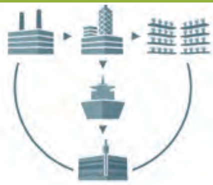
# New Challenges Toward a Carbon-

## Build an innovative solutions ecosystem to realize a carbon neutral future

**1** Decarbonize existing infrastructure

**2** Build a hydrogen solutions ecosystem


**3** Build a $CO_2$ solutions ecosystem



Build a $CO_2$ solutions ecosystem

### Basic approach to realizing a carbon-neutral society

Efforts to decarbonize are accelerating globally amid a widespread recognition that global warming and climate change associated with it are challenges facing all of humanity. Another challenge that must be addressed in earnest is ensuring stable, economical energy supplies. We believe this challenge requires both short- and longer-term initiatives backed by MHI Group technologies and resources. While we plan to decarbonize and enable more efficient use of existing infrastructure in the near term, we aim to build hydrogen and $CO_2$ ecosystems instrumental to bringing about a carbon-neutral society in the longer term.

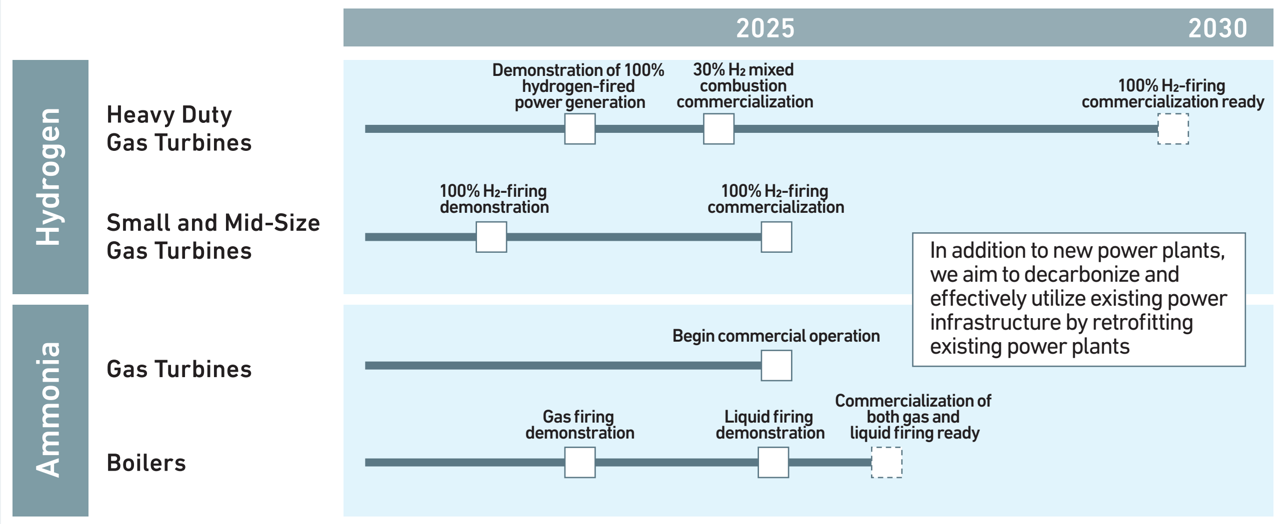
## 1 Decarbonize existing infrastructure

Electric power is essential to both people's daily lives and industry. We must both ensure stable supplies of electricity and reduce its societal costs. Toward this end, we will decarbonize existing thermal power plants and promote utilization of nuclear power as a stable, large-scale and carbon-free source of electricity.

To decarbonize thermal power, we are endeavoring to validate and commercialize carbon-free power generation that is fueled by hydrogen and/or ammonia and enables effective utilization of existing infrastructure. As a first step, we are testing gas turbines that burn a fuel mix containing 30% hydrogen. We aim to commercialize

# Neutral Society

### Roadmap to validation and commercialization of carbon-free power generation fueled by hydrogen/ammonia

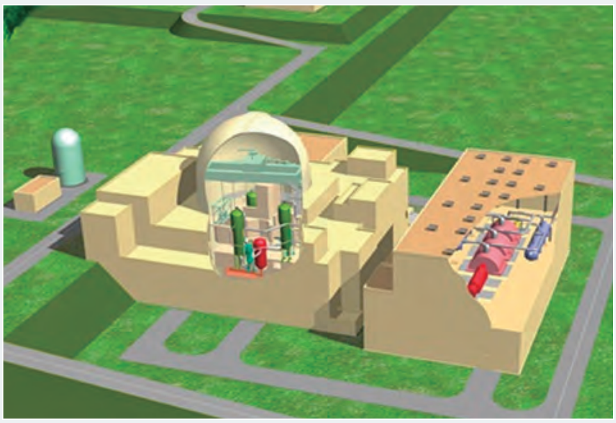



* The above diagram includes New Energy and Industrial Technology Development Organization (NEDO) projects' development outcomes.

them by around 2025. We are also developing combustors, a key technology for enabling 100% hydrogen-firing, for both large and smaller gas turbines. We aim to commercialize 100% hydrogen-fired turbines by around 2030. We are developing technology for ammonia-fired power generation also. We are targeting commercialization by around 2025. To adequately improve our gas turbines' reliability and thoroughly test them before delivering them to customers, we have integrated the entire process from development through production and testing at our Takasago Machinery Works.

We will contribute to nuclear power plants' safety and stable operation over the near term by helping customers restart existing plants, improve the safety of operational plants on an ongoing basis and build a nuclear fuel cycle in Japan. To achieve the highest level of nuclear safety in the world, we are developing next-generation light water reactors that will realize a new concept of safety through the use of innovative technologies and stronger safeguards against all types of disasters. We aim to commercialize them by the mid-2030s. We are also developing small modular reactors, fast reactors and microreactors to meet increasingly diverse future societal needs. From an even longer-term perspective, we are pursuing the development of nuclear fusion reactors, a dream energy source. Through such short- and longer-term initiatives, we will contribute to the realization of a decarbonized society through nuclear power technology.

### Next-generation light water reactor



## Special Feature: New Challenges Toward a Carbon-Neutral Society

# 2 Build a hydrogen solutions ecosystem

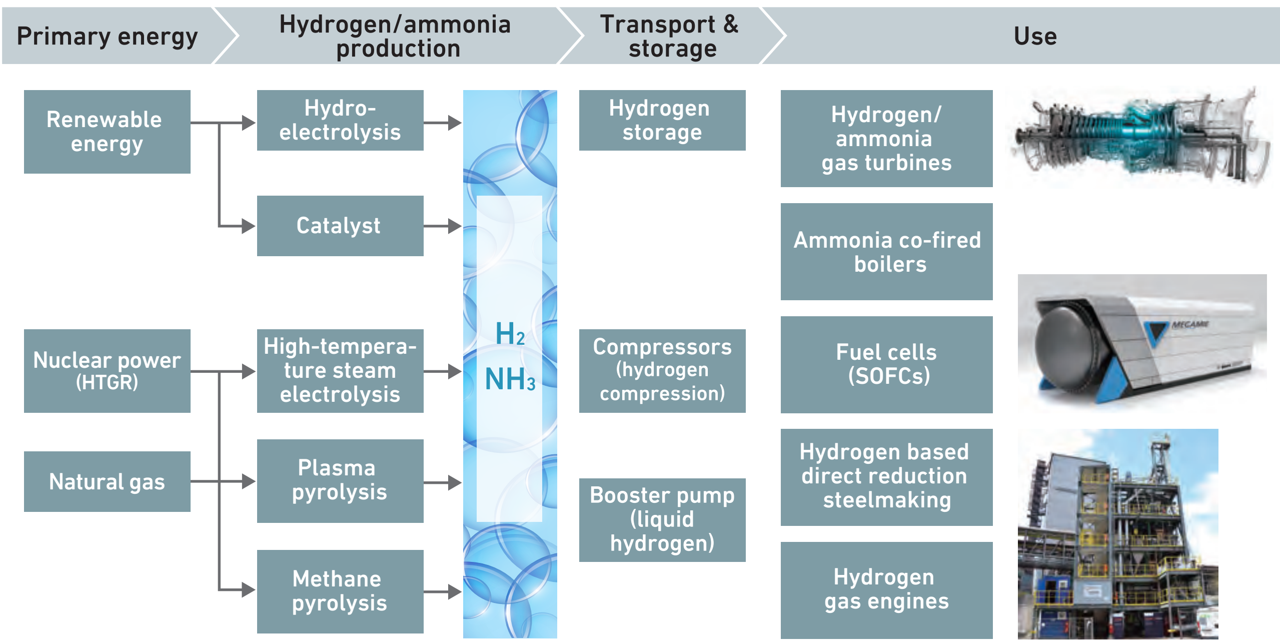
Pure hydrogen does not exist in nature. It is expensive to produce because its production is highly energy-intensive. Additionally, if hydrogen is to be produced and used at different locations, it would require both a means of transport and storage infrastructure. These issues must be addressed at every link in the hydrogen value chain, from the supply of primary energy required for production through transport, storage and even use. MHI Group aims to build a value chain in proactive collaboration with other companies. We are also participating in leading-edge projects globally.

In the U.S., for example, we are involved in an advanced clean energy storage project in Utah. The project produces hydrogen through wind- and solar-powered hydro-electrolysis and stores it in underground salt caverns. Some of the hydrogen is supplied to power plants equipped with hydrogen-fired gas turbines developed by MHI Group. We plan to supply the project with an 840MW-class hydrogen-fired gas turbine that will initially be fired with a 30%-hydrogen fuel mix from 2025 before eventually transitioning to 100% hydrogen.

We are also launching an initiative to utilize nuclear energy to produce hydrogen. We aim to mass-produce hydrogen efficiently and stably using high-temperature gas reactors that generate heat at temperatures in excess of 900°C. The hydrogen thus produced will meet large-scale hydrogen demand for purposes such as decarbonizing the steel industry.

Additionally, we developed the world's first hydrogen-based fine ore reduction (HYFOR) process for the steel industry and commenced the operation of a HYFOR pilot plant. Since the HYFOR process uses pure hydrogen as a reducing agent, consequently, the $CO_2$ footprint is close to zero. We will continue to test and develop this game-changing process to realize $CO_2$-free steel production.

### Hydrogen Value Chain




* The above diagram includes NEDO projects' development outcomes.

# 3 Build a $CO_2$ solutions ecosystem

$CO_2$ capture and storage technologies and initiatives that productively utilize captured $CO_2$ are garnering considerable attention as pathways to carbon neutrality.

In 1990, MHI Group and Kansai Electric Power Co. (KEPCO), Inc., started jointly developing technologies to capture $CO_2$ from flue gases. Today, MHI Group is the global market share leader in $CO_2$ capture from exhaust gases, with proven track records that include the world's largest $CO_2$ capture project in the U.S. In the UK, MHI's Advanced KM CDR Process™ was selected to be used in the project to capture $CO_2$ from a biomass power station in recognition of MHI Group's track records, state-of-the-art retrofittable $CO_2$ capture technology and technical capabilities of capturing $CO_2$ from diverse exhaust gas sources. The UK project aims to realize the world's first commercial-scale carbon-negative power plant (net negative $CO_2$ emissions) by combining bioenergy, which can achieve carbon neutrality (net zero $CO_2$ emissions) by using plant-based fuels, and $CO_2$ capture technology from exhaust gas. To promote widespread adoption of $CO_2$ capture technology across a broad range of industrial sectors, including at cement plants, LNG liquefaction plants and waste incineration plants, we will focus on more feasible applications by developing simple $CO_2$ capture systems.

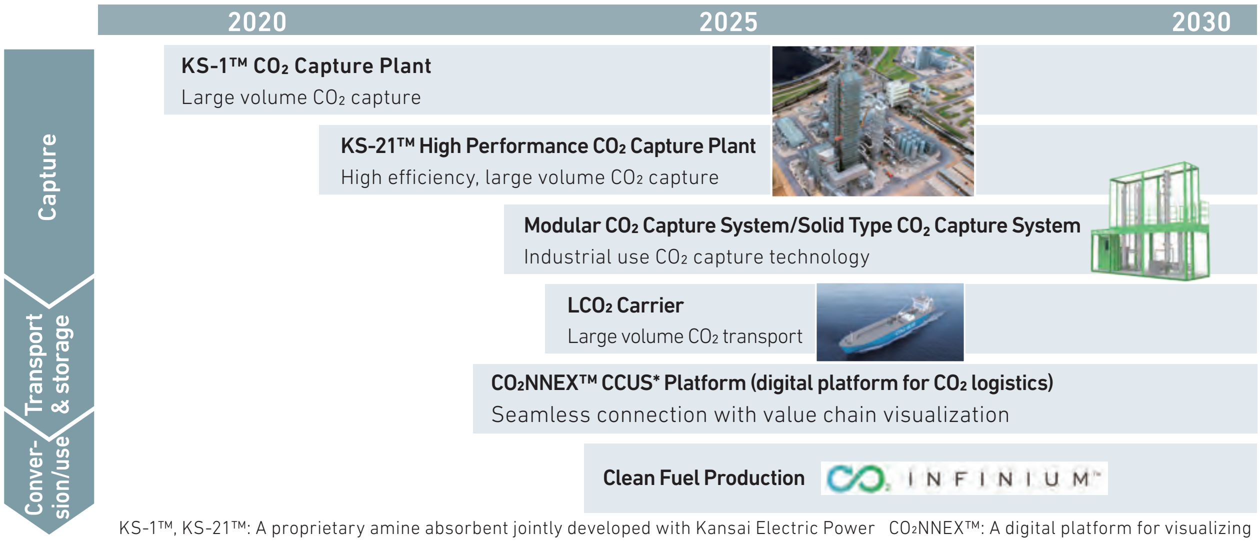
Liquefied $CO_2$ ($LCO_2$) carriers are expected to be in growing demand as a key link in the CCUS ($CO_2$ capture, utilization and storage) value chain. We will proactively develop technologies in collaboration with external partners to develop an $LCO_2$ carrier business in the aim of forming a $CO_2$ value-chain market.

Building a value chain that encompasses $CO_2$ capture, transport, storage, distribution, conversion and utilization is essential to realizing a $CO_2$ ecosystem. We are working on doing so. Specifically, we started building a digital platform named $CO_2$NNEX™ in collaboration with IBM Japan, Ltd., to render visible $CO_2$ flows within the ecosystem. $CO_2$NNEX™ will enable us to visualize and coordinate flows of $CO_2$ for which options are currently limited to storage and utilization, and optimize the overall value chain through such means as assessing $CO_2$ flows from an investment or cost perspective and efficiently matching emitters with users.

## Roadmap to $CO_2$ Ecosystem-building

**Create a solutions ecosystem covering carbon capture, transport, storage, and conversion/use**

**Expand carbon capture product lineup by 2023**




KS-1™, KS-21™: A proprietary amine absorbent jointly developed with Kansai Electric Power  $CO_2$NNEX™: A digital platform for visualizing $CO_2$ logistics to be jointly developed with IBM Japan

* CCUS : Carbon dioxide Capture, Utilization and Storage