

Development of Environmental Technology

Principle and Outline

The Daigas Group views technology as the foundation for its corporate competitiveness and views research and development as one of its most important strategies for differentiating itself from the competition. While accelerating low-carbon transitions through development of technologies contributing to the reduction of CO₂ emissions, we take on the challenge of technical research and development for the carbon neutrality of our gas and electricity. We will actively tackle a wide range of subjects, from the advanced use of natural gas to the further utilization of renewable energy and the research and development of carbon-neutral gas technologies such as methanation, to accelerate development of technologies that will contribute to achieving carbon neutrality.

Development of New Technologies that Contribute to Carbon-Neutral Solutions

The Daigas Group believes that e-methane*, which is synthesized from hydrogen produced using renewable energy and CO₂, is the key to making city gas carbon-neutral. The Group is working on establishing a variety of methanation technologies toward full-scale introduction of e-methane, etc. in 2030. Moreover, we are promoting development of technologies that contribute to further low-carbon/carbon-neutral solutions by making use of the gas synthesis/catalyst technology, combustion technology, and material technology that Osaka Gas has developed so far. For example, the Company is now developing hydrogen and ammonia combustion technologies by leveraging the know-how cultivated through the development of a variety of natural gas combustion technologies tailored to our customers' uses. We are working with Toyota Industries Corporation to expand the use of ammonia fuel. Specifically, we are collaborating on small engine research at the Advanced Technology Institute and the development of heat treatment burners at Daigas Energy Co., Ltd. We are also promoting the use of bio-methane and biogas and working on the development of chemical looping combustion technology as a technique for producing carbon-neutral hydrogen and electricity from biomass. In addition to energy, Osaka Gas also develops and sells SPACECOOL®, a radiative cooling material. The Carbon Neutral Research Hub of Osaka Gas and Daigas Innovation Center, which was completed in September 2025, conduct R&D on these technologies, disseminate information, and form business alliances.

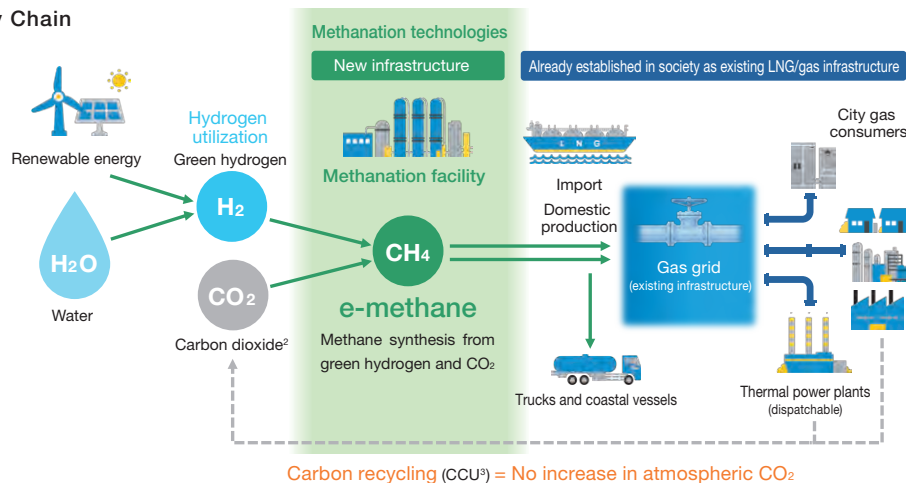
* Synthetic methane produced from non-fossil energy sources, such as green hydrogen, is called "e-methane."

"e-methane"—the key to carbon-neutral solutions created by methanation technology

"e-methane," which is produced by recycling CO₂ otherwise emitted into the atmosphere and synthesizing it with hydrogen, is a carbon-neutral hydrogen carrier¹.

Since "e-methane" has almost the same composition as city gas, existing city gas infrastructure and combustion equipment at customers' sites can be used as is, enabling seamless carbon neutralization during the transition period and advantageously reducing the cost of its social implementation.

■ e-methane Supply Chain



¹ Hydrogen compounds that make it possible to store, transport and use hydrogen efficiently. (Hydrogen is inefficient to store or transport over long distances in its gaseous state.)

² Biogenic CO₂ and possibly CO₂ derived from DAC (Direct Air Capture: a technology used to capture and remove CO₂ directly from the atmosphere) might be utilized in the future.

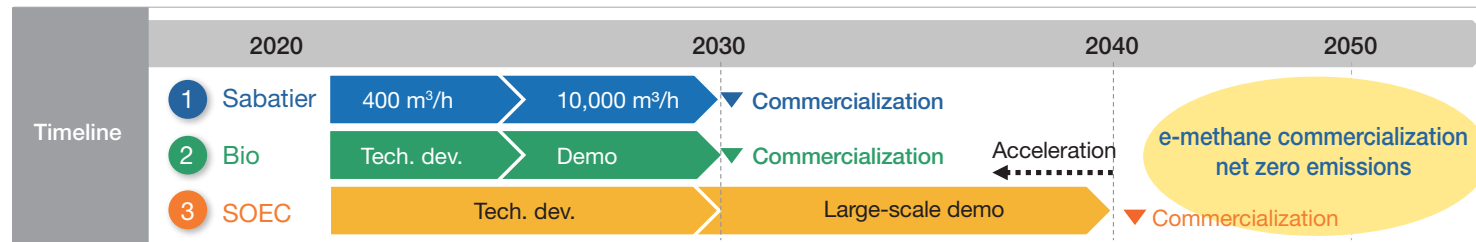
³ Carbon dioxide Capture and Utilization

Efforts to establish three methanation technologies to enable the introduction of "e-methane"

In addition to working to scale up the existing technology, Sabatier methanation, we aim to commercialize biomethanation, a locally produced and locally consumed energy generation technology, and to achieve early introduction of highly efficient SOEC methanation, an innovative technology.

- ① **Sabatier methanation**¹ (existing technology): Scaled up and implemented in society at an early stage
- ② **Biomethanation**² (innovative technology): Produce and use energy locally for local consumption
- ③ **SOEC methanation**³ (Innovative technology): Reduce cost by enhancing energy efficiency

Roadmap for Social Implementation of Methanation Technology



1 CO₂ conversion by a catalytic reaction with hydrogen derived from renewable energy, etc. to synthesize methane.

2 Technology that uses biological reactions to synthesize methane from CO₂ and hydrogen

3 Use of SOEC equipment to electrolyze water and CO₂ into hydrogen and carbon monoxide using renewable energy, etc., and then synthesize methane by catalytic reaction of the hydrogen and carbon monoxide.

Progress in Sabatier methanation development

In February 2026, we began a Sabatier methanation demonstration tests in Nagaoka jointly with INPEX CORPORATION, marking one of the largest technology development projects in the world for the commercialization of methanation for the reduction and effective use of CO₂ emissions. With a processing capacity of 400 Nm³-CO₂/h, the equipment's annual manufacturing capacity is equivalent to the gas consumption of around 10,000 households. The demonstration will continue until the end of FY2027, as we aim to acquire the technical expertise required for scale expansion, including reactive behavior of methanation and durability evaluation. Leveraging the technical expertise we obtain through this demonstration, we will conduct an outline design for a large-scale Sabatier methanation facility (10,000 m³/h) as we aim to contribute to carbon neutrality. The demonstration test equipment has acquired clean gas production equipment certification under the Clean Gas Certificate Program¹, while we also plan to implement CO₂NNEX^{®2}, a system for the transfer and management of clean gas certificates.

1 A program in which certificates are issued to clean gas (synthetic methane and biogas) with value that is considered not to increase CO₂ in the atmosphere when combusted (environmental value), and in which environmental value can be separated from energy value for transfer.

2 CO₂NNEX is a registered trademark of Mitsubishi Heavy Industries, Ltd.

Progress in biomethanation development

From May to July 2024, we conducted a demonstration of e-methane production from food waste and renewable energy at a waste incineration plant in Osaka City (Maishima Plant), successfully achieving the target production of 5 Nm³/h of e-methane (methane concentration of 95% or higher).

Moreover, in April 2025, we started to demonstrate this technology* at the Osaka/Kansai Expo site and confirmed that e-methane production reached the target of 7 Nm³/h.

* Ministry of the Environment Commissioned Project: "FY2023 Demonstration Project for a Low-Cost Hydrogen Supply Model Utilizing Existing Infrastructure"

Progress in SOEC methanation development

In 2021, Osaka Gas became the first company in Japan to succeed in creating a full-sized cell prototype for metal-supported SOEC, the key to SOEC methanation technology.

In April 2022, in response to a call for proposals by the National Institute of Advanced Industrial Science and Technology (AIST) and the New Energy and Industrial Technology Development Organization (NEDO), we proposed an SOEC methanation technology innovation project for the “development of innovative technology for the production of synthetic methane,” one of the research and development themes of the Green Innovation Fund Project’s Development of Technology for Producing Fuel Using CO₂, etc. The Group’s proposal was adopted for the project.

The project will bring together technologies related to SOEC methanation and aims to establish synthetic methane production technologies with the world’s highest levels of energy conversion efficiency.

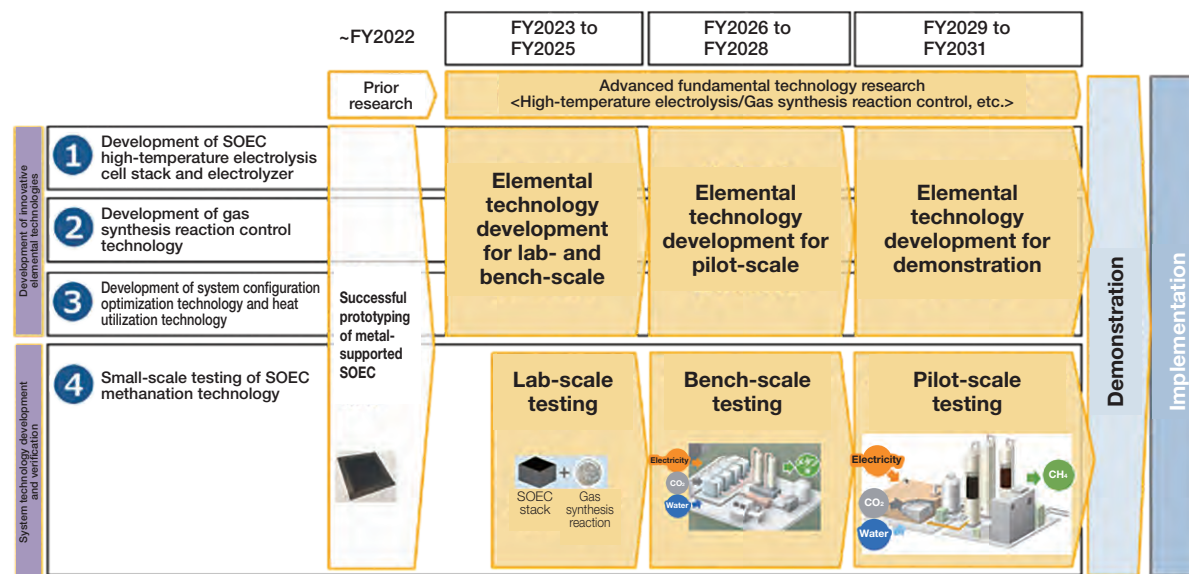
As a small-scale experiment, from FY2023 to FY2025, we built a lab-scale pilot facility and confirmed an energy conversion efficiency of 60% or higher.

In June 2025, we completed construction of a bench-scale testing facility at Daigas Innovation Center +. At the facility, we test the performance of a SOEC steam electrolyzer¹ and obtain operating data from the entire process to conduct verification aiming at achieving high energy conversion efficiency. To aim for further efficiency, we will set up a new SOEC co-electrolyzer² with greater durability and test its performance. After these bench-scale tests, we will scale up to pilot-scale testing and aim to achieve world-class energy conversion efficiency in the future.

¹ A high temperature electrolyzer that generates hydrogen by electrolysis of water vapor. Manufactured by our subcontractor Toshiba Corporation.

² A high temperature electrolyzer that electrolyzes CO₂ together with water vapor to produce hydrogen and CO.

SOEC Methanation Technology Innovation Project Schedule



Methane synthesizer/reactor



Methane synthesizer/reactor

Development of chemical looping combustion technology for simultaneous production of hydrogen, electricity and CO₂

Osaka Gas is working on the development of chemical looping combustion (CLC¹) technology², which produces electricity, hydrogen, and CO₂ simultaneously by leveraging the redox action of iron oxide. CLC technology circulates iron oxide to have it react with fuel, water, and air, through which electricity, hydrogen, and CO₂ are produced simultaneously. Biomass and organic waste liquid can be used as fuels. This technology is expected to produce and supply green electricity, hydrogen and biomass-derived CO₂ when carbon-neutral biomass is used as fuel, and electricity, hydrogen, and CO₂ through the recycling of waste materials when organic liquid waste is used as fuel.

Meanwhile, there has been no implementation example of CLC technology aimed at producing hydrogen using biomass or organic waste liquid as fuel. For commercialization, it is necessary to solve technical issues such as elemental technology development toward the establishment of system design technology and process verification. The Daigas Group plans to use this technology to generate electricity, hydrogen, and CO₂ using biomass and organic waste liquid as fuel and to supply them to customers who want to contribute to carbon neutrality and the circular economy.

1 CLC: Chemical Looping Combustion

2 NEDO- subsidized project: "Development of Technology for Carbon Recycling and Next-Generation Thermal Power Generation/ Development of Fundamental Technologies for Next-generation Thermal Power/ Development of technology for a poly-generation system with CO₂ separation and capture capabilities/ Development of technology for chemical looping combustion poly-generation"

Our vision for the practical application of CLC technology



Radiative cooling material SPACECOOL®, a new product by SPACECOOL Inc.

—Also contributing to realizing a carbon neutral society with world-class cooling performance—

SPACECOOL® is a radiative cooling material with zero-energy cooling capability developed by Osaka Gas, with applications continuing to be developed by SPACECOOL Inc. By releasing heat into space under direct sunlight, it lowers the temperature¹ below the outside temperature without using energy. It has the potential of contributing to carbon-neutral solutions for society as a whole.

A demonstration test confirmed that the temperature inside the structure was up to about 10°C² lower than the outside air temperature under direct sunlight, realizing world-class³ cooling performance.

The material is available in film, magnet sheet, tarpaulins, etc., and is expected to be deployed in products for implementing measures against global warming, achieving energy conservation and ensuring cooling comfort. It was adopted in the Gas Pavilion exhibited by The Japan Gas Association at the Osaka/Kansai Expo (©Expo2025), reducing the air conditioning burden in the Gas Pavilion and contributing to lower CO₂ emissions.



Radiative cooling material (film)

In the future, we would like to promote the spread of this material both domestically and internationally and contribute to the realization of a carbon neutral society.

1 This has been achieved by using Osaka Gas's proprietary optical control technology to develop a material design that reduces the solar heat input and increases heat dissipation through thermal radiation.

2 The temperature was measured at Osaka Gas Energy Technology Laboratories (currently, the Advanced Technology Institute) in Konohana-Ward, Osaka City.

3 The survey was conducted by the Company, based on published papers.

Development of technology for predicting renewable energy power generation

With an eye on the increasing number of renewable energy power plants such as solar power plants to realize a carbon neutral society, the Daigas Group is working to develop technology to predict renewable energy power generation amounts and improve the accuracy of the prediction.

For example, previously, electricity generated in solar power plants was traded at a fixed price, known as FIT. In recent years, a growing number of solar power plants are using schemes other than FIT, as a new purchase method, FIP, has been implemented. Therefore, power producers are increasingly required to predict power generation with a high level of accuracy, given the risk of needing to pay imbalance costs*. The Group has developed technologies for predicting weather at a level comparable to that of weather companies, based on our long-accumulated knowledge of fluid analysis, and has been implementing highly accurate solar power generation predictions utilizing this technology. In the future, solar power generation will be joined by wind power generation, and we will work to further improve the accuracy of our renewable energy power generation forecasts.

* Imbalance costs: Monetary penalties incurred when there is a discrepancy between the planned and actual amount of electricity generated when operating a power plant.

Initiatives to develop the world's first “ultra-long life” storage batteries that last five times longer than current storage batteries

The storage battery market is expected to continue to expand worldwide for multiple applications, such as automotive and stationary use. In Japan as well, storage batteries are positioned as one of the most crucial technologies to achieve the electrification of automobiles and the utilization of renewable energy as the main power source, with a view to achieving the greenhouse gas emissions reduction target for FY2031 and carbon neutrality by 2050.

KRI, Inc. (“KRI”), one of the Group companies, is a comprehensive private contract research company with both advanced research and development capabilities and consulting functions. The company supports customer businesses by engaging in contract research and analysis evaluation, primarily focusing on energy, environmental technology, and material technology. It also pursues the excavation of new technological seeds and the creation of new value through its own research. In particular, storage batteries are emphasized as one of its key fields of focus, and the company is actively expanding its contract research and development business related to such products and strengthening value chains. As one part of these efforts, in December 2025 we made ENAX, Inc., a company with strengths in storage battery prototyping and battery pack and system development, into a subsidiary. As a result, we enhanced our large-scale prototyping technologies and battery pack and system development technologies. With KRI's strengths in research and development, evaluation technologies, and battery operation and management support technologies including degradation diagnosis, combined with the small-scale prototyping technologies of SEI CORPORATION, which was made into a subsidiary in February 2024, we have created a one-stop structure within the Group for contract research and development services for storage batteries.

Osaka Gas is also working on the development of “ultra-long life” storage batteries, as it aims to expand its business into EV-related fields. We have been discussing and developing “ultra-long life” storage batteries from two aspects of “materials, electrodes, and batteries” and “diagnosis and operation” with manufacturers who agree on KRI's “ultra-long life concept,” with the aim of achieving “ultra-long life,” which is the direction of the storage batteries needed for a 2030 society.

Having had the prospect of completing the basic technology for “ultra-long life” lithium ion batteries (LIB)¹ that last five times longer than current storage batteries and reaching its goal, KRI started supplying 10 Ah (around 400 Wh/L)² samples for user evaluation in FY2026. The three KRI Group companies are working together to accelerate the process from development to implementation. Ultimately, they aim to increase the life of conventional 30 kWh batteries installed in electric vehicles (e.g. 160,000 km guaranteed) by more than five times.

1 A type of storage battery that uses an oxide containing lithium for the positive electrode and carbon material for the negative electrode. This battery has high performance and can be miniaturized. It is used in a variety of applications, including batteries for mobile devices and electric vehicles.

2 Approximately the capacity installed in an electric motorcycle.

Development of a new technology for the diagnosis of a rapid loss of capacity in EV storage batteries (secondary degradation)

Osaka Gas and KRI, Inc. have developed a new technology to diagnose a rapid loss of capacity (“secondary degradation”) in the lithium ion storage batteries installed in electric vehicles (“EVs”) and other products. Ahead of its goal to achieve carbon neutrality by 2050, Japan is working to promote and expand use of EVs and other electrified vehicles. While this is expected to lead to increased activity in the used EV market, it is difficult to assess the extent of degradation in used EV storage batteries due to insufficient information on vehicles’ use history. As a result, concerns surrounding declining storage battery performance and capacity are hindering the appropriate valuation of used EVs and causing hesitation to purchase them. This is the industry-first technology that can diagnose signs of secondary degradation on the spot from limited data

obtained from short-time charging, even for EV storage batteries with insufficient use history information.

Going forward, we will advance the technology's practical application and roll out services to support appropriate valuations of used EVs, with a view to contributing to the expansion of the used EV market.

Development of degradation diagnosis and lifespan prediction technologies for battery energy storage system

Osaka Gas and KRI, Inc. have used KRI's technologies to develop deterioration diagnosis and forecast technology for battery energy storage system for grid storage batteries³ and other equipment.

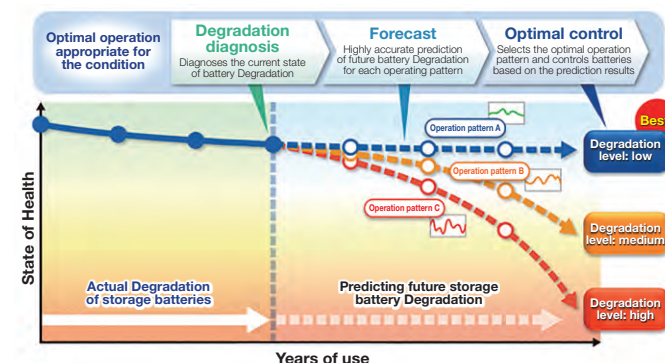
In recent years, renewable energy has come to be used more widely, increasing the need for storage batteries that help mitigate the variability in renewable energy output. The Company decided to enter the grid storage battery business in February 2023, and in FY2026, it began commercial operations at the Senri Power Storage Plant and the Takeo Power Storage Plant, the Company's first grid-use storage plants in Japan.

Meanwhile, by their nature, storage batteries can undergo sudden degradation and become less safe if their charging and recharging is not controlled based on their State of Health. For large-scale battery energy storage system, in particular, there has been a need for the development of operation technologies that enable safe, long-term use.

This technology not only diagnoses the State of Health of storage batteries from monitoring data such as in-service voltage, current, and temperature, but also predicts future deterioration for each operating pattern. Furthermore, combining theoretical models based on physical phenomena with data makes it possible to select optimal operation methods from a wider range of operation patterns, compared to conventional prediction methods that use only data. This has the potential to slow down degradation and allow storage batteries to be used for long periods of time.

Going forward, we will gradually expand our application of this technology to our own storage battery business, and proceed with detailed design work aimed at their practical application. At the same time, we will use this technology and the power trading know-how we have developed to create a system for determining optimal operation of storage batteries to achieve longer storage battery lifespans and greater safety, as well as the economic efficiency. Furthermore, throughout the storage battery business, we will leverage the comprehensive strengths of the Daigas Group and aim to achieve a storage battery operation capacity of 1 million kW by FY2031 through both grid storage batteries and storage batteries installed with renewable energy facilities (including projects for which decisions have already been made).

3 Large-scale storage batteries directly connected to the power grid



Initiatives at NEXT 21, Osaka Gas's experimental residential complex

NEXT 21, Osaka Gas's experimental residential complex, was awarded in FY2025, the "Minister of Land, Infrastructure, Transport and Tourism Award in the 44th Green City Award," "the Organization for Landscape and Urban Green Infrastructure President's Award in the 23rd Innovative Green Tech Awards," and "the Good Design Award 2024."

As a verification model for environmentally symbiotic housing, NEXT 21 is continuing its efforts aimed at developing urban housing in which people live in harmony with nature. These awards are a recognition of the results this housing experiment has produced over the past 30 years.

Further, at the 504 housing units in which renovations were completed in February 2026, to promote the achievement of a circular economy, we recovered materials from existing NEXT 21 housing units, as well as locally sourced waste materials, and used them for the renovation work.

Through these renovations, we examined careful dismantling methods and the required workloads for the recovery of materials, and assessed the environmental impact reduction effects from the recovery and use of the materials.

As a result of these initiatives, we helped reduce CO₂ emissions by around 8 tons compared to when procuring conventional new building materials.

■ Details of major initiatives

● Energy experiments

Experiments have been carried out regarding efficient energy systems, healthy and comfortable living spaces, disaster-ready housing, and more.

● Environmental symbiosis activities

Through planting management and the growth of local vegetables in rooftop gardens by residents, the residential complex is continuing its environmental protection activities.

● Community formation

NEXT 21 is engaging in community-rooted activities such as building illumination, music events, disaster drills, cooking workshops, and more.