Policy proposal by Urban Heat Energy Committee of Advisory Committee for Natural Resources and Energy

Desirable Gas Utility Business in Low-Carbon Society

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Urban Heat Energy Committee of Advisory Committee for Natural Resources and Energy

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Chapter 1. Introduction --Recent situations of world energy market and policy

In recent years, the prices of fossil fuels once recorded high levels against the background of energy demand growth in countries all over the world, mainly in Asia, an upsurge of resource nationalism, an increase in geopolitical risks and others, but the prices declined in and after July 2008 in response to the impact of financial instability. The situation has still remained unstable. In such circumstances, Japan, whose dependency on fossil fuels still exceeds 80% and whose supply of fossil fuels heavily depends on overseas sources, now has concerns about weakening of its energy supply structure.

To cope with such situation, the direction of efforts for sophistication of Japan's energy supply structure was presented in February 2009 at a meeting of Coordination Subcommittee of Advisory Committee for Natural Resources and Energy. In response, two proposed legislations related to energy were presented to the Diet in March 2009, and the proposed legislations were passed into laws on July 1, 2009.

[Fig. 1] Promotion of Japan's Energy and Environmental Policies

[Fig. 2] Outline of the Proposed Legislation for Amendment of Alternative Energy Act and the Proposed Legislation for Upgrading the Energy Supply Structure

On the other hand, the "Action Plan for Achieving a Low-carbon Society" was developed in July 2008. Japan has declared a long-term target toward 2050 to reduce greenhouse gas emissions by 60-80% from the present level. Moreover, on June 10, 2009, Prime Minister Taro Aso announced a mid-term target to reduce Japan's greenhouse gas emissions in 2020 by 15% from the 2005 level. From now on, full-scale international negotiations are expected to be conducted in preparation for COP15 that is scheduled to be held in Copenhagen in late 2009.

[Fig. 3] Action Plan for Achieving a Low-carbon Society (July 2008)

As described above, the situation surrounding Japan's energy and environment policies is rapidly changing. From the viewpoint of promoting measures for ensuring of energy security and against global warming issues in such circumstances, it is necessary to present a mid-to-long term scenario concerning how the gas utility business(Note) should be as a major energy supply industry in low-carbon society. At the same time, it is required to present an appropriate policy package to allow the steady

Note: In the report, the "gas utility business" means the business that supplies natural gas mainly through pipelines. The core of Japan's "gas utility business" is the "general gas utility business" based on the Gas Utility Industry Act.

development of the gas utility business to contribute to realize the low-carbon society in accordance with the mid-to-long term scenario.

To cope with such demand, the Urban Heat Energy Committee proposes a policy concerning how the gas utility business should be in low-carbon society.

It is decided to work out the policy proposal in full consideration of the deliberations made by the committee and based on the discussions made by the “study group on the future of gas utility business in low-carbon society,” which was formed in April 2009 as a private study group of Director-General, the Electricity and Gas Industry Department of the Agency for Natural Resources and Energy.

Chapter 2. Present state of natural gas and gas utility business

1. Present state of natural gas

(1) Properties of natural gas

Natural gas is a clean energy that causes the least environmental load among fossil fuels. CO_2 emissions of natural gas are 40% less than that of coal and 25% less than that of oil. Moreover, in terms of the life cycle from production to transportation and consumption, natural gas causes the least CO_2 emissions among fossil fuels.

As the main ingredient of natural gas is methane (CH_4), it can be used as the material to produce hydrogen (H_2) and used for the technologies such as fuel cells that contribute to energy conservation and CO_2 emissions reduction.

[Fig. 4] Environmental Characteristics of Natural Gas

(2) Trends of international natural gas market

1) Potential of natural gas

Natural gas has an abundance of distributed supply sources (reserves), and new LNG (liquefied natural gas) projects are planned in many countries. It is a kind of energy whose supply potential is high. In addition, the development of new production technologies that are suitable for development of small-to-medium gas fields is also underway such as offshore LNG production systems.

Because of its environmental friendliness and utility, the world's demand for natural gas is expected to drastically rise mainly in the Asian and Middle East regions in the future, according to an outlook of the International Energy Agency (IEA) as well.

[Fig. 5] Proved Reserves of Natural Gas in the World

[Fig. 6] Outlook for Natural Gas Demand in the World

2) Development of un-conventional natural gas resources

In recent years, moreover, the approaches to utilize un-conventional natural gas resources have been taken in many countries such as production expansion and production development of shale gas and CBM (coal bed methane), which are planned in the U.S., Australia and others. The supply of natural gas is expected to increase in the future.

[Fig. 7] Production Expansion of Un-conventional Natural Gas Resources in the U.S.

[Fig. 8] Outline of CBM Projects in Australia

3) Changes in natural gas markets

As for the forms of natural gas transactions, LNG exports from Southeast Asia and the African Continent are growing, in addition to the pipeline transportation from the U.S. and the European Continent. The amount of LNG transactions in the world has risen twice in the past ten years. As for LNG, in addition to traditional long-term contract deals, the ratio of nontraditional spot deals has increased up to about 20%. With such spot deals, the structures of natural gas markets in the world have become more flexible.

[Fig. 9] Changes in the Amount of LNG Exported in the World

On the other hand, the uncertainty about the supply and demand balance in the world's natural gas market is now increased by the competition for procurement among the countries in need of natural gas against the background of increase in demand mainly in the Asia and Middle East regions, and the delay in planning of new LNG projects in Indonesia and Australia.

(3) Present state of natural gas procurement and possibility of domestic resources (methane hydrate, etc.)

About 96% of natural gas supply to Japan depends on LNG procurement from overseas. The diversification of supply sources is promoted to ensure stable supply by combining short-term contracts and spot procurement together, in addition to long-term contracts with nine countries(Note).

In the future, moreover, possible use of methane hydrate whose occurrence is confirmed in the sea areas around Japan as well as the occurrence of conventional natural gas fields are also expected as domestic resources. Based on the "Basic Plan on Ocean Policy" that was decided by the Cabinet in March 2008 and the "Ocean Energy and Mineral Resource Development Plan" that was developed by the Ministry of Economy, Trade and Industry in March 2009 and approved by the meeting of the Headquarters for Ocean Policy, technology development and offshore exploration that uses a geophysical exploration ship and others are now actively in progress.

[Fig. 10] List of Japan's Long-term LNG Contracts

[Fig. 11] Changes in the Countries from which Japan Imports LNG

[Fig. 12] Present State of Development of Methane Hydrate

Note: For reference, in the case of long-term contacts, difficulties in ensuring supply sources may happen in these days of drastic decrease in domestic demand.

(4) Present state of natural gas utilization in European countries and the U.S.

Natural gas has been produced and developed since the 1930s in the U.S. and since the 1960s in Europe, and pipeline networks have been constructed proportionally. Moreover, the ratios of natural gas to primary energy supply in European countries and the U.S. are higher than that in Japan (The ratios of natural gas to primary energy supply: 15% in Japan, 22% in the U.S., 35% in the U.K., 23% in Germany, 38% in Italy, 21% in Spain and 54% in Russia).

[Fig. 13] Percentage of Natural Gas in Primary Energy Supply by Countries

2. Present state of gas utility business

(1) Evolution of gas utility business to date

Gas utility business in Japan has been developed by making the shift of city gas material to natural gas since the commencement of LNG import from Alaska in 1969. Particularly in and after 1995 when the liberalization of gas utility business started, the amount of city gas sold as a whole increased by about 1.8 times and that of city gas sold for industrial use increased by about three times partly because of the rise of environmental awareness.

[Fig. 14] Changes in the Amount of Gas Sold in Japan (General Gas Utility Business)

1) Shift of city gas material to natural gas (higher calorie: IGF 21 Plan)

There are various types of gases depending on their calories and burning velocities. Japan has made the shift of the gas for the gas utility business to gases of higher calories, mainly natural gas, since the commencement of LNG import from Alaska (higher calorie: IGF 21 Plan). The increase in the calories of the gas supplied has led to an increase in the benefits of consumers such as increased choices of consumer equipment and improvement of safety. Moreover, gas supply infrastructure has been reinforced through long-term cost reduction by increasing the pipeline capacity of general gas utility business. At the same time, the advantage of lower CO_2 emissions has also been realized.

As of June 2009, 198 general gas utilities have completed the shift to gases of higher calories. Other general gas utilities are also making efforts to complete the shift to gases of higher calories in late 2010.

[Fig. 15] IGF 21 Plan (Integrated Gas Family 21)

2) Expansion of demand for industrial use (shift of fuel to natural gas)

In the past, the demand for city gas was mainly for residential use. Since the 1970s when the supply of city gas produced from natural gas as its material started, the shift to natural gas (fuel conversion) has been promoted in the industrial heat market from the viewpoints of energy security and environmental friendliness, and the industrial demand for city gas has rapidly expanded.

3) Establishment of gas supply infrastructures

As for gas supply infrastructures, the construction and establishment of high-pressure pipelines and LNG terminals have been well underway. On the other hand, the establishment of pipelines for connection between major cities and between LNG terminals has not necessarily been promoted in a sufficient manner. Promotion of establishment of infrastructures still remains as an important challenge.

[Fig. 16] Present State of Japan's Pipelines, LNG Terminals, etc.

[Fig. 17] Networks of Trunk Pipelines for Natural Gas in the U.S.

[Fig. 18] Networks of Trunk Pipelines for Natural Gas in Europe

(2) Approaches of gas suppliers to energy conservation and CO_2 emissions reduction

1) Development and introduction of high-efficiency equipment, etc.

Japanese gas suppliers have promoted advanced and effective use of natural gas through promotion of development and introduction of highly efficient equipment including latent heat recovery water heaters, gas air-conditioners, etc., contribution of highly efficient gas air-conditioners to electric power load leveling, and diversification of fuels through the introduction of natural-gas-powered vehicles. Particularly, fuel cells have high effects of energy conservation and CO_2 emissions reduction as their overall energy efficiency will reach about 80% if electricity and heat can be simultaneously utilized. Therefore, research and development activities of fuel cells have been intensively conducted through demonstration tests under the projects of New Energy and Industrial Technology Development Organization (NEDO).

[Fig. 19] Dissemination of High-efficiency Gas Water Heaters (Eco-Jozu)

[Fig. 20] Fuel Cell and Hydrogen-related Projects of New Energy and Industrial Technology Development Organization (NEDO)

2) Promotion of cogeneration (combined heat and power)

In addition to the shift of industrial fuels to natural gas, Japanese gas suppliers have facilitated energy conservation and CO_2 emissions reduction mainly in the commercial and industrial sectors through technology development of gas engines, gas turbines, fuel cells, etc. as well as promotion of development and dissemination of cogeneration systems to effectively utilize waste heat, etc.

[Fig. 21] Cogeneration Systems

(3) Institutional reform of gas utility business (expanded liberalization)

Japan’s gas utility business has carried out reforms by expanding the liberalization three times in steps since the liberalization of retail gas market started in 1995. Since the commencement of liberalization, in addition to the growth of the amount of gas sold mainly for industrial use, gas rates have been lowered by reduction in gas supply cost through the competition in the liberalized sectors, and positive effects of market liberalization have been realized to a certain degree as the number of new entrants and their shares in the amount of gas supply have increased.

In April 2008, the results of evaluation and verification of the reform were put together at the Urban Heat Energy Committee of Advisory Committee for Natural Resources and Energy. At present, the committee is making discussions about the challenges found by the evaluation and verification as well as a desirable gas utility business system in the future.

[Fig. 22] Institutional reforms of Japan’s Gas Utility Business

[Fig. 23] Evaluation of Institutional Reforms Achieved to Date

[Fig. 24] Position of Gas Utility Business under the Present Policy

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As for the positions of measures related to natural gas in various plans at present, see the references below:

[Fig. 25] Measures Related to Natural Gas in the Energy Basic Plan ①-④

[Fig. 26] Measures Related to Natural Gas in the New National Energy Strategy ①-③

[Fig. 27] Measures Related to Natural Gas in the Energy Technology Strategy (Technology Strategy Map 2007)

[Fig. 28] Measures Related to Natural Gas in the Kyoto Protocol Target Achievement Plan ①-③

[Fig. 29] Measures Related to Natural Gas in the Action Plan for Achieving a Low-carbon Society

Chapter 3. Med-to-long term scenario for gas utility business

1. Basic direction toward low-carbon society (mid-to-long term scenario toward 2050)

As mentioned earlier, natural gas is a useful energy having advantages in terms of environmental friendliness and supply stability. In the future, it is necessary for Japan's gas utility business to make a basic direction (med-to-long term scenario toward 2050) with two pillars, stable supply of energy and measures against global warming.

From the perspective of stable supply of energy, it is important to undertake diversification of energy not to excessively depend only on one supply source and one supply method in consideration of the realities. For this purpose, it is necessary to promote the best mix of natural energy and other energy sources in the whole system of energy supply. Then, the gas utility business should try to ensure stable supply while encouraging advanced use of natural gas as an important energy that has various advantages mentioned in the previous chapter. From the perspective of response to global warming, it is necessary to destine natural gas for playing a role in smooth shift to low-carbon society in the med-to-long term. In order for the gas utility business to put the above-mentioned points into action, it is essential to establish them in more steps, while effectively utilizing as much as possible the basic infrastructures that have been established to date such as natural gas pipelines and others.

Keeping the matters mentioned above in mind, it is required for Japan's gas utility business to push ahead with the following points through further advanced use of natural gas in order to realize low-carbon society in the future. Through such evolution of the business, it is desirable for the gas utility business to evolve into a new comprehensive energy service business. At the same time, it is also important to consider allowing various users to have a variety of choices.

① Promotion of distributed energy system

② Contribution to creation of hydrogen energy society

③ Advanced use of natural gas in the industrial sector (energy conservation and CO_2 emissions reduction)

④ Introduction of renewable energy, etc.

2. Promotion of distributed energy system
-- Achievement of energy conservation and CO_2 emissions reduction through the best mix of electricity and heat in the demand and supply sides --

(1) Creation of distributed energy system with cogeneration equipment as the core

As for the demand side of energy, electricity and heat are used in various forms in daily life and business activities. For example, more than half of the energy required by ordinary households and business facilities are used for satisfying heat demand such as hot water supply, air-conditioning, kitchens, etc.

As for the supply side of energy, on the other hand, electricity and heat are also supplied in various forms. After transportation through pipeline networks, gases can be used to supply electricity and heat at the places where electricity and heat are required. Therefore, if gases are transported to generate electricity at the places where electricity is required, and at the same time if waste heat from power generation can be successfully used at such places, overall energy efficiency can be improved.

From this point of view, one of the important challenges is to create a distributed energy system to facilitate energy conservation and CO_2 emissions reduction through the electricity and heat combination (best mix) that integrates the demand and supply of energy together with cogeneration equipment as the core[Note 1].

At a meeting of the Mid-term Target Committee in March 2009, the emissions reduction in the commercial sector was regarded as a great challenge to be addressed to reduce Japan's greenhouse gas emissions in 2020 by 15% from the 2005 level. As one of the measures for emissions reduction, the introduction of highly efficient distributed energy system is expected to be promoted in the commercial sector[Note 2].

[Fig. 30] Trends of Energy Consumption for Residential Use and Business Use

Note 1: In the Kyoto Protocol Target Achievement Plan (March 2008), the "promotion of energy use on a district-wide basis" is considered as an important measure. Under the plan, the introduction and dissemination of highly environment-friendly district heating and cooling will be promoted in consideration of characteristics of each district, promotion entities, feasibility, etc. because efficient energy use on a district-wide basis such as efficient energy supply to multiple facilities and buildings, interchange of energy between facilities and buildings, and utilization of untapped energy is expected to yield a great effect of CO_2 emissions reduction in districts.

Note 2: According to the results of analyses by the Institute of Energy Economics, Japan, at a meeting of the Mid-term Target Committee (on March 27, 2009), CO_2 emissions have to be reduced by 126 million t-CO_2 from the level achieved in "case of continuing efforts (6% reduction in CO_2 emissions)" to realize the level achieved in "case of maximum introduction (15% reduction in CO_2 emissions)." Of this, the reduction in the commercial sector accounts for 65 million t-CO_2.

(2) Promotion of distributed energy system (creation of “smart energy network”)

The technical environment to promote the distributed energy system with cogeneration equipment as the core has been prepared in recent years.

As for the supply side, full-scale introduction of distributed generation resources that utilize renewable energy such as photovoltaic power generation and others is expected, and the sale of fuel cells for residential use as cogeneration equipment is also started. Biogas and solar heat are also expected to be utilized. Furthermore, the “transparency” of energy information on the demand side by making use of IT technology and the energy utilization equipment controlled by sensor networks have made it possible to closely and carefully integrate and adjust supply and demand of various types of energy in the future.

In consideration of such environmental change and technological innovation, one of the important challenges is to promote the distributed energy system (creation of “smart energy network”) that encourages the best mix of energy with an aim to save energy and reduce CO_2 emissions through the electricity and heat combination that integrates the demand and supply systems together. For realization, it is crucial to review the technology and cost of the most appropriate network system management through demonstration projects and others.

[Fig. 31] Conceptual Scheme of Smart Energy Network

[Fig. 32] Type of Smart Energy Network

In EU, the Seventh Framework Programme (FP7) started in January 2007, under which the “Smart Energy Network” is positioned in the energy field to intensively undertake the research and demonstration activities of integration of distributed generation resources and renewable energy into electric power networks in Europe(Note).

As for the promotion of a distributed energy system in the future, it is considered possible to pursue the optimum combination of electricity and heat in consideration of characteristics of respective facilities and equipment as a supply side approach with cogeneration equipment such as fuel cells as the core, including utilization of renewable energy and untapped energy. Also, it is important to pursue the improvement of efficiency of individual equipment such as high-efficiency water heaters, etc., to the greatest extent.

As for a demand side approach, it is considered possible to pursue the combination of demands of houses, apartments, districts and others or the control of individual demands themselves in proportion to the structure of energy demand (ratios of heat and electricity, applications and time-of-use demand) and the scale of demand (households, apartments, factories, districts and cities).

Note: Under FP7, EU plans to support major research themes in a total of ten fields, including the energy field, and provide them with a total of 2.3 billion euros in seven years.

(3) Possibility of distributed energy system

If cogeneration equipment with an emergency power generating function is installed, such equipment can serve as an emergency power source for the customer in the event of an emergency such as disaster, outage and others. If cogeneration equipment is put into operation during the peak hours of electricity use, electric power loads can be leveled. Moreover, as for renewable energy such as photovoltaic power generation whose output and supply are unstable, cogeneration equipment that is added with control systems can provide the functions to make up for fluctuations of output of renewable energy by combining an operation system to always ensure surplus power for output adjustment as necessary and a control system. Though such operation may lower the total energy efficiency, an overall efficiency in consideration of energy conservation, CO_2 emissions reduction and cost can be increased. For the construction of smart energy network, the effects on electric power systems, including such points as discussed above, must be fully reviewed.

As for the cogeneration equipment playing a central role in distributed energy system, various systems are constructed in proportion to the scale of demand and the ratio of demand for electricity and heat such as gas engines, gas turbines, fuel cells and others. As the development of technology to improve power generation efficiency and reduce cost has been moved forward, various customers and groups of customers are expected to take approaches to the introduction of distributed energy system.

3. For creation of hydrogen energy society

(1) Need to create hydrogen energy society

To ensure stable supply of energy while reducing CO_2 emissions for creation of low-carbon society, it is important to effectively utilize renewable energy. However, as renewable energy has low energy density and significantly fluctuates with season and time, this energy is very inconvenient to use as-is.

To effectively utilize renewable energy, the utilization of “hydrogen” as secondary energy in the future will pose an important challenge[Note 1].

(2) Role and challenge of natural gas for creation of hydrogen energy society

Hydrogen is a clean energy that emits no CO_2 when it is used[Note 2].

Note 1: “Hydrogen” can be produced from various types of primary energy, and can also be stored in application-specific forms such as gas and liquid. Hydrogen is suited for mass storage and long range transportation. The substance cycles that can be used by human beings for energy systems include the hydrogen cycle and the carbon cycle. As for the comparison between the two cycles, the abundance of water in the atmosphere is far larger than that of carbon, and the amount of water moved per year from the atmosphere is large, whereas the average residence time of water in the atmosphere is short. Therefore, the effect of increase in substance cycles due to energy consumption by human beings on the hydrogen cycle is smaller than that on the carbon cycle.

Note 2: As “hydrogen” (H2) is a substance that does not contain any carbon component (C) in its composition, it produces only “water” (H2O) when it reacts with oxygen during combustion and does not produce any

As an ideal shape of hydrogen energy society, it is considered possible to produce hydrogen by using a large quantity of electricity generated by renewable natural energy, but there are many hurdles to be cleared in terms of cost efficiency, supply stability and others. If these hurdles are taken into consideration, it is more realistic to produce hydrogen by reforming natural gas and others for the time being.

CO_2 emitted in the process of hydrogen production by reforming natural gas can be largely reduced, if the systems to separate and collect CO_2 are created and the systems to transport collected CO_2 as well as carbon capture and storage (CCS) systems are realized in the future, making it possible to contribute to the realization of low-carbon society.

[Fig. 33] Hydrogen Energy System

[Fig. 34] Mechanism of Hydrogen Production by Reforming Natural Gas

(3) Construction of local hydrogen networks

In creating hydrogen society where hydrogen can be effectively utilized, one of the important challenges is to construct hydrogen stations as a large-scale system to produce hydrogen by reforming natural gas and create a network (local hydrogen network) to supply hydrogen through hydrogen pipelines from such stations as the starting points in a certain area (adjacent to places of consumption)[Note 3].

In producing hydrogen, it is more cost-advantageous for capital investment to produce hydrogen by reforming natural gas on a large scale at one place from the viewpoint of economies of scale, rather than to produce hydrogen on a small scale at multiple places. Moreover, collection of CO_2 is easier and this point is advantageous for CCS.

For establishment of such hydrogen stations, it is also considered vital to review a possibility of making use of the infrastructures for natural-gas-powered vehicles (natural gas stations), of which the introduction has been pushed ahead to date by gas suppliers, from the viewpoint of effective utilization of existing infrastructures.

[Fig. 35] Conceptual Scheme of Local Hydrogen Network

(4) Utilization of fuel cells

One of the leading parts in hydrogen energy society is represented by fuel cells. Fuel cells are a highly efficient system to extract electrical energy and thermal energy from electrochemical reaction. Moreover, as fuel cells create electrical energy and thermal energy at places of consumption and both energies are used on-site, the efficiency of energy use is improved under certain conditions and they can play a core

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carbon dioxide (CO_2).

Note 3: A demonstration project to create hydrogen utilization society is now under consideration.

role in a distributed energy system(Note).

Fuel cells have partly come into commercial use and some types of them are still under development. In order for fuel cells to come into wide use in large quantities, it is needed to continue to improve their performance, reliability, durability, cost and others.

[Fig. 36] Energy Conversion by Fuel Cells

4. Advanced use of natural gas in the industrial sector (energy conservation and CO_2 emissions reduction)

(1) Significance of natural gas utilization in the industrial sector

CO_2 emissions from Japan's industrial sector in fiscal 2007 decreased from the base year level but still accounted for about 40% of the total CO_2 emissions of energy origin. On the other hand, as for the final energy consumption in Japan's industrial sector, the shares of oil and coal are large (both account for about 30%), and the share of natural gas is only about 7%. Natural gas is of course a clean energy whose CO_2 emissions are the least among fossil fuels, and is expected to further save energy and reduce CO_2 emissions through various kinds of advanced use.

[Fig. 37] CO_2 Emissions of Energy Origin by Sector in Japan

Particularly in the demand for high-temperature heat in the industrial sector, it is necessary to facilitate the introduction and advanced use of natural gas to conserve energy and reduce CO_2 emissions in consideration of technology and cost.

Moreover, in those plants like food-products plants where there are various demands for electricity and heat for sterilization, drying, cooling, etc. and where biogas can be used, it is essential as mentioned earlier concerning the distributed energy system to promote the optimum combination (best mix) of electricity and heat, which integrates the demand and supply systems together. In addition, district-wide use of waste heat from plants is also expected.

For these approaches to energy conservation and CO_2 emissions reduction in the industrial sector, it is important to establish an environment where such approaches are appropriately evaluated for promotion thereof.

Note: As for characteristics, fuel cells have such advantages as high energy conversion efficiency (it is possible in case of small fuel cells, too), CO_2 emissions separated from nitrogen with no NOx emissions, quiet and smooth startup, and a possibility of research and development for longer service life to spread to various other industries involved. Disadvantages include low power density compared with that of internal combustion engines and high cost at present.

(2) Advanced use of natural gas

In the metal and glass production fields in the industrial sector, which use high-temperature combustion heat generated from fossil fuels, burners and other devices are used for melting, drying, etc. In these fields, great effects of energy conservation and CO_2 emissions reduction can be produced by replacement of conventional combustors with more efficient equipment (regenerative burners, etc.) that utilize natural gas.

[Fig. 38] Mechanism of Regenerative Burner

Additionally, as specific methodologies to make it possible to reduce CO_2 emissions produced from specific manufacturing processes in the industrial sector to almost zero, it is considered possible to introduce a high-efficiency combustion system that is composed of those processes of raising flame temperature (combustion of oxygen), minimizing heat loss by exhaust (removal of nitrogen) and increasing the quantity of waste heat recovered (high-performance heat exchanger), and to combine such system with separation of CO_2 from exhaust gas, and capture and storage thereof (CCS).

[Fig. 39] Mechanism of High-efficiency Combustion System

(3) Utilization of cogeneration (distributed energy system)

To foster energy conservation and CO_2 emissions reduction in the industrial sector, biogas and renewable energy are expected to be combined with cogeneration equipment as the core, and moreover the best mix is expected to be promoted, including use of waste heat in each district, if it is found to be effective, in addition to the points mentioned above.

5. Introduction of renewable energy, etc.

(1) Biogas

1) Need to effectively utilize biomass resources

Biomass means a renewable organic resource of biological origin other than fossil resources, and its CO_2 emissions caused by combustion, etc. do not have effect on global warming, which is called carbon neutral property. Japan has such biomass resources as sewage sludge, food wastes, non-industrial wastes (mixed wastes produced in urban areas) and others.

Of these biomass resources, sewage sludge is produced inevitably by the lives of human beings and its quality and quantity remain stable. It is confirmed that the quantity of sewage sludge produced per year amounts to about 2,230,000 tons (dry weight). If sewage sludge of this quantity is fully utilized as energy, it would be equivalent to about 1,040,000 kiloliters of crude oil, but only about 7% of sewage sludge is utilized as energy in reality. On the other hand, sewage treatment plants consume a large amount of energy in the process of collection and treatment of sewage (about 1.9 million kiloliters of crude oil equivalent in fiscal 2003, which account for about 0.3% of the total amount of primary energy supplied in Japan). A challenge is to utilize sewage sludge as energy while saving energy required in its collection and treatment.

The amount of food wastes produced at food-products plants and non-industrial wastes (mixed wastes) produced in urban areas is stable and abundant. There would be an advantage of waste reduction if food wastes are successfully utilized as energy. In spite of such advantage, wastes are not much utilized yet as energy because of some hurdles to be cleared such as establishment of recovery method and cost reduction.

From the viewpoint of promoting CO_2 emissions reduction and effective use of energy resources in preparation for low-carbon society in 2050, it is a significant challenge for Japanese gas suppliers to convert these biomass resources into energy (biogasification) and promote advanced use thereof together with natural gas.

2) Method of use of biogas

Considering places of biogas generation and the cost of equipment to convert biogas into city gas, it is most reasonable to consume biogas on a self-consumption basis at the place (on-site) where biogas is generated. For utilization of biogas, first, it is important to promote on-site use. In food-products plants, for example, biogas is generated by methane fermentation of food wastes, and the electricity and heat generated by cofiring biogas and city gas in cogeneration equipment can be effectively utilized. As a result, energy consumption in plants can be lowered, and energy conservation and CO_2 emissions reduction can be facilitated. To increase such on-site use of biogas, it is necessary for gas suppliers and other related businesses to encourage the development of technology for gas refining and storage.

Instead of using biogas on-site, on the other hand, it is also possible to utilize biogas as a material of city gas at city gas production plants. For example, in the case where a city gas production plant is located close to a sewage treatment plant, biogas converted from sewage sludge produced at the sewage treatment plant can be transported through pipelines to the city gas production plant and mixed with city gas. Consequently, the consumption of natural gas as a material of city gas can be lowered, and energy can be saved. At present, there are actual cases where biogas transported from a sewage treatment plant is mixed with natural gas and utilized in Nagaoka-city, Niigata Prefecture and in Kanazawa-city, Ishikawa Prefecture.

Moreover, it is also possible to reduce consumption of natural gas as a material of city gas and save energy, if a gas supplier receives biogas, which is refined and whose quantity of heat is adjusted at the place of biogas generation in the vicinity of the gas supplier, through pipelines and supply the gas as city gas. To date, there is no case where biogas is received and supplied through city gas pipelines. However, the preparation work for establishment of an environment to receive and supply biogas through city gas pipelines is now in progress by major gas suppliers playing a leading role such as formulation of procedures for purchase of biogas.

To enhance such utilization of biogas, it is indispensable for the parties concerned, including relevant ministries and agencies and local governments, to work together and cooperate with each other.

[Fig. 40] Method of Use of Biogas

(2) Solar heat

1) Need to effectively utilize solar heat

Like sunlight, solar heat is a renewable energy that can be used permanently. Solar heat has a huge quantity of energy and its potential is high. Particularly, solar heat can be utilized all over the country as a locally available energy to be produced and consumed locally. As a new energy for the commercial sector (residential sector and business sector), solar heat is a kind of energy that is highly compatible with gas suppliers that deal with thermal energy.

Particularly, as solar heating systems (solar heating systems and solar heat water heaters) directly collect thermal energy with their heat collectors, their energy conversion efficiency is higher than that of photovoltaic power generation, and their costs are relatively low. Moreover, as the required area of heat collector is small, it is easy for houses and buildings, whose areas exposed to sunlight and areas of roofs are small, to introduce such systems[(Note)].

In order for Japan's gas utility business to shift to low-carbon society in the future, it is important to promote energy conservation and CO_2 emissions reduction by advanced use of combination of solar heat and natural gas, in addition to biogas.

2) Method of use of solar heat

There are various methods of utilizing solar heat such as cooling, heating, hot water supply and others. The most effective methods are to use solar heat for hot water supply and heating. However, solar heat can also be used for cooling. For example, as for the thermal energy required for gas air-conditioning systems for business use (absorption water cooling and heating machines), it is possible to reduce consumption of city gas and facilitate energy conservation and CO_2 emissions reduction by installing solar heat panels on buildings and utilizing the accumulated solar heat energy together with city gas in absorption water cooling and heating machines.

In the residential sector, moreover, solar heated hot water supply systems and solar space heating systems are installed, and the accumulated solar heat energy is delivered to high-efficiency water heaters and heat sources for heating. With these systems, gas consumption for hot water supply and heating can be reduced, leading to energy

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Note: In general, the energy conversion efficiency of photovoltaic power generation is about 14%, and that of solar heat utilization is said to be about 50%. Moreover, a photovoltaic power generation panel for a detached house requires an area of 20-30 square meters, whereas it is said to be possible to install a solar heat panel in an area of 4-6 square meters.

conservation and CO_2 emissions reduction.

[Fig. 41] Combination of High-efficiency Equipment and Solar Heat

(3) Utilization of untapped energy, etc.

In addition to the approaches mentioned above, it is also essential to utilize untapped energy, etc. such as waste heat produced at plants and factories. As such utilization of waste heat contributes to energy conservation and CO_2 emissions reduction, it is important to enhance such approaches in the future.

6. Roles of gas utility business and gas suppliers

The gas utility business and gas suppliers have carried out the following functions and roles, and they will also be important players for: ① promotion of distributed energy system; ② contribution to creation of hydrogen energy society; ③ advanced use of natural gas in the industrial sector (energy conservation and CO_2 emissions reduction); and ④ introduction of renewable energy, etc., as mentioned above.

○ Establish infrastructures to supply gas (equipment to transport and supply gases)

○ Provide services for combination of electricity and heat (proposals for and operation of district heating and cooling services by cogeneration)

○ Develop and provide cogeneration equipment (gas engines, gas turbines, fuel cells, etc.)

○ Supply natural gas as the material of hydrogen

○ Develop and provide various high-efficiency equipment to meet the needs of customers in the industrial and commercial sectors

○ Develop and provide the technologies to effectively utilize biogas

Based on these functions and roles, the gas utility business and gas suppliers are expected to play active roles from now on to realize the mid-to-long term scenarios for creation of low-carbon society by capitalizing on the experience and knowledge they have accumulated to date.

Chapter 4. Specific approaches to realization of mid-to-long term scenarios

In this chapter, specific challenges to be addressed with an eye toward about ten years ahead are outlined based on the targets for 2050 as shown in Chapter 3.

1. Promotion of distributed energy system

(1) Dissemination and development of cogeneration equipment (including fuel cells)

Cogeneration equipment is the core of distributed energy system. As for cogeneration equipment, gas turbines for the industries that use relatively large amount of thermal energy and gas engines for the industries that use relatively large amount of electric energy have already been introduced in large numbers.

From now on, it is vital to move ahead with the development of the technology to realize far more efficient combustion such as a gas turbine exhaust after-burning system, etc., the technology to improve power generation efficiency such as long stroke technology for engines, compressed self-ignition technology, etc., and highly efficient equipment such as waste heat recovery boilers, etc.

It is also important to advance the development and introduction of fuel cells that can be the core of cogeneration in the future. At present, polymer electrolyte fuel cell (PEFC) for residential use, which has the highest rated power generation efficiency of about 37% (LHV), is commercialized. For further dissemination, from now on, the technologies to further improve durability and further reduce cost of fuel cells are expected to be developed, and the cost of fuel cell is also expected to be reduced by volume production through promotion of the strategy to enlarge the market in cooperation with the housing industry.

At present, moreover, the development of solid oxide fuel cell (SOFC), which has a rated power generation efficiency of about 45% (LHV), is underway by gas suppliers, manufacturers and others, and SOFC is expected to be launched in the market in a few years. As SOFC has high power generation efficiency, it is expected to be introduced on a large scale into the commercial sector where the demand for electricity is large. At the same time, as waste heat of about 800℃ is produced in the process of power generation, it is also expected to be introduced into the industrial sector that has demand for high-temperature heat.

Furthermore, the utilization of cogeneration systems (including fuel cells) is also encouraged in western countries. Therefore, if improvement of overall energy efficiency in Japan can be expected, it is essential to promote the utilization of cogeneration systems(Note).

Note: The U.S. announced the National CHP Roadmap in 2001 and Europe adopted EU CHP (Combined Heat and Power) Directive in 2004, aiming at further promoting highly efficient cogeneration.

(2) Reinforcement of approaches to creation of smart energy network (demonstration of integration of demand and supply systems, etc.)

It is important to conduct demonstration tests on the integration of demand and supply systems at various levels, including detached houses, apartment houses, districts, cities and others, and enhance the approaches to create optimum networks for energy conservation and CO_2 emissions reduction also from a cost-benefit point of view.

Conceivable important factors of such smart energy network include distributed generation resources such as cogeneration equipment, renewable energy such as photovoltaic and wind power generation and biogas, infrastructures for interchange of heat and electricity such as pipings for interchange of electricity and heat between buildings, and control systems for area optimization. To develop specific projects, it is indispensable to review the optimum management of network systems, technical aspects concerning impact on electric power systems, and cost effectiveness through demonstration projects.

1) Household (detached house)

In households, electric and thermal energies are used by various appliances during various time periods. In addition to efficiency improvement of these appliances, it is desirable to “visualize” the information about energy on the demand side by using information technology (IT) and to promote optimization (energy optimum management) from the viewpoint of energy utilization by combining solar cells, fuel cells and storage batteries. Then, it becomes possible to construct low-carbon houses.

For this purpose, it is required to facilitate the development of a mechanism to grasp the information about energy in households and sensor networks that can control operation of energy utilization equipment. Then, it is necessary to review a possibility of dissemination through demonstration tests and others in cooperation with the housing industry as an energy utilization model in households.

2) Apartment houses

As for the electric and thermal energies used quite unevenly by respective households, the effects of energy conservation and CO_2 emissions reduction can be expected in apartment houses as a whole by system control in apartment buildings and by interchange of electricity and heat between neighboring households, if conditions are satisfied.

It is needed, from now on, to verify the effects of demonstration tests conducted by gas suppliers and others, accumulate the know-how about optimum system control, and consider introduction as a business model in cooperation with housing suppliers.

3) District and city

Under certain conditions, the effect of integration of demand makes it possible to effectively utilize energy in an area as a whole by interchanging electricity and waste heat from cogeneration equipment between multiple facilities and buildings such as office buildings (in a city), and the effects of energy conservation and CO_2 emissions reduction can be expected. In addition, energy can be further saved and CO_2 emissions can be further reduced by utilizing renewable energy and untapped energy (including waste heat, etc. from waste incineration plants) in conformity with characteristics of districts.

It is expected to create a model of energy use on a district-wide basis, which can encourage energy conservation and CO_2 emissions reduction pulling together with design offices and local developers and in consideration of efficient use of overall energy from the town-designing stage. It is also desirable to efficiently promote the construction of infrastructures for electricity and heat use on a district-wide basis.

2. For creation of hydrogen energy society

(1) Dissemination and development of fuel cells and development of hydrogen production technology, etc.

To undertake dissemination of fuel cells as the core technology of hydrogen society, it is important for Japan's gas utility business to develop the aforementioned PEFC and SOFC, establish the technologies to produce them in volume, and reduce the costs thereof. It is also important to develop a combined system composed of SOFC that has high power generation efficiency and gas turbine, aiming at introducing a system with 60% or more of power generation efficiency.

As for hydrogen as the fuel of fuel cells, moreover, it is essential to continue to develop the technologies for production, transportation and storage of hydrogen.

(2) Establishment of infrastructures for hydrogen (creation of local hydrogen networks, etc.)

The present equipment of fuel cell for home use is equipped with a natural gas reformer. In the future, it is conceivable to supply hydrogen through hydrogen pipelines from large natural gas reformers (hydrogen stations), and fuel cells are used in each house (local hydrogen network). In this case, if fuel cells can be combined with CCS in the future, it will be possible to drastically reduce CO_2 emissions.

Therefore, the approaches to the establishment and commercialization of hydrogen infrastructures (hydrogen pipelines and hydrogen stations) are required. Specifically, the industrial, academic and government sectors are expected to cooperate with each other to conduct the verification of hydrogen brittleness of pipelines, technology development and demonstration tests from the viewpoint of ensuring safety, research and study on safety standards and others in other countries, and research and development for cost reduction.

3. Advanced use of natural gas in the industrial sector (energy conservation and CO_2 emissions reduction)

(1) Development and dissemination of high efficiency equipment and combustion

system

Manufacturing processes in the industrial sector often require high-temperature heat for metal melting and drying, and a substantial amount of heat including steam and hot water as well as electricity for sterilization, drying, cooling and other purposes. To facilitate energy conservation and CO_2 emissions reduction, the challenge is how efficiently natural gas can be burnt and how thermal energy can be used without loss.

From the viewpoint of CO_2 emissions reduction, the industrial sector is expected to continue to expedite the introduction of natural gas. Moreover, advanced use of energy can be realized by replacing combustors with more efficient equipment (regenerative burners, oxygen-fuel burners, etc.). In addition to improved efficiency of such equipment, combustion efficiency can be significantly brought up by the introduction of high-efficiency combustion system, and greater effects of energy conservation and CO_2 emissions reduction can be produced. Moreover, the effects of saving energy and reducing CO_2 emissions of the entire plant can be produced by creating a mechanism to allow a system as a whole to utilize a large amount of steam, hot water and electricity to the greatest extent.

To realize energy conservation and CO_2 emissions reduction in the industrial sector through advanced use of natural gas in Japan's gas utility business, it is vital to encourage the approaches to the development of technologies and products that allow such high-efficiency equipment and systems to become de facto standards in the industrial sector, improvement of engineering technology, and expansion of introduction thereof.

(2) Approaches to advanced use in small-to-medium businesses

Compared with large businesses, the approaches to installation and introduction of energy-saving equipment have been delayed in the plants and factories of small-to-medium businesses because of funds shortage and cost efficiency. To enhance the effects of energy conservation and CO_2 emissions reduction, however, it is important to encourage the approaches to advanced use of natural gas in the industrial and business sectors of such small-to-medium businesses.

4. Introduction of renewable energy, etc.

(1) Biogas

To widen the utilization of biogas in the industrial sector, it is required for gas suppliers to develop the technology to improve the efficiency of generation of biogas such as ultra high temperature solubilization technology, partial combustion gasification technology, etc., provide combustion and control technologies to introduce the equipment for cofiring natural gas and biogas, and provide various technologies to introduce the equipment for refining, storage and utilization of biogas. It is of importance to promote them.

It is also indispensable to identify challenges concerning installation of refining and thermal conditioning equipment, pipeline transportation, etc., in order to establish a system that receives and supplies biogas generated by sewage treatment plants through city gas pipelines.

Furthermore, from the viewpoint of effectively utilizing mixed wastes produced in homes and cities as energy resources, it is required to promote the dry methane fermentation technology to generate biogas from mixed wastes. As this method can reduce the quantity of waste water to be treated compared with wet methane fermentation from sewage sludge, energy and cost can be saved. In advancing this approach, it is necessary to establish waste collection methods and solve challenges including cost reduction.

For widespread utilization of biogas in Japan, it is essential to foster cooperation of the ministries and agencies concerned that have charge of biogas generation facilities including sewage treatment plants and other parties concerned such as local governments.

As things now stand, moreover, biogas generation sources are limited, and the cost to utilize biogas remains high and the economic viability of utilization of biogas is low in reality. In the proposed legislation for upgrading the energy supply structures, energy suppliers are required to strive to promote utilization of non-fossil energy sources, and the government is required to take necessary financial measures. It is a key element for the public and private sectors to cooperate in promoting approaches to generation, recovery and utilization of biogas.

(2) Solar heat

As mentioned above, solar heat can be used as thermal energy needed by hot water supply and heating for residential and business use as well as gas air-conditioning systems (absorption water cooling and heating machines) for business use. Therefore, it is important for gas suppliers to conduct surveys on collectors and system technologies, which are suitable for hot water supply applications, collectors and system technologies, which are suitable for air-conditioning applications, technologies to design and install heat collecting systems in office buildings, and know-how about optimum control of air-conditioning loads and solar heat, and to identify challenges and encourage dissemination of gas air-conditioning systems (absorption water cooling and heating machines) in cooperation with those who manufacture, sell, install and design solar heat equipment as well as owners of houses and buildings to be constructed.

To promote the combination of high-efficiency water heaters for home use and solar heat, it is important for gas suppliers to facilitate the introduction of solar heat equipment into houses in cooperation with those who manufacture and sell solar heat equipment, engineering firms, builders, etc., and enhance dissemination of such equipment contributing to energy and cost savings and reduce the cost thereof by volume production.

(3) Utilization of untapped energy, etc.

In addition to the introduction of renewable energy, the use of untapped energy on a district-wide basis such as waste heat from plants and factories makes it possible to promote efficient use of energy in the district under certain conditions. Therefore, gas suppliers who have the know-how about handling of thermal energy are expected to establish steam pipes and others for utilization of waste heat in partnership with the central and local governments in consideration of efficient utilization of overall energy.

5. Basic approaches

(1) Ensuring of stable supply of natural gas

In Japan, it is a significant challenge to stably supply natural gas, most of which depends on imports from overseas. It is important to continue to diversify LNG procurement sources and facilitate resource diplomacy as well as energy and environmental cooperation from an overall point of view.

According to “Ocean Energy and Mineral Resource Development Plan” that was formulated by the Ministry of Economy, Trade and Industry in March 2009 and approved by the Headquarters for Ocean Policy, methane hydrate is expected to be utilized as domestic resources in the future. Japan aims to commercialize the utilization of methane hydrate in about ten years, and also plans to explore and develop conventional natural gas fields in a well-planned and steady manner.

In addition, it is also important to promote the development of un-conventional natural gas from the viewpoints of improvement of energy security and diversification of supply sources.

(2) Establishment of basic infrastructures

Of the gas supply infrastructures in Japan, the construction and development activities of high-pressure pipelines and LNG terminals are well underway. However, the construction of pipelines between major cities and between LNG terminals is not necessarily sufficiently advanced. This is still a significant challenge from the viewpoint of ensuring stable and low-cost supply of natural gas.

From the viewpoint of invigoration of the gas market and fair competition, it is also important to encourage the development of gas pipeline networks, mutual connection thereof and utilization of the pipeline networks by third parties through provision of appropriate incentives to the investments in pipelines.

From the viewpoint of customers such as the people and businesses, moreover, it is necessary to extend pipeline networks to places where natural gas has not come into wide use to make it possible to enjoy the merits of energy conservation and CO_2 emissions reduction through further advanced use of natural gas as mentioned above.

As for development of infrastructures in Japan such as pipelines, basically energy suppliers should estimate potential demand and make decisions on investments in consideration of profitability (cost effectiveness). Then, the government provides support to encourage energy suppliers to make investments. For the construction of basic infrastructures for the gas utility business that contributes to low-carbon society, it is desirable to continue public support.

(3) Transfer of energy-saving technology overseas

Japan has the world's most advanced energy-saving technologies and know-how. The transfer of these technologies and know-how overseas makes it possible to realize energy conservation and CO_2 emissions reduction not only in Japan but also all over the world.

Japanese gas suppliers and manufacturers have accumulated a lot of know-hows about energy-saving technologies to date by promoting the introduction of cogeneration systems and developing high-efficiency equipment. The transfer of these energy-saving technologies to other countries contributes to the international community as well as to development of Japanese businesses, including the gas utility business, and it is necessary to continue to reinforce such efforts.

(4) Evolution into comprehensive energy service business

To date, gas suppliers have provided gas services mainly by using pipelines, and have been engaged in the energy service business in various ways such as: ① construction of energy infrastructures including pipelines; ② improvement of efficiency of water heaters, etc., and development of fuel cells; ③ provision of integrated services of heat and electricity through cogeneration; ④ energy-saving services in plants and offices; ⑤ proposal for utilization of waste heat in plants and factories, etc.; and ⑥ dissemination of district cooling and heating, etc. From now on, gas suppliers are expected to capitalize on such experience and encourage not only conventional businesses but also the "comprehensive energy service business" to contribute to creation of low-carbon society.

(5) Creation of framework to reinforce approaches of local communities and local governments

To advance the approaches to the creation of distributed energy system, it is important to reinforce the approaches of local communities, local governments and others.

For example, it is vital to create frameworks that enable active approaches in consideration of the realities of local communities concerned in city plans of local government such as presentation of the direction to advance the approaches to efficient utilization of overall energy.

(6) Publicity to and education of people

The people are involved in energy utilization at various levels. To smoothly implement energy policies, it is crucial for the people as end users to fully recognize and understand the necessity of energy policies. However, the information about the utilization of energy, including natural gas, is not fully understood by the people. Therefore, it is important to position such information, including the basic concept, specific approaches and others as mentioned in this paper, in overall energy policies, and have the people understand the policies in an easy-to-understand manner through various channels of publicity and education. At the same time, it is required to appropriately disseminate the information about the results of measures to be taken in the future and assistance to consumers, and to allow the people to actually feel the results of policies and the roles of the people.

Chapter 5. Conclusion

To continuously utilize natural gas as an important energy in the low-carbon society that Japan aim to create in 2050, it is necessary to thoroughly pursue energy conservation and CO_2 emissions reductions and promotion of advanced use of natural gas is important.

For this purpose, Japan's gas utility business is required to carry out an overall business, including the introduction of renewable energy such as biogas, solar heat, photovoltaic power and others with putting focus on the development and dissemination of distributed energy system, fuel cells, hydrogen utilization technology, high-efficiency equipment and systems, etc., as the core.

To make it possible to carry out such business, moreover, it is necessary to steadily promote the construction of infrastructures such as pipelines as the basis of the gas utility business with an eye to utilization in hydrogen society in the future.

From now on, Japan's gas utility business is strongly expected to undertake continuous efforts for realization of the mid-to-long term scenarios presented in this report.

For reference, this report has put together urgent and important challenges concerning the gas utility business. It is vital to continue to make appropriate discussions as necessary in response to changes in the environment such as ensuring of stable procurement of natural gas and others.