Innovation/ Technological Development

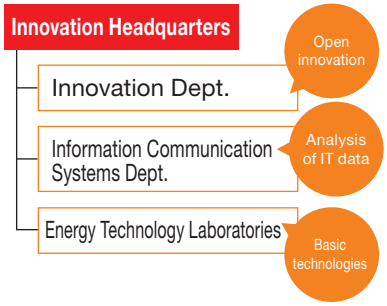
To address the challenge of creating new value beyond conventional frameworks, the Daigas Group will further commit to innovation, including open innovation and digital technologies, with the aim of ensuring optimized solutions for customers and fostering next-generation innovation.

Promotion of Innovation

Establish the Innovation Headquarters

- Establish the Innovation Headquarters with the aim of creating new values through business reforms
- Set up the Innovation Promotion Department and integrally promote companywide innovation activities

Challenge of creating new value



Advance Open Innovation

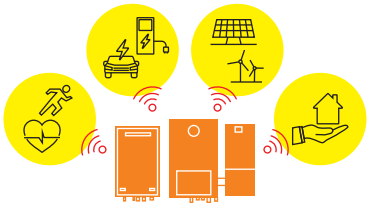
- Collaborate with diverse corporate partners not only in the field of technology but also in the service field
- Strengthen Silicon Valley-based activities
- Collaborate with start-up companies at home and abroad

Co-create New Businesses

Promote digitization Exploration of technology

- More convenient lifestyle services and business solutions utilizing IoT and AI
- New electric power business utilizing distributed energy sources and ICT
- High-level infrastructure operations with digitalization
- Innovative technology development such as fuel cells

Equipment and energy bringing lifestyle reforms



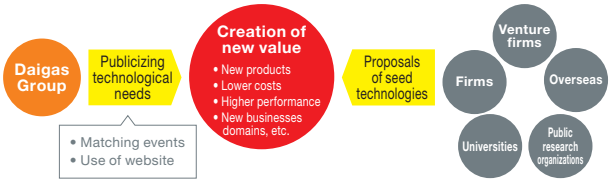
Business reforms in preparation for a paradigm change

Products and services that go beyond customer expectations

Achieving drastic business reforms

Open Innovation Developments

By fusing proprietary and outside technologies, Daigas Group is developing open innovation, aiming to speed up the pace of technological development while improving functionality and cutting costs. In fiscal 2009, we began publicizing technological needs. We have sponsored technology exhibitions, formed alliances with other companies, attended technology-matching conventions and developed alliances with universities.



Promoting Technological Exploration Using Programs Created by Plug and Play, LLC (Silicon Valley in the United States)

To step up open innovation activities, in July 2017 we began participating in energy sustainability programs organized by Plug and Play, an influential accelerator business in Silicon Valley in the United States. We are also exploring cutting-edge technologies and services with the aim of accelerating technological developments and creating new services.

Investment in US Venture Fund

In April 2018, we invested in a venture investment fund operated by WiL LLC, a venture capital company headquartered in Silicon Valley. Through this investment, we aim to invest in and form alliances with start-up companies mainly in Japan and the United States, and so accelerate the pace of innovation-oriented activities, including creation of convenient daily services and business solutions using the IoT, AI and other digital technologies, as well as ensuring high infrastructure operational standards.

Launch of Pilot Project in Biogas Refining and Supplies of Automotive Natural Gas Fuel in Thailand - Making Possible World-class Levels of Efficiency in Methane Recovery -

In collaboration with Agriculture of Basin Company Limited (ABC) of Thailand, we have launched a pilot project supplying natural gas to vehicles in Thailand. It features production of highly pure methane gas by removing carbon dioxide and other impurities from biogas generated from agricultural waste. In this pilot project*1, ABC applies methane fermentation to organic materials in industrial wastewater supplied from ABC-owned palm oil manufacturing facilities. The biogas generated is refined by Osaka Gas into methane gas. ABC uses*2 the refined methane gas as fuel in its company-owned natural gas vehicles. The pilot project is scheduled to run for approximately one year, during which time Osaka Gas will test operate a 250 Nm^3/h-scale biogas refining system with a view to commercial application. It will also confirm the long-term stability of operations, verify methods to minimize the cost of producing methane gas, and determine the effectiveness of the gas produced in automotive fuel applications. Based on these pilot test results, ABC will take further measures to make efficient use of biogases produced by its plants as fuel for natural gas vehicles.

Since 2012, Osaka Gas has been developing biogas-refining technologies, so as to make efficient use of excess biogases to promote energy-saving and protection of the global environment. By using an independently developed hybrid biogas-refining system (see image at right) that combines pressure swing adsorption (PSA) that selectively adsorbs and eliminates carbon dioxide with carbon dioxide separation membrane technologies, we were able to produce high-purity methane gas with a methane recovery rate of at least 99% *3, one of the highest levels in the world.

In Thailand, the Company is already developing energy-service businesses and co-generation systems on-site at its business bases, principally at Osaka Gas (Thailand) Co., Ltd. Looking ahead, through this pilot project, we plan to commercialize biogas refinery technologies before the end of 2018, and to further expand energy businesses in Southeast Asia, so as to contribute to reduction of greenhouse gas emission volumes through the active use of biomass resources.

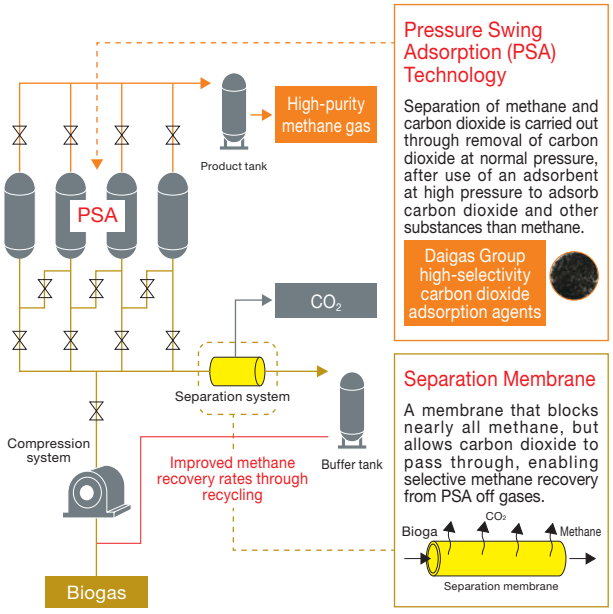
*1 Osaka Gas (Thailand) Co., Ltd., a local subsidiary of Osaka Gas, is in charge of construction of the pilot testing system. Osaka Gas (Thailand) Co., Ltd. is also scheduled to provide needed cooperation during the pilot testing period.

*2 To be implemented after confirmation of compliance with Thailand's quality standards for automotive fuel.

*3 Proportion of methane by volume in high-purity methane gas product, compared with volume of methane in raw-material biogas.

Osaka Gas' Independently Developed Hybrid Biogas-refining System

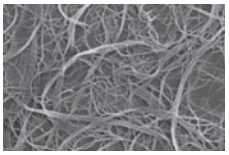
A system that combines PSA removal of carbon dioxide from biogases (using an adsorbent that selectively adsorbs carbon dioxide) with a separation membrane system that recovers methane gas by eliminating carbon dioxide from off gases discharged from PSA. By recycling off gases while refining high-purity methane gas from PSA, we have achieved a methane recovery rate of at least 99%, one of the highest levels in the world.



Development of Fluorene Cellulose® as a Fiber for Strengthening Resin

Osaka Gas developed fluorene cellulose, a cellulose fiber with uniform dispersion, by reacting the cellulose fiber surface with a fluorene derivative. Fluorene cellulose does not mix easily with water but mixes easily with resin.

Fluorene cellulose is a resin fiber material with low environmental impact and has strong potential for use in home appliances and as a structural material in automobiles.


Electron microscope image of fluorene cellulose

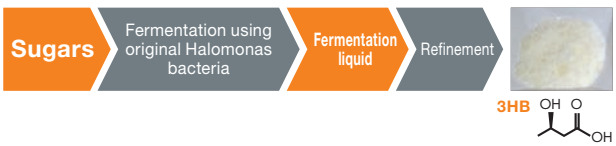
Successful Production of Ketone Bodies, Known for Their Use in Diets

Osaka Gas has developed a method for manufacturing ketone bodies, (R)-3-hydroxybutyric acid (3HB), using bioprocess (fermentation) technology cultivated over many years in collaboration with the National Institute of Advanced Industrial Science and Technology.

Recent years have seen rising interest in ketone bodies for their effectiveness in dieting and improving athletic performance. Osaka Gas has succeeded for the first time in effectively generating and isolating 3HB using bio-processes.

We anticipate new applications for their use in the future in health foods, supplements, and cosmetics.

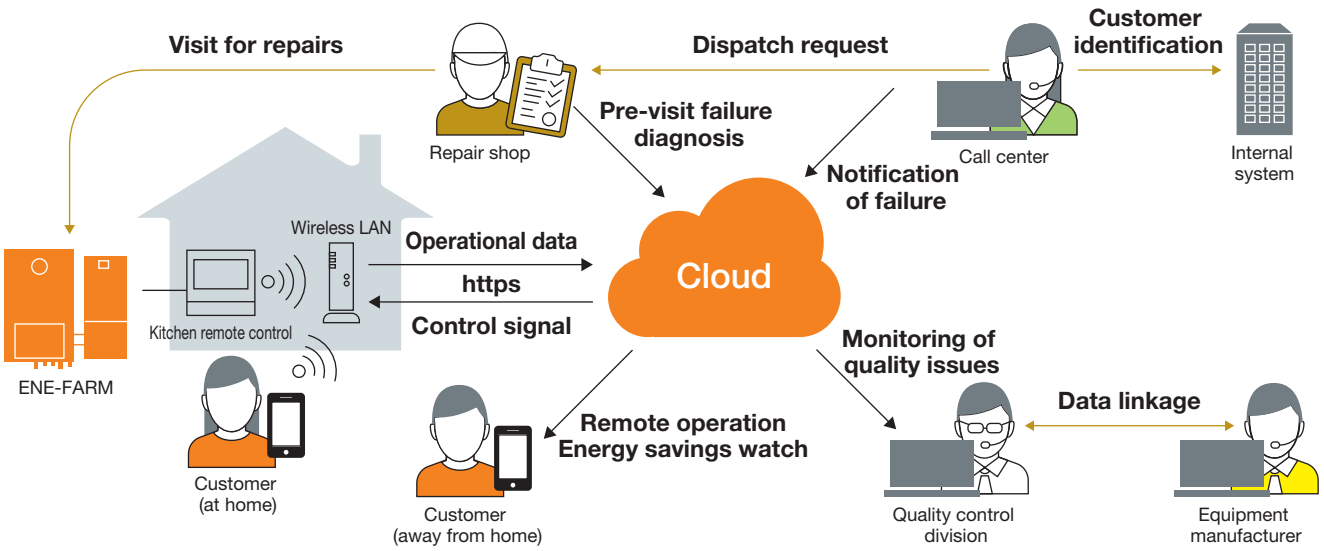
Fermentative production of (R)-3-hydroxybutyric acid (3HB), ethyl (R)-3-hydroxybutyrate (3HB ethyl)



The Creation of New Services Utilizing IoT Functionality Built into the ENE-FARM Residential Fuel Cell System

As of April 2016, residential fuel cell systems, such as ENE-FARM type S, feature an always-on connection to the Internet and uses the cloud for remote monitoring.
This capability allows detection of any abnormality in the system's power generation. In that event, Osaka Gas will then call to notify the customer of the situation and provide an emergency repair service visit when necessary. This power generation monitoring service gives customers peace of mind. The on-site repair time can also be shortened by analyzing the data sent to the cloud in the event of a failure, thereby streamlining maintenance work. Customers also get improved convenience through such remote control features as filling the bath with hot water or controlling the floor heating using their smartphones.
In October 2017, the Company took measures to expand services using the IoT, including making the "ECO-JOZU" energy-saving water heater IoT-compatible, and, in April 2018, introducing gas equipment operation using smart speakers.

IoT System for ENE-FARM



Interview with the Developers of ENE-FARM IoT System

Q1.

What induced you to launch the remote power generation monitoring service with ENE-FARM in April 2016?

In conventional maintenance, we would identify causes of error by connecting ENE-FARM with maintenance computers in situ, and extracting and analyzing sensor values and operating data from inside fuel cells. For this reason, operations in situ required a lot of time and manpower, and this was inconvenient for the customer too.
However, with the spread of smartphones, which are increasingly being linked to home electronics, we conceived the idea of connecting wirelessly using the Internet. The aim was to generate value from new gas equipment and raise the standards of response quality when repair and maintenance work are needed.

Q2.

What particular problems did you have in developing this service?

Around 2014, people were wondering what the IoT is. It was very difficult to make business proposals because there was no precedent for maintenance systems for gas equipment compatible with the IoT. That meant development of wireless LAN compatible gas equipment, of servers, of smartphone applications, as well as coordination among affected departments within the Company and other issues, all had to be undertaken through a continuous process of trial and error. It was tough trying to realize and propose things that did not yet exist outside the lab.

Q3.

What were the breakthroughs that led to success in commercial applications?

First of all, it was the development of wireless LAN communications modules dedicated for gas equipment. When sending data, it was necessary to hook up to the Internet using a wireless module with encryption functions to prevent eavesdropping and interception built into the gas equipment. However, at that time there was not a single company in Japan developing this kind of module. We succeeded in developing it after asking a semiconductor maker that we had long had a relationship with if they were interested in working with us to develop a communications module that can hook ENE-FARM equipment to the Internet. Later, some months after we had launched the development, other manufacturers in Japan launched similar programs. Osaka Gas was able to show the world it was a pioneer with an "enterprising spirit," which is one of our guiding principles.
Second was the question of the server. In the world of IoT-compatible equipment, the number of connections to servers and the volumes of data increase in proportion with the sale of a product. While it is essential to introduce mechanisms that readily enable extension, it is also necessary to have safe connections for in-house networks to external cloud servers. We had repeated discussions with OGIS Research Institute Co., Ltd., who are responsible for internal computer systems at Osaka Gas, regarding what kind of connection could be safely established. In the end, we opted for Amazon Web Services (AWS) as cloud server, in light of their security performance, and their global track record and future extension potential.

Q4.

How did you deal with front-line response regarding operations and services?

We got used to hearing the maintenance technician saying, "looking at the server data…" and things like that. We had a sure feeling that the IoT system was being used in a natural way within operations. It brought it home to us that the quality of response when repairs or maintenance are needed had further improved.
Some studies show that the Internet connection rate for IoT-compatible consumer electronics is around 10-20%. However, the Osaka Gas ENE-FARM connection rate is over 8 0%. We feel that one of our strengths is that we are able to convince customers of the merits of online connection during installation and inspection of gas equipment, showing how we value our relations with the customer.

Development team members, from left, Takuya Aoki, Masahiko Yagi (Manager), Masaki Takamizo, Tomoyuki Suzuki (Chief)

Q5.

What are the prospects for the business model of using the IoT?

First, we began marketing the IoT-compatible "ECO-JOZU" water heating system in October 2017, and in April 2018, we released a new service that enables voice-activated operation of a system for running a bath and controlling the floor heating via a smart speaker, and for notifying hot water usage history to remote family members. Looking ahead, we aim to create innovative new services and develop technology using the latest advances, such as interlinked servers and services and technologies using AI and the IoT.

Intellectual Property Strategy

The Daigas Gas Group positions intellectual property rights as an important management resource. At the same time, the Group takes proactive steps to secure and utilize intellectual property rights in concert with its business and technology development strategies.

Strategically Acquiring Intellectual Property Rights

We acquire patents on a steady basis by focusing on invention and discovery that is closely related to specific development sites, incorporating judgments on patentability from external authorities after filing. Through patent analysis and mapping we are able to build a thorough and complete network of patents, which is an important motif. In fiscal 2017, 366 patents were filed, totaling 3,343 held by the Daigas Group, including patents for upstream gas production, distribution and supply, and downstream gas appliances and material technologies. The intellectual property rights that we possess are used for business and are actively licensed to other companies.
In addition, we are careful to acquire trademarks for services and products we offer and protect company brands. As of March 31, 2018, the Daigas Group holds 1,084 trademarks.

Strengthening Intellectual Property throughout the Group

We employ a variety of educational and instructional tools to further improve Daigas Group employees' understanding of intellectual property rights. For example, instructors from both inside and outside the Company conduct training sessions based on both goals and employee career level. We also publish an email magazine and distribute the latest news articles on relevant topics.

The Daigas Group's Patent Portfolio by Business Type (number)