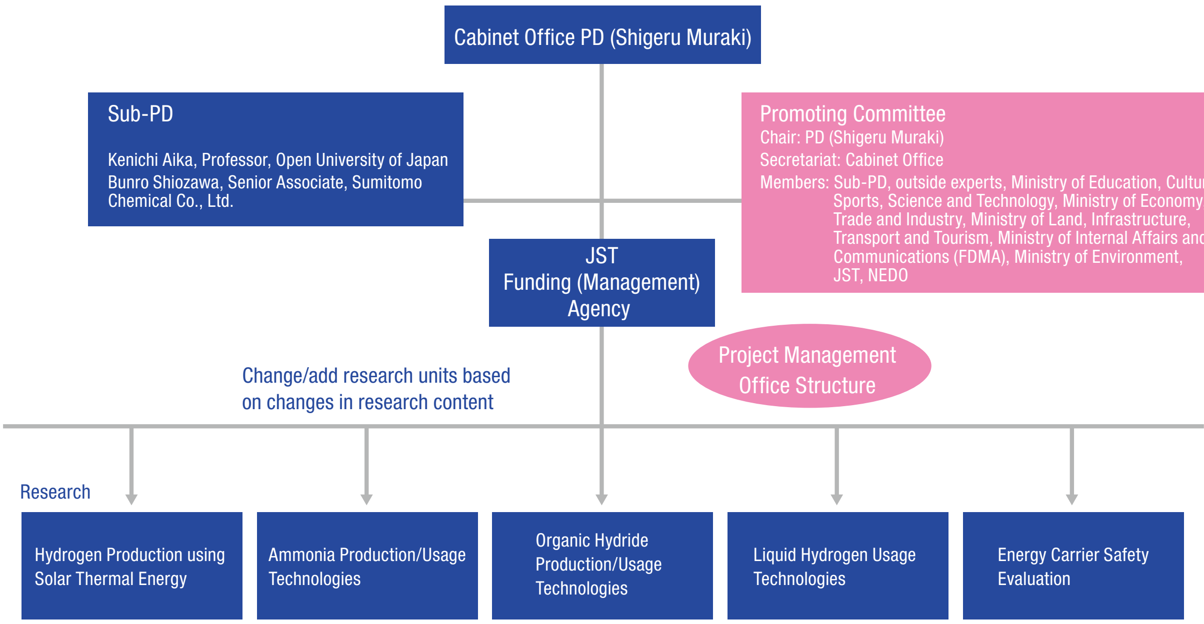
And, to reach that point, we must investigate new elemental technologies and practical usage methods, while at the same time expanding use cases in concrete, measured stages. Then, there are the mechanisms and systems for safety that need to be developed as well."

Muraki continues, "Leaving it solely to the ingenuity and technological development of the private sector wouldn't give us the speed and sense of urgency needed. With the government taking the lead in an industry-academy-government program, we should be able to speed development by a significant margin." A cooperative approach like this may help Japan take the lead in the global race to building a low-carbon society, helping solve the nation's energy problems, while at the same time offering opportunities for new global businesses that address the greater energy needs of the entire world. Says Mr. Muraki, "This is definitely a challenging program. But, I think the potential rewards are immeasurable."

Three Energy Carriers at the Top of the R&D Checklist

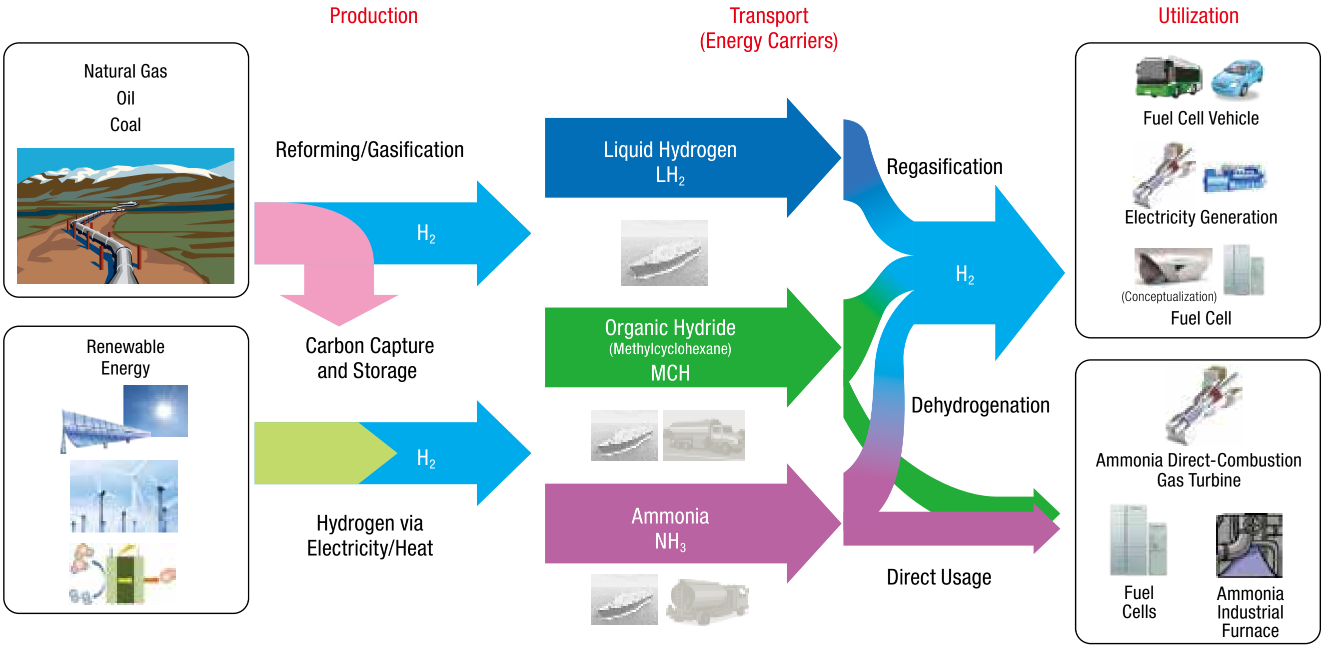
The first order of business is to develop energy carriers and practical use cases for hydrogen as a power source. Presently, the program has identified three potential carriers: liquid hydrogen, organic hydride, and ammonia.

Liquid hydrogen is familiar as a propellant for rocket engines. However, liquid hydrogen must be transported at -253°C, which demands further technological development for pipe joints, emergency separation mechanisms, and other loading systems. Further, new rules for safety and handling need to be created in advance of liquid hydrogen becoming an everyday power source for society.



•Implementation Structure

Shigeru Muraki



•CO_2-Free Hydrogen Value Chain Structure

Organic hydride is a substance resulting from bonding hydrogen with aromatic compounds.

Methylcyclohexane (MCH) has been identified as the most promising candidate. MCH is combined with toluene that has been infused with hydrogen molecules. This substance is a liquid at room temperature, making it easy to handle. And, once the hydrogen is separated back out, the substance returns to its original form of toluene, which can then be used again. If this program can develop more efficient dehydrogenation technologies, we could be seeing hydrogen-refilling stations with systems that separate hydrogen from organic hydride in the not-so-distant future. This would be a major step forward in popularizing hydrogen fuel cell vehicles.

Ammonia, used widely in industry, is a substance that consists of hydrogen and nitrogen. This SIP program is developing and testing technologies for efficient small-scale ammonia production, to be used in fuel cells, turbines, and industrial furnaces that can use ammonia directly.

However, “Not all of these carriers may remain viable selections through to the practical implementation stage,” says Muraki. The program needs to select and focus on certain energy carriers for research that leads to early adoption of practical hydrogen energy in real-world use.

This project will develop technologies for using electricity and heat from renewable energy sources to produce CO_2-free hydrogen or energy carriers efficiently and at acceptable costs. The project will also develop and test large-scale hydrogen engines and turbines, which will be key for future real-world use of hydrogen.

2020 Olympics/Paralympics: The First Milestone to becoming a Hydrogen-Based Society

While this technological development will ultimately lead to a hydrogen-based society, the road forward is long.

“There’s no miracle formula to suddenly discovering low-cost hydrogen,” says Mr. Muraki. “What we are doing is looking to create economies at every point in the value chain, slowly but surely establishing a foundation for wider hydrogen usage. This will lead to lower costs for carriers and large-scale adoption.” Muraki continues, “Lower costs or wider adoption is almost a chicken-or-egg type of discussion, but it’s important to keep moving forward in promoting hydrogen use in society. Our project runs through 2018, but we’re looking toward the 2020 Olympics and Paralympics to show the world our results. That’s our first milestone. Beyond that, we’re aiming for the year 2030, by which time we hope to see hydrogen used for large-scale electricity production.”

If this project can reach those goals, Japan stands to be a leading nation in hydrogen-based industries, establishing a major presence in the global markets. Not only will this program contribute to solving Japan’s energy issues, it should serve as an impetus for exporting hydrogen-based infrastructure to developing nations and the rest of the world.

Safety is one major hurdle to greater hydrogen adoption. This project will perform risk assessments for energy carriers, reflecting our findings in safety policies, risk communication, and other initiatives to generate greater public acceptance.

Research and Development Topics

1. Develop energy carriers and identify promising candidates

Advance the use of liquid hydrogen, organic hydride, and ammonia as energy carriers for hydrogen production, transport, and storage; structure a practical cost model to sever 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 test 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, atmospheric diffusion modeling, etc. 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.

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 develop hydrogen use cases, engaging in technological development driven by flexible 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 at the 2020 Tokyo Olympics/Paralympics. Finalize 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 cooperation for using renewable energy overseas (2018 -)

Promote international cooperative development of CO_2-free hydrogen production in overseas markets.
Prove systems ranging from hydrogen energy production to usage.

We will leverage industry-academy-government cooperation to hasten initiatives leading to a true hydrogen-based society.

Deliver tangible results by the 2020 Tokyo Olympics/Paralympics