

A Conversation with the CTO

MHI Group is making important contributions toward realizing Carbon Neutrality

Hydrogen technologies are key to achieving a decarbonized world

Executive Vice President
and CTO

Eisaku Ito

Former Director-General of the
Japan Meteorological Agency

Toshihiko Hashida

Takasago Machinery Works in western Japan is where MHI develops and manufactures gas turbines featuring world-class power generation efficiency. Today, development of hydrogen gas turbines, which are expected to play a key role in decarbonization, is underway. We invited Dr. Toshihiko Hashida, former Director-General of the Japan Meteorological Agency (JMA), to meet with Executive Vice President and CTO Eisaku Ito for a discussion on a variety of topics.

MHI Group Efforts to Address Climate Change

Ito Thank you very much for taking the time to be with us today. Takasago Machinery Works is the main manufacturing facility for MHI's production of gas turbines, which boast world-class efficiency in power generation. This is also our base for conducting R&D on hydrogen gas turbines and other hydrogen technologies. We're especially happy to have you, an expert in meteorology, here today to observe MHI's cutting-edge Carbon Neutrality initiatives.

Hashida I have many opportunities to discuss climate change issues, especially from the perspective of natural disaster prevention, but I'm eager also to learn more

about what measures are being taken to mitigate climate change and to achieve decarbonization. So I was very much looking forward to my visit here today.

Earlier, I was briefed on the different types of research currently underway here at Takasago Machinery Works, including on the combustion properties of hydrogen. I learned that investigation of these properties, through computation and experimentation, supports the engineering of your products. In the field of meteorology, we too use vast numbers of simulations of the natural world in order to make numerical projections, so I feel that we have many points in common. I was especially impressed at how MHI combines elemental technologies in order to create usable products.

Ito As a climate specialist, what are your views on climate change?

Hashida Almost every year now, summers bring frequent debilitating heat waves and disaster-causing torrential rains, and these weather events are making people increasingly aware of the impact of global warming. In Japan, torrential downpours and severe heat waves are the most obvious adverse effects caused by global warming, while outside Japan, other parts of the world are also experiencing prolonged droughts. The Intergovernmental Panel on Climate Change (IPCC) has also provided evidence of how climate change has impacted our lives, livelihoods, and property in recent years.

The most urgent challenges we face today are to mitigate natural disasters caused by global warming, to lessen the physical risks arising from environmental changes, and to reduce greenhouse gas emissions, the cause of global warming. Under the Glasgow Climate Pact adopted at COP26 in November 2021, participating nations jointly committed to reducing greenhouse gas emissions in pursuit of decarbonization. Today, it's absolutely imperative that we stop the situation from deteriorating any more than it already has. This is a matter that our generation has a responsibility to deal with now, so that we can pass on a sustainable world to future generations.

Ito I completely agree. We need to address these matters with utmost urgency. At MHI, we have identified important issues—which we call Materiality—that need to be resolved in order to better society and to ensure growth as a company in the medium to long term. Foremost among

Hydrogen Technologies: Key to Achieving Carbon Neutrality

Hashida In October 2021, MHI Group announced MISSION NET ZERO. I find your goal of achieving Carbon Neutrality by 2040 extremely ambitious.

Ito Today, efforts are being made all around the world to achieve Carbon Neutrality. In Japan, the government has declared its commitment to attain Carbon Neutrality on a national level by 2050. It's within that context



these issues are to provide energy solutions to enable a carbon neutral world and to build a safer and more secure world.

Earlier, you mentioned the physical risks arising from environmental changes, and related to that, I believe that MHI has simulation technologies that could be useful in addressing the increasing intensity of natural disasters—floods, tsunamis, and powerful windstorms which can cause buildings to collapse. Today, we're conducting research creating detailed disaster simulations which integrate data on water and air flow patterns as well as movement of people.

We also have solutions pertaining to decarbonization, which will be necessary to stop global warming. Power generation systems, for example, are one of our mainstay products. We can reduce CO₂ emissions by power plants across the globe by improving the performance of these plants and also by converting them to carbon-free fuels, such as hydrogen. I firmly believe that by combining all of MHI Group's decarbonization technologies, we will be able to make a positive impact on society.

that we announced our commitment to achieve Carbon Neutrality Groupwide by 2040. We set our target for 2040, because we believe that in order for Japan to achieve Carbon Neutrality by 2050, MHI needs to be carbon neutral before that, to allow for our customers to prepare for their own decarbonization efforts.

In our case, more CO₂ emissions result from customers using our products than from our own business. If

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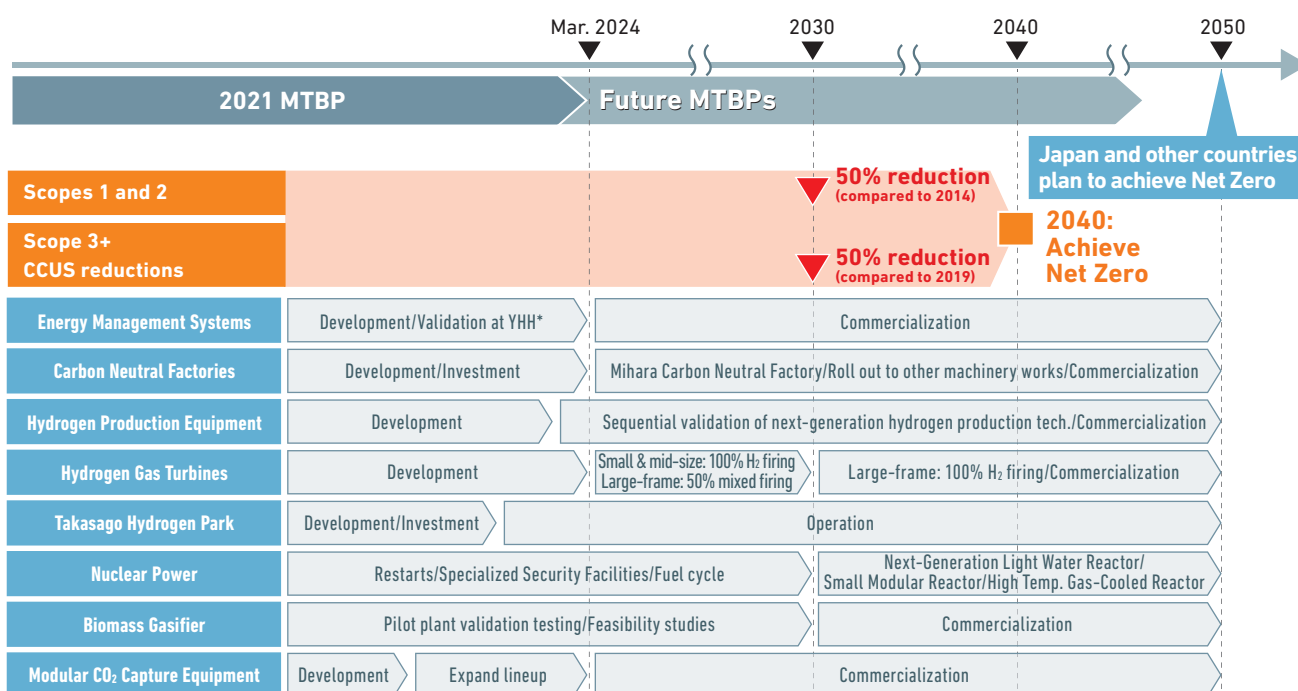
these emissions can be reduced through CO₂ capture and conversions to alternative fuels such as hydrogen, we can make a major contribution to cutting global CO₂ emissions by an estimated 3% to 4%. At MHI Group, we're also hopeful that as we take steps to achieve decarbonization, our customers and competitors will be inspired to do the same, which will produce a ripple effect reducing carbon emissions worldwide.

Hashida It seems to me that the development of hydrogen gas turbines is key to achieving Carbon Neutrality. What are some of your strengths in this area?

Ito One is hydrogen combustion. At MHI, we have been providing gas turbines to the steel industry for more than 50 years, and we have core technologies for the firing of high hydrogen-content off-gas. We have also accumulated expertise in the handling and combustion of hydrogen during our many years of rocket engine development. Today, we're applying our technologies and experience to the development of hydrogen gas turbines.

Hashida During my visit here today, I got to see the facility where gas turbines are manufactured, the Gas Turbine Combined Cycle power plant, and the site where Takasago Hydrogen Park will be built. On the premises here, you have a large-scale power generation facility for in-house technology validation, which is in fact a fully operational power plant in its own right. I think the ability to conduct validation testing on real-world equipment is an outstanding environment for your development engineers to work in.

▶ Roadmap to a Carbon Neutral Society



* Yokohama Hardtech Hub: A co-creation space, located at the Honmoku Plant of MHI's Yokohama Dockyard & Machinery Works, where startups, manufacturing companies, local governments, and educational institutions can collaborate

Ito Exactly. What sets Takasago Machinery Works apart is the presence of four disparate functions all at one location: R&D, engineering, manufacturing, and validation testing. Since the staff involved in these respective functions are all located near each other, any problems that arise can be resolved quickly. Also, validation test results can be fed back immediately to facilitate any necessary modifications in development and engineering. The large-scale demonstration power plant facility (output: 566 MW) which you saw today went into operation in July 2020, and the power generated here is supplied to homes, factories, and other users through the local power utility's grid. If the plant were to stop operating, there would be significant impact to the community. We feel this pressure while we're working on development, and there's no room for excuses. This environment has been especially useful in our development of high-efficiency gas turbines, and it gives us a major advantage in the development of hydrogen gas turbines.

As you saw today, we have already started construction work on Takasago Hydrogen Park, which is slated to begin operations in FY2023. At this new facility, validation testing will be performed for next-generation hydrogen manufacturing technologies, including water electrolysis and turquoise hydrogen produced by methane pyrolysis. Testing of hydrogen combustion technologies and validation operations will be performed at the adjacent demonstration power plant. The resulting facility will be capable of fully integrated validation of hydrogen production, storage, and power generation.

Hashida With a setup like this, development is sure to proceed even more quickly. What innovations is MHI pursuing in the R&D of new decarbonization technologies?

Ito There are many core aspects of development that need to be resolved. One example is hydrogen combustors, which are a key component of hydrogen gas turbines.

Still, if we attempted to resolve the major technological challenges that lie before us all at once, we would be sure to fail. MHI Group has many businesses producing a wide range of products, and supporting them are more than 600 different types of technologies. When approaching a major challenge, you need to break it down into small parts,



each of which must be addressed in gradual steps through iterative hypothesis testing. If we work on these small challenges in parallel, then overall development speed can be accelerated.

Under our Shared Technology Framework, we're increasing our development speed as well as our success rate by applying this kind of approach, which we call Pivot Development. Even when the barriers to development success seem high, I firmly believe that if we set the correct targets, our development process will bring success without fail.



Toshihiko Hashida, PhD

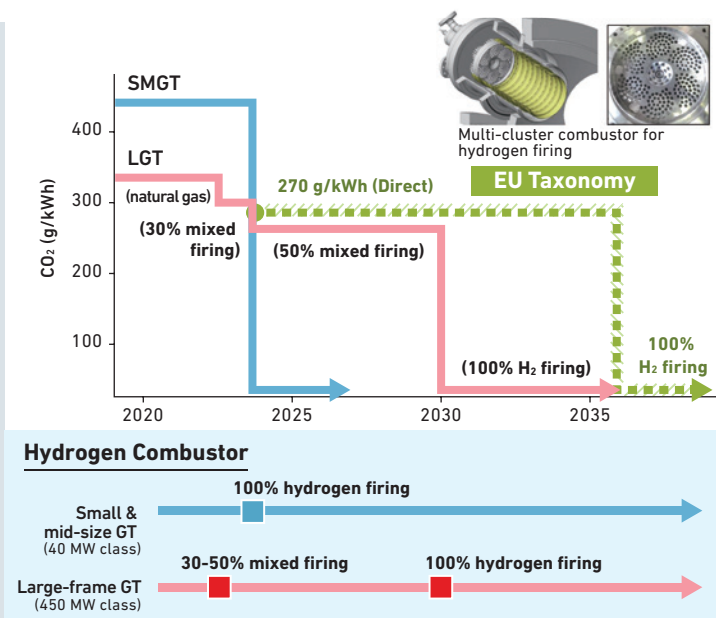
Dr. Hashida served as the 25th Director-General of the Japan Meteorological Agency from 2016 to 2019. He has broad experience in meteorological services related to weather, the global environment, earthquakes, tsunamis, and volcanoes, and was involved in the planning and management of meteorological administration, including disaster prevention, international cooperation, and technology development. He also promoted public-private engagements, especially in the use of meteorological data.

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► Hydrogen Gas Turbine (EU Taxonomy Compliant)

EU Taxonomy Compliant
Leveraging Takasago Hydrogen Park, develop hydrogen gas turbine technology that complies with the EU Taxonomy's strict CO₂ emissions standards. Development schedule meets Taxonomy timing requirements as well.

- Small & mid-size gas turbines**
 - Validate on actual equipment at Takasago Hydrogen Park in preparation for commercialization of hydrogen gas turbines by 2025, meeting the EU Taxonomy deadline
- Large-frame gas turbines**
 - Development of 30% mixed hydrogen firing technology was completed in 2018. Validation will be performed at Takasago Hydrogen Park in the lead up to commercialization in 2025.
 - Forecasted to achieve 100% hydrogen firing by 2030 and meet the EU Taxonomy requirements before the deadline



Hashida In the EU, steady progress is being made in adoption of the EU Taxonomy, a system that defines environmentally sustainable economic activities. I think this will have an impact on MHI's product development as well. The strict standards announced appear to serve as an incentive for pursuing the Energy Transition. How does MHI Group view the new taxonomy system?

Ito The EU Taxonomy has classified gas-fired thermal power and nuclear power as important energy sources in the transition to Carbon Neutrality. But the criteria for approval of new power plants are, as you say, difficult to achieve using conventional performance en-

hancement approaches. I see the taxonomy system as a mechanism to guide users to adopt hydrogen combustion and other technologies.

Even before the EU Taxonomy standards were issued, we at MHI Group have been preparing based on our own future projections. We have already completed development of large-frame gas turbine combustors for 30% mixed hydrogen firing, and we have achieved a technology to enable stable combustion of a 50% hydrogen mix. We're now at the stage where we're applying the sum of our technological resources toward achieving 100% firing in large-frame gas turbines, aiming for commercialization by 2030.

It's Important for the Energy Transition to Be Realistic

Hashida Decarbonization has become somewhat of a trend these days, but in the case of MHI Group's MISSION NET ZERO, your program is supported by concrete technologies, and you're confidently tackling the decarbonization challenge. Also, the way you're working to resolve issues of global scale with your technologies brings to mind the spirit imbued in MHI's corporate philosophy, Our Principles. Given the role that businesses play as members of society, I think expectations are high that MHI will

continue to carry out business in a stable manner.

Ito As you say, business continuity is a matter of extreme importance, and for us to sustain our business, I believe the products and solutions we propose must be what the customer is looking for. What I mean to say is that, besides environmental value, our products and solutions must also make economic sense. I believe customers normally want to keep using their existing as-

▶ Takasago Hydrogen Park

Begin operation in FY2023

A one-stop-shop for validating hydrogen-related technologies from hydrogen production to power generation

■ Add hydrogen production and storage equipment to existing demonstration plant

Test and validate water electrolysis, turquoise hydrogen^{*1}, SOEC^{*2} and other technologies in-house and improve product reliability

^{*1} Turquoise hydrogen: H₂ obtained through pyrolysis of methane into H₂ and solid carbon

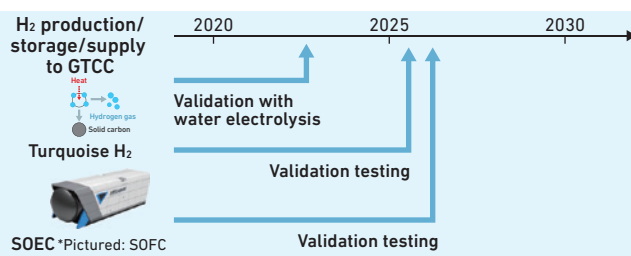
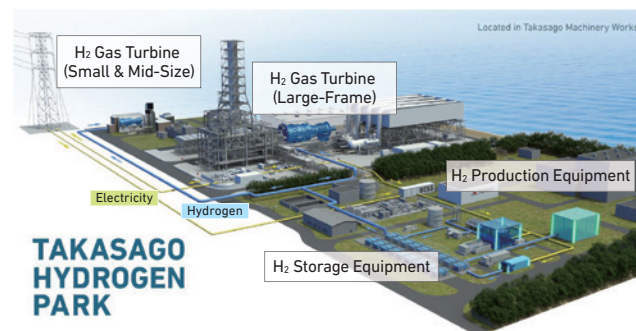
^{*2} SOEC (Solid Oxide Electrolyzer Cell): High temperature steam electrolysis

■ Validate hydrogen gas turbine technology

Validate technology in lead up to commercialization of 30% mixed firing in large-frame gas turbines and 100% hydrogen firing in small & mid-size gas turbines by 2025

■ Combine and evolve energy infrastructure and hydrogen technologies

Make progress toward establishing a hydrogen solutions ecosystem, which will help achieve a sustainable society by linking various industries with hydrogen technologies



sets as long as possible. They want to be able to achieve decarbonization by making the minimum necessary modifications and/or additions to their current facilities. For example, in the case of fuel conversions, a customer can achieve hydrogen mixed firing simply by replacing their gas turbine combustors and installing a hydrogen tank and production equipment next to their existing power plant. In hard-to-abate industries such as steel and cement manufacturing, we can propose installation of our proprietary CO₂ capture equipment, enabling companies to capture their carbon emissions. Making proposals like these, I believe, will be advantageous both to the customer and to society as a whole.

Hashida Also, given the nature of the infrastructure that supports daily economic activity and indeed our very lives, it's necessary to resolve the issues at hand in a realistic way, keeping infrastructure running with minimal shutdowns.

Ito Exactly. We firmly embrace the pursuit of a realistic Energy Transition. As a manufacturer, we have a responsibility to come up with solutions that simultaneously address all S+3E issues: Safety, Energy Security, Economic Efficiency, and the Environment. Without doing so, we will not be able to achieve Carbon Neutrality. Some

people may think this issue could be solved simply by immediately changing all existing infrastructure, but not only is this not economically feasible, carrying out such upgrades would be unsustainable. We approach the situation by considering whether our proposals would truly be good for society. At MHI Group, we aim to contribute to society by setting clear transitional goals: targeting what we want to accomplish by 2030, 2040, and beyond.

Hashida Hearing what you have told me today, I have gotten a sense that MHI Group not only possesses advanced technological capabilities but also clear strategies for achieving its targets for 2040. I strongly feel that MHI will play a leading role in the global effort to achieve a carbon neutral world, and I have high expectations that MISSION NET ZERO will be a success.

Ito Thank you for your kind words of encouragement. At MHI Group, we see the decarbonization of both energy supply and use as growth opportunities. In addition to the hydrogen solutions which you saw here today, we offer numerous other solutions as well which will allow us to meet our commitment to help achieve Carbon Neutrality. We pledge to keep taking on new challenges to realize a future where everyone in the world can live in peace and security.