Gas Supply Infrastructure

Yasuhiko Urabe, Toshio Kawamura, Takashi Sakanoue, Osamu Uno, and Yoshio Matsuzaki

Abstract In 2012, Japan imported 87 million tons of LNG or 36.2 % of total worldwide LNG imports of 239 million tons. The main sources, accounting for over 70 % of the total, are Asia-Pacific countries such as Australia, Malaysia, Russia, and Brunei. LNG production is dispersed more widely around the world, making it less exposed to geopolitical risk than oil. LNG can be transported in several ways, such as tank lorries and tank containers, to satellite bases for distribution. Gas pipelines are the primary means in Japan, where there are two kinds of gas pipelines. One is for transport of natural gas produced in domestic gas fields; the other is for transport of city gas produced in LNG terminals to areas of demand. For metering gas consumption at customer sites, there is an increasing need for remote meter reading. Furthermore, it is believed that demand will increase for services that emphasize security and safety or for those facilitating monitoring of senior citizens or those living alone via their gas use. Energy saving is another important consideration. To meet all these expectations, a smart gas meter is being developed.

Keywords Natural gas • LNG • LP gas • Pipeline • Smart meter

1 Introduction

The infrastructure of gas, one of the major energies in Japan, is described. As described in the following session, “characteristics comparison of LNG (liquefied natural gas) and LP (liquefied petroleum) gas,” the LNG share in the gas market has increased, and LP gas still has an important role. The infrastructure of gas energy, therefore, is described with a focus on natural gas, with a supplemental description of LP gas. According to an energy white paper published by the Ministry of Economy, Trade and Industry (METI) [1], the ratio of natural gas as a primary energy source was ~24.5 % in 2012, the second largest behind oil (44.3 %).

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In Japan, most energy sources are imported. Therefore, gas infrastructure includes production facilities for import, storage, and vaporization of LNG, domestic pipelines for transport from terminals to customers, and a huge number of metering devices at customer sites. This infrastructure is classified into the three categories of production, transmission, and metering, whose present status and future vision are described herein.

Although nationwide construction of pipelines is not adequate in Japan, a shift in primary energy source to natural gas is expected to proceed continuously, with support from the government. In the meantime, LP gas is important as a heat source in areas without sufficient pipelines for city gas and as an emergency fuel. LP gas has four main advantages [2]: (1) relatively small CO_2 emission, (2) established systems of supply and storage, (3) easy transport and storage, and (4) contribution to emergencies. On average in Japan, natural gas has twice the share of LP gas in the gas market on a weight basis.

2 Present Status

2.1 Need for Robustness Against Disasters

As shown in Fig. 1, the LNG terminal of the Gas Bureau of the city of Sendai was affected by the tsunami after the 2011 Tohoku Earthquake off the Pacific coast [2]. Because of this disaster, there were initial concerns that the base would suspend its city gas supply to Sendai for about a year, because of the period of restoration of

Fig. 1 Damage to LNG terminal from tsunami caused by 2011 Tohoku earthquake off the Pacific coast (shipping facilities for LNG tank truck) [3]

gas pipelines. However, there was success in providing an alternate supply using a gas pipeline that connects to the base from the Sea of Japan side. LP gas has additional advantages and robustness in emergencies, because there is no need for pipelines for transport to customers. Such robustness is required for disasters.

2.2 Gas Storage

Stockpiles of oil and LP gas are required by Japanese law, among which natural gas is not included. There are two types of stockpiles, private and government.

The required LP gas stockpile for the private sector is 50 days of import volume. The government stockpile also has a capability of several tens of days of such volume. As of September 2014, volumes of LP gas stockpiles were 72.0 and 28.0 days of import volume in the private and government sectors, respectively.

There are many natural gas underground storage facilities in Europe. However, Japan has only five natural gas underground storage facilities in operation, and these are limited to the storage of natural gas produced in domestic gas fields. However, if sufficient transport capacity and a robust network can be developed, wide-area gas pipelines have the potential to act as backup for large-scale demand. Thus, they are extremely important in increasing the robustness of the natural gas supply system.

2.3 LNG Production

2.3.1 Resources to Produce City Gas

2.3.1.1 Outline

City gas began to be supplied in Japan following construction of the country's first city gas plant, at Yokohama in 1872. It was initially produced from coal rather than natural gas. The proportion of naphtha used in production rose in the 1970s. After the introduction of LNG to Japan in 1969, LNG's share of resources used to make city gas continued to grow; it is presently >90 %, making it the primary resource (Fig. 2).

2.3.1.2 Characteristics of LNG

The first LNG carrier arrived in Japan from Alaska in 1969, since which LNG imports have risen drastically.

In 2012, Japan imported 87 million tons of LNG or 36.2 % of total worldwide LNG imports of 239 million tons (Fig. 3). The main sources, representing >70 % of

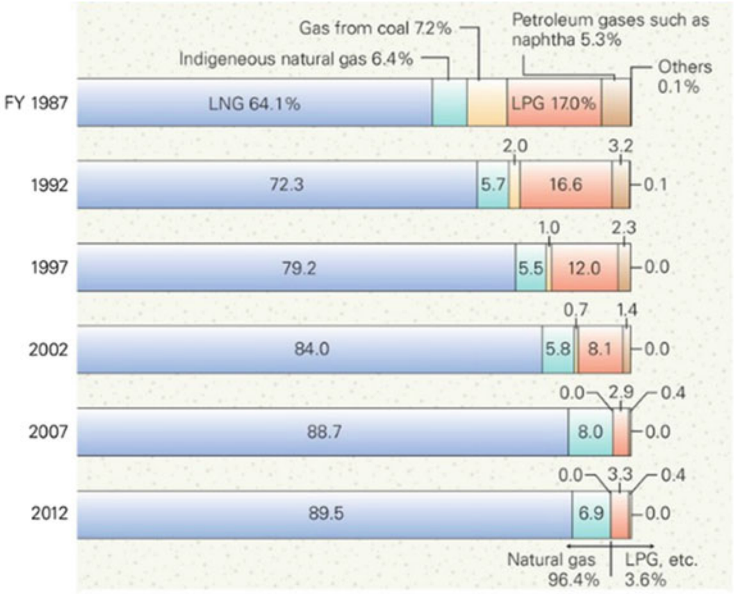
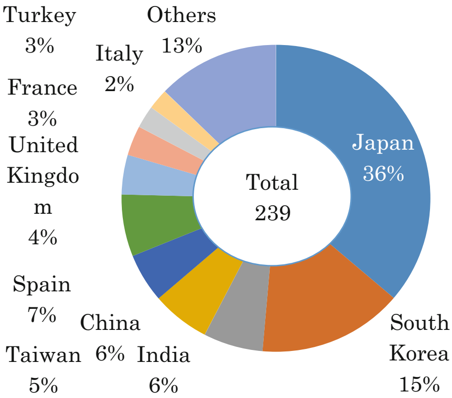


Fig. 2 Trends of resources of city gas [4]

Fig. 3 LNG importers [5]



the total, are Asia-Pacific countries such as Australia, Malaysia, Russia, and Brunei. LNG production is dispersed more widely around the world, making it less exposed to geopolitical risk than oil.

Figure 4 shows the LNG caloric value of projects that began to supply LNG in years shown on the horizontal axis. Caloric values of nearly all projects used to be 43–46 MJ/m^3. Since around the early 2000s, however, the number of projects producing LNG with relatively small caloric value (~41 MJ/m^3) has steadily increased. As a result, the volume of LPG required to adjust caloric value rose in

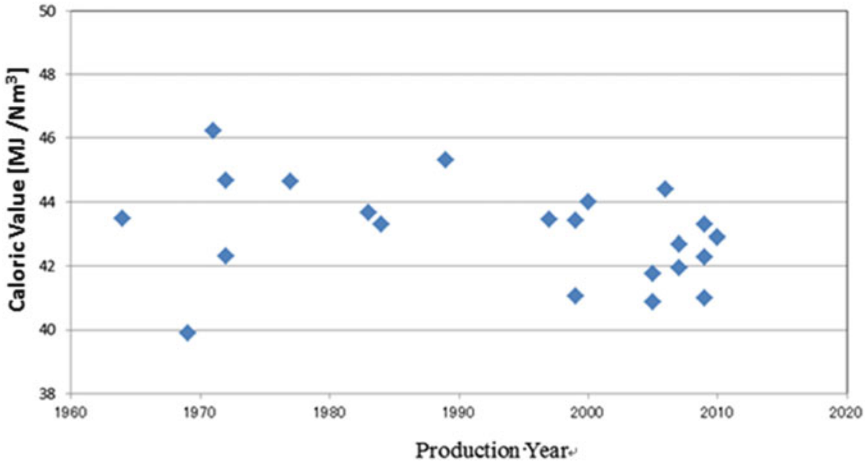


Fig. 4 LNG caloric value

Japan, so that several city gas suppliers lowered the standard caloric value of city gas to reduce the volume of LPG used. The caloric value of gas from unconventional sources now being developed (such as shale gas and coalbed methane) also tends to be low, from 40 MJ/m^3 or less to ~42 MJ/m^3.

The characteristics of LNG as a city gas resource are as follows. LNG is cooled and liquefied natural gas and under normal pressure has a very low temperature, approximately −160 °C. The main component of LNG is methane, and its caloric value varies with its percentage of ethane, propane, butane, and others. Because it has the smallest C/H ratio of any fossil fuel, it produces the least CO_2 per unit caloric value when combusted. Because impurities such as sulfur and nitrogen content are removed during liquefaction, LNG produces the least NOx and SOx emissions of any fossil fuel when combusted (Fig. 5). However, special receiving terminals and gas facilities are required to handle very low-temperature LNG. Given the importance of its low exposure to geopolitical risk and strong environmental friendliness, LNG is rated an "important energy source that will assume a growing role" in Japanese energy policy [2].

2.3.2 Facilities for Producing City Gas from LNG

2.3.2.1 LNG Terminals in Japan

Japan had 32 LNG import terminals in operation as of the end of March 2014 as shown in Fig. 6.

The main facilities of LNG import terminals are receiving, storage, and regasification (Fig. 7).

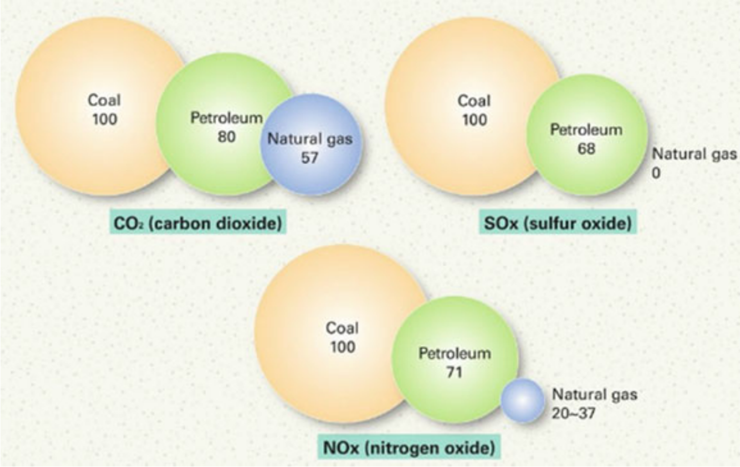


Fig. 5 Emissions of fossil fuel combustion (Coal = 100) [4]

Fig. 6 Regasification plant sites in Japan [4, 6]. There is one more LNG import terminal, "Yoshinoura-Okinawa Electric" on Okinawa Island, which is south of the area shown on this map

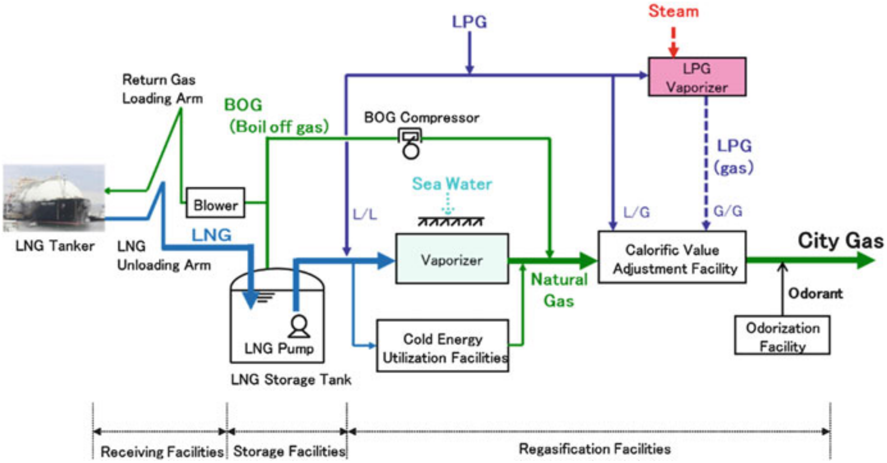


Fig. 7 Typical city gas production flowchart

LNG terminal facilities have high earthquake resistance in accordance with technological standards based on relevant laws and regulations and the industry's own engineering guidelines and are equipped to withstand a seven-class earthquake on the Japanese scale of seismic intensity. Measures are also taken to minimize as far as possible interruptions to production and supply after assuring prevention of secondary disasters caused by tsunamis, in accordance with the same guidelines.

To minimize damage to facilities and impacts beyond a terminal from a disaster or other incident, numerous safety systems are equipped to quickly detect incidents, minimize damage, and protect neighboring facilities. Smaller LNG terminals called "satellite" terminals are sometimes found at sites of demand located far from existing LNG terminals and city gas pipelines. Satellite terminals produce city gas from LNG transported to them by small LNG carriers such as lorries.

2.3.2.2 Receiving Facilities

These are facilities including jetties where large LNG carriers can berth to unload their LNG, and there are LNG unloading and return-gas loading arms connecting LNG carriers to the terminal, receiving pipes, and return-gas blowers for feeding gas back to the carriers. After berthing at a jetty, an LNG carrier is connected to the receiving terminal's facilities by LNG unloading and return-gas loading arms. LNG on the carrier is then pressurized by cargo pumps and discharged to the storage facilities on the terminal side. To maintain pressure in carrier cargo tanks during unloading, boil-off gas (BOG) is sent from the terminal by a return-gas blower. So that carriers can unberth as soon as possible in an emergency, LNG unloading and return-gas loading arms are equipped with emergency release mechanisms.

2.3.2.3 Storage Facilities

LNG received from jetties is sent to storage tanks via receiving pipes. The design and operating vapor pressure of high-capacity LNG storage tanks capable of handling large LNG carriers is normally around dozens of kPa-G, and LNG temperature in the tanks is around −160 °C. The BOG generated owing to heat input from the environment is maintained at ~0.1 wt.%/day storage capacity by a heat-insulating material. BOG is pressurized by a compressor and used as a city gas resource or fuel for nearby thermal power plants (some terminals are also equipped with "BOG reliquefaction systems," which reliquefy BOG using the cold energy of LNG and then inject it into LNG pipelines).

There are two main forms of LNG tanks, aboveground and in-ground (Fig. 8). As construction engineering has advanced in recent years, the tank capacity that can be constructed has increased. The largest capacities in 2014 were 230,000 kL (aboveground) and 250,000 kL (in-ground). LNG tanks built since the 1980s are equipped with liquid densimeters, top and bottom feed lines, and jet mixing nozzles that enable them to store LNG of dissimilar densities without causing rollover.

"Rollover" is a phenomenon that can occur when two types of LNG with dissimilar densities are introduced in the same storage tank. The heavier LNG moves to the bottom and the lighter type to the top. The density of the lower layer then decreases as its temperature rises because of heat from the outside, while the upper LNG density becomes heavier as BOG is generated. When the densities of the two approach each other, they mix rapidly, and a large quantity of BOG is generated. This should be avoided, because it can cause a sudden pressure surge in the tank.

2.3.2.4 Regasification Facilities

(a) Vaporization facilities

There are two main types of vaporization facilities, open rack vaporizers (ORVs) and submerged combustion vaporizers (SCVs) as shown in Figs. 9 and 10. ORVs vaporize LNG using water such as seawater as a heat source. Seawater flows outside of panels consisting of numerous finned heat transfer

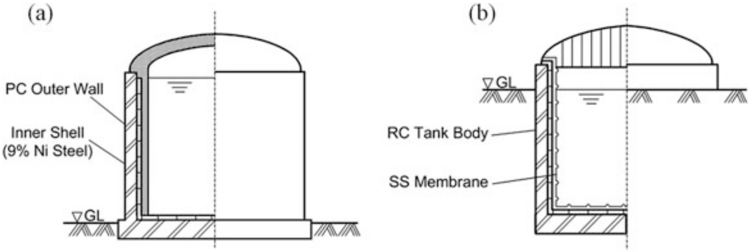


Fig. 8 LNG storage tank: (**a**) aboveground; (**b**) in-ground

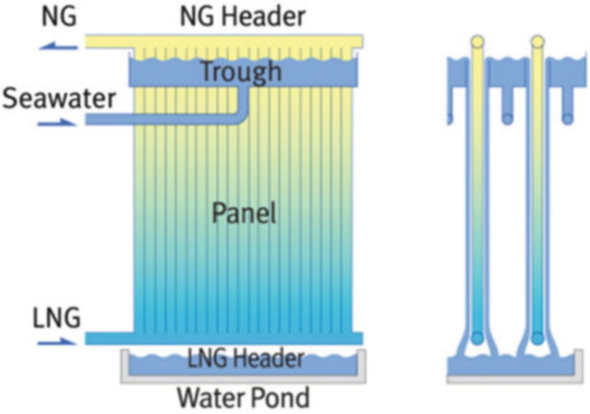


Fig. 9 Open rack vaporizer [7]

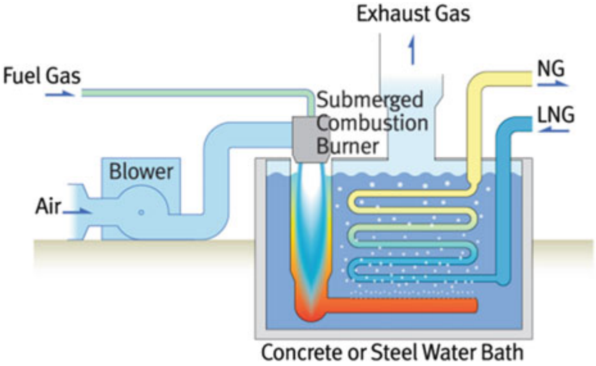


Fig. 10 Submerged combustion vaporizer [7]

tubes ("fin tubes"), and LNG is vaporized by heat exchange between the film of seawater outside the tubes and LNG inside the tubes. Because of their low-operating cost, these are widely used in Japan to meet baseload needs. However, their vaporization performance typically declines when the seawater temperature falls below ~8 °C. SCVs vaporize LNG using heat from submerged combustion of natural gas (fuel gas) as a heat source. Natural gas is combusted by a submersion burner in a concrete or steel water bath to make hot water in the bath. LNG is vaporized by heat exchange between the hot water in the bath and LNG in the heat exchanger tubes. Being less economical than ORVs, these are commonly used for peak saving and as emergency backups in Japan. Other vaporizers in addition to the above include air-fin types that use air-finned heat exchangers and hot water types that use shell and tube heat exchangers.

(b) Caloric value adjustment facilities

The caloric value of city gas is adjusted to the standard caloric value by mixing LPG or vaporized LPG with LNG or vaporized LNG. There are three ways of adding LPG to LNG to adjust the caloric value: the gas-gas (G/G) method, which mixes vaporized LNG and vaporized LPG; the liquid-gas (L/G) method, whereby LPG is mixed with vaporized LNG; and the liquid-liquid (L/L) method, which mixes LNG and LPG. The L/L method is the most economical, because vaporization facilities using this method can also be used to adjust the caloric value without any other equipment. The next cheapest is the L/G method, which does not require LPG vaporization, followed by the G/G method, which requires such vaporization.

(c) Odorization facilities

Odorant is added so that city gas can be quickly detected in the event of a leak. It is injected by pumps or drip into city gas pipelines. In Japan, odorization is a statutory requirement imposed on the city gas industry.

(d) Use of cold energy of LNG

About 840 kJ/kg of cold energy is normally contained in LNG, and effective use of such a vast amount of energy has long been studied. The main practical applications of cold energy are in BOG reliquefaction, air separation, and refrigerated warehousing, where it contributes to energy savings and cuts in CO_2 emissions. LNG is vaporized using cold energy, and the vaporized LNG is used to make city gas. Use of LNG cold energy thus also saves energy and reduces CO_2 emissions in city gas production.

2.4 LP Gas

The number of customers for LP gas is nearly the same as that for natural gas. Around 80 % of LP gas consumed in Japan is imported, and 20 % is generated domestically by refined crude oil. This gas in an underground gas layer exists as a mixture with other gas species, such as methane and ethane. Therefore it should be separated from the mixture and refined by removing impurities before its distribution as LP gas. LP gas dissolved in crude oil is separated and extracted from oil during petroleum refining.

2.5 Transport

LNG can be transported in several ways, such as tank lorries and tank containers, to satellite bases for distribution. Gas pipelines are the primary means of this distribution in Japan, where there are two types of pipelines. One is for the transport of natural gas produced in domestic gas fields. The other is for the transport of city gas produced in LNG terminals to areas of demand. The latter pipelines are primarily operated by city gas utilities. Table 1 lists the extent of these gas pipelines according to the Gas Industry Handbook published in 2013 [4]. Highly

Table 1 Total length of gas pipelines installed by city gas business entities [8]

	High	Medium	Low
Pressure level	≥1 MPa	<1 MPa, ≥0.1 MPa	<0.1 MPa
Total length	2220 km	32,644 km	250,649 km
Main role	Transport	Transport and distribution	Distribution
Material	Steel	Steel, cast iron	Steel, cast iron, polyethylene

earthquake-resistant polyethylene pipes are used for ~40 % of low-pressure (≤0.1 MPa) gas pipelines.

Historically, gas pipelines managed by city gas utilities were constructed over long periods, mainly driven by potential demand and private-sector businesses. As a result, the pipeline network has become extensive and based on LNG terminals, and LNG has become an important source of energy for households, consumers, and industrial applications in urban areas. However, it cannot be said that the development of these pipelines is progressing well.

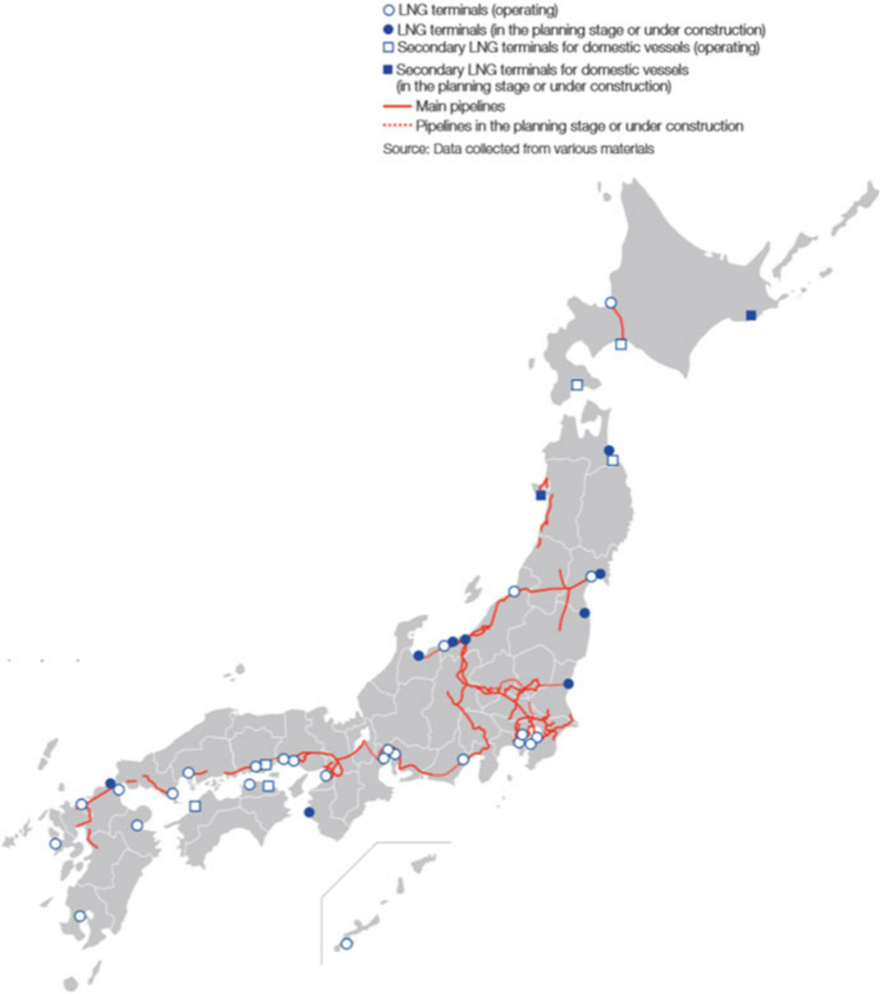
Figure 11 shows pipeline construction conditions for high-pressure (≥1 MPa) gas pipelines in Japan that were primarily built for transport [5]. Although some regions have high-pressure gas pipelines connecting metropolitan areas, pipeline networks of each gas operator have been established separately, and standardization or unification of their specification (such as diameter) has not been achieved. Construction of gas pipelines to connect LNG terminals and main metropolitan areas has not progressed. Therefore, it cannot be said that present gas pipeline networks have sufficient robustness to secure gas supplies for large-scale demand areas in case of emergency.

Gas pipelines in Europe differ greatly from those in Japan in terms of density and network maturity. Those pipelines, connecting gas fields and consumption areas, have been established to secure a stable supply of natural resources. These have not been built in Japan. Even though a pipeline has been envisaged to transport natural gas produced at Sakhalin to Japan, such a project has not materialized.

2.5.1 Case of LP Gas

Imported and domestically produced LP gas is transported by coastal tanker ships and tank lorries from primary to secondary facilities, which are operated by import traders and wholesalers, respectively.

For residential use, LP gas is filled into compressed gas cylinders and distributed by other retail sellers, so this gas is used as a fuel in areas without gas pipelines.



Source: Data collected from various materials

Fig. 11 Route map of high-pressure (≥1 MPa) gas pipelines in Japan [9]

2.6 Gas Meters

2.6.1 Overview

Japan imported all its gas meters until early in the Meiji period, 1868–1912. In 1904, the country developed its own gas meter (type A). Since then, this model has been modified and improved by manufacturers (changing the type from A through B and C and H to T). In 1969, when natural gas was first introduced in the country, the Japan Gas Association standardized the gas meter, and, accordingly, the type N meter was developed. In 1983, microcomputer-controlled gas meters called

“Micom Meters” for residential customers (see section below on their safety functionality) were developed to ensure safe gas operation. This meter was capable of detecting earthquake waves or abnormal gas flow rates; once detected, it blocks the flow of gas. Among these meters, types NB and NS (the latter adding telecommunication functionality) are the most common at present.

Manufacturers have furthered new developments in the gas measurement method of the diaphragm gas meter, and the ultrasonic gas meter entered use in 2005. This meter uses the difference in propagation times of ultrasonic waves in the gas flow to measure its rate. At locations such as industrial plants where the gas consumption rate is high, rotary, turbine, and vortex flowmeters are used instead of diaphragm gas meters.

2.6.1.1 Safety Functionality of Micom Meters

Micom Meters have various built-in sensors and a shutoff valve. The gas flow is blocked automatically during the situations listed below. When the gas flow is blocked, the user must manually restore the meter, and the gas can be used after the built-in microcomputer confirms that it is safe to operate. Gas is shut off in the event of a strong earthquake, with intensity equivalent to 5 or greater on the Japanese seismic scale.

1. The gas remains on for a long period, for reasons such as forgetting to turn off the equipment.
2. The gas hose detaches, or there is a problem in the piping, and a large amount of gas flows immediately.
3. An obstacle blocks the gas supply, reducing gas pressure.

2.6.2 Types of Gas Meters and Their Characteristics

2.6.2.1 Diaphragm Gas Meter (Fig. 12)

This meter measures the actual amount of gas used. Within the meter are chambers of a certain volume, partitioned by rubber diaphragms. After the chambers are filled with gas and discharged, a crank mechanism converts diaphragm motion into rotary motion, and the coupled mechanical counter counts the number of revolutions and displays the value. The meter is highly reliable and has been used not only in Japan but all over the world. The meter is used to measure small rates of gas flow for households, up to a maximum flow rate of 120 m^3/h.

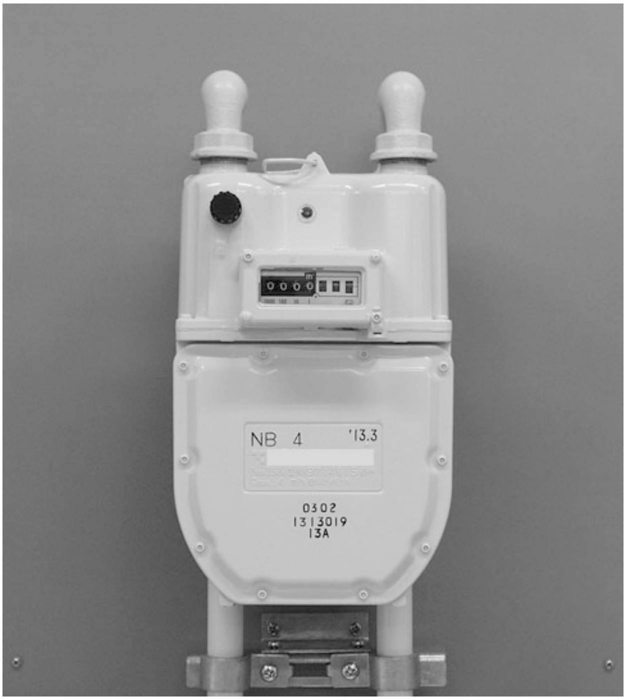


Fig. 12 Diaphragm meter (household use)

Fig. 13 Ultrasonic meter (household use)

2.6.2.2 Ultrasonic Gas Meter (Fig. 13)

This meter estimates the amount of gas used. It transmits ultrasonic waves through the gas flow channel and detects differences in propagation times of these waves to measure flow speed. It thereby computes the volume of gas used and displays the value. The compact size of this meter was achieved using the ultrasonic sensor for measurements. This also enables instantaneous measurement of flow rates. The meter is used to measure gas flow rates up to 6 m^3/h for household use and between 200 and 4000 m^3/h for industrial use (at medium gas pressure).

2.6.2.3 Rotary Meter

The rotary meter measures the actual amount of gas used. Precise measurement is possible because two rotors directly measure the volume of the gas flow. Instrumental error has not changed significantly over the years because the rotors and body of the meter do not make contact. The meter is capable of measuring gas flow rates up to 2000 m^3/h (at low and medium gas pressures).

2.6.2.4 Turbine Meter

This meter measures the volume of gas flow by counting the number of rotations of a bladed rotor within the gas flow channel. Gas volume is measured using only the bladed rotor, which makes the body of the meter small and light. This also allows precise measurement. The meter is capable of measuring flow rates up to 4000 m^3/h (at medium gas pressure).

2.6.2.5 Vortex Flowmeter

Theodore von Kármán discovered in 1911 that when a pillar is placed in a flowing medium, a repeating pattern of swirling vortices is formed in the downstream direction. The volume of gas flow in this meter is measured by counting these vortices. The simple structure of the meter allows a small and light body and precise measurement. The meter is capable of measuring flow rates up to 7500 m^3/h (at medium and high gas pressures).

3 Technology Road Map

We have classified the infrastructure of gas energy, one of the core energies in Japan, into the three categories of production, transport, and metering and described present and future states of the technology. Future states of gas energy will be tied to the advancement of many energy technologies. We hope that the following description of gas energy infrastructure improves the energy technology road map.

1. Response to trend toward diversification and lower caloric value of LNG

   The downward trend in LNG caloric value is being accelerated by rising output of LNG from shale gas, coalbed methane, and other unconventional natural gas projects. In the United States, numerous LNG projects (including shale gas) are being pursued, and Japan is set to begin importing from those in 2017.

2. Action on aging facilities

   Because some 45 years have elapsed since Japan began importing LNG, further investigation and implementation of steps to counter the aging of all types of LNG facilities will become necessary. More specifically, technologies to assess aging facilities, extend their useful lives, and upgrade large-scale plants must be developed.

3. Wide-area gas pipelines

   Considering construction costs and recovery of investment, wide-area gas pipelines clearly cannot be realized solely on the initiative of private-sector companies as before. Approaches to accelerate the construction of gas pipelines have been investigated for projects related to increasing the robustness of the industrial energy infrastructure [3, 10, 11]. As reported in the “List of Officials of Agency for Natural Resources and Energy (2014)” [12], deregulation has been broached as one measure for promoting robustness from an institutional aspect, via the construction of these pipelines. Support measures include the national government (a) exerting initiatives related to pipeline construction, (b) granting rights for gas pipelines to pass through agricultural land, and (c) introducing funding incentives like subsidies and interest waivers, which will be effective for constructing wide-area gas pipelines.

   Gas pipeline construction is more advanced overseas, so examples and lessons from other countries can be used to overcome technical challenges in Japan. Although high-strength steel pipes, undersea pipelines, and design factors local to construction sites are effective approaches for accelerating pipeline construction, all these have little or no proven record in Japan. Technical study is necessary to introduce these practices. In such a study, it is necessary to consider the unique characteristics of Japan, such as gas pipelines buried in earthquake-prone regions and densely populated cities.

4. Prevalence of smart gas meters

   There is increasing need for remote meter reading, because many residences are now using advanced home security systems. Thus, entering these houses and buildings for the inspection of gas meters has become challenging. For example, certain apartment buildings have automatic security lock systems, which require permission from a resident before entry. Furthermore, it is believed that demand will increase for services that emphasize security and safety or that permit monitoring of solitary or senior citizens through their gas use. Saving energy is another important consideration.

   To meet all these expectations, a smart gas meter is being developed to provide telecommunications functionality, remote switching systems, and detection systems that can acquire information on the amount of gas used per time zone.

4 Benefit and Future Vision

4.1 Production

Because LNG gas pricing for recent projects has been linked to the US Henry Hub price rather than JCC (Japanese Customs-Cleared Crude Oil), procurements from these projects are likely to increase because of the greater diversity of pricing mechanisms anticipated.

Advances must be made in LNG mixing technology to furnish the flexibility to receive the many types of LNG. Using simulations and actual testing on LNG tanks, the main challenges in the near future will be to clarify conditions required to mix LNG of variable densities in LNG tanks with various mixing capabilities and to enable mixing of LNG in LNG tanks without such capabilities.

4.2 Transport

Even in 2050 (the target in the third edition of the *Energy Roadmap*), natural gas is expected to be an important source of energy in Japan, and gas pipelines are anticipated to continue to be the primary method of natural gas transport. City gas utilities are actively pursuing construction of gas pipelines to meet the tremendous demand for natural gas and improve energy security [13]. In addition, as shown in the New Strategic Energy Plan of June 2014 [4], because a stable supply of energy is the foundation of energy policy, enhancing the robustness of the natural gas supply system is a major challenge. As shown in Fig. 14 and discussed in "Working for Gas Infrastructure Development" [14], it has been clearly demonstrated that wide-area gas pipelines that connect metropolitan areas and LNG bases effectively increase the robustness of the natural gas supply system.

4.3 Smart Gas Meters

To achieve the functionalities of smart gas meters, a telecommunications network is required that connects individual meters to a centralized control center, where information from each household is managed. The telephone line was once used for this purpose, but with new technological advancements such as cellular phones and the Internet, the telecommunications method for individual households has become much more diverse and liable to variation. Therefore, a method that does not depend on the telephone line has become necessary.

Consequently, infrastructure that uses radio communications is being developed to facilitate the use of smart gas meters (Fig. 15). Through this type of system, energy consumption data can be collected in detail. The collected data will be useful for

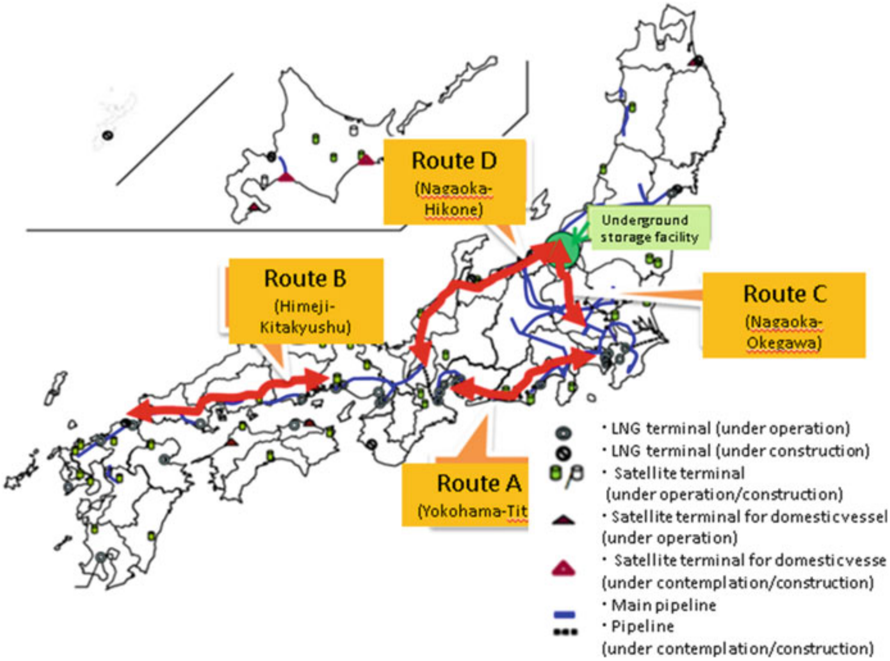


Fig. 14 Concept of wide-area transport gas pipelines to enhance energy security [12]

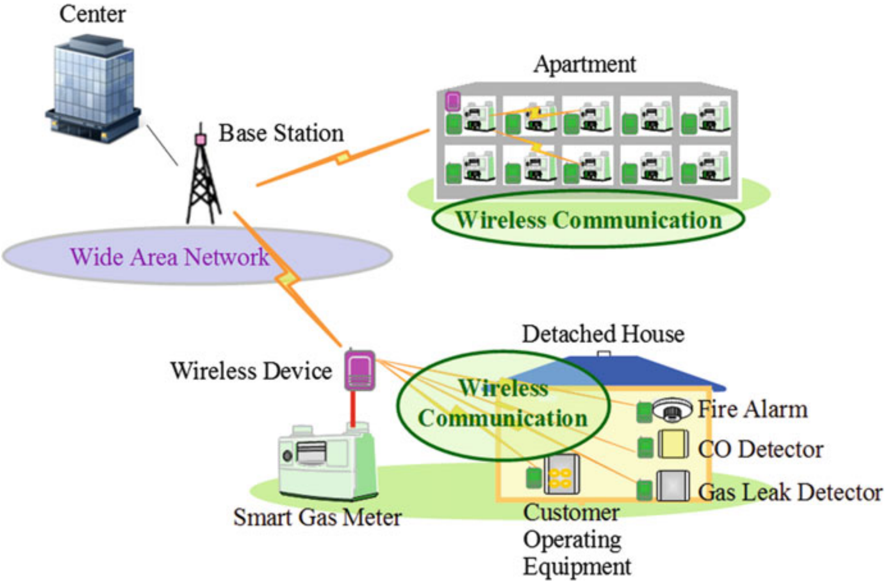
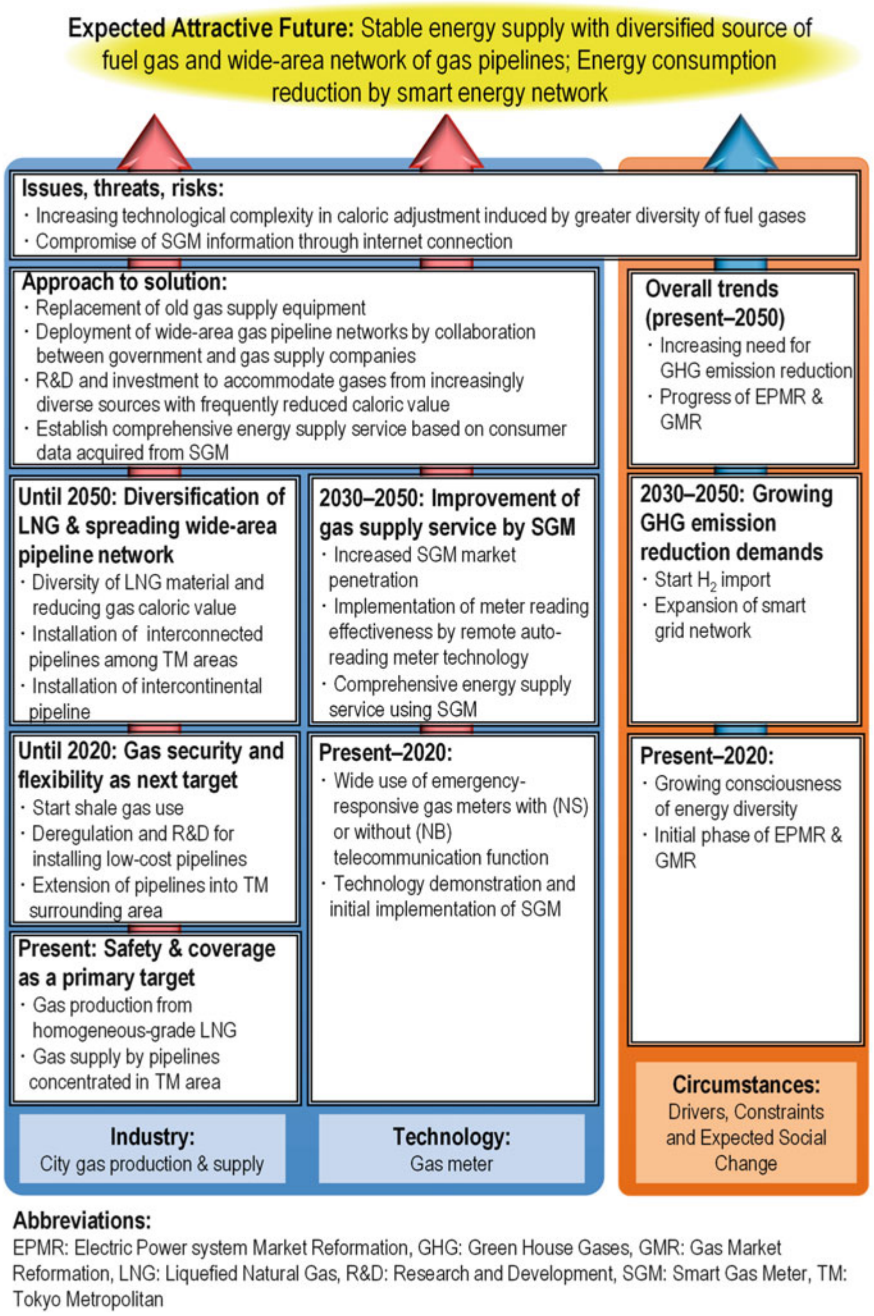


Fig. 15 Schematic illustration of remote meter-reading system



Expected Attractive Future: Stable energy supply with diversified source of fuel gas and wide-area network of gas pipelines; Energy consumption reduction by smart energy network

Issues, threats, risks:
- Increasing technological complexity in caloric adjustment induced by greater diversity of fuel gases
- Compromise of SGM information through internet connection

Approach to solution:
- Replacement of old gas supply equipment
- Deployment of wide-area gas pipeline networks by collaboration between government and gas supply companies
- R&D and investment to accommodate gases from increasingly diverse sources with frequently reduced caloric value
- Establish comprehensive energy supply service based on consumer data acquired from SGM

Until 2050: Diversification of LNG & spreading wide-area pipeline network
- Diversity of LNG material and reducing gas caloric value
- Installation of interconnected pipelines among TM areas
- Installation of intercontinental pipeline

Until 2020: Gas security and flexibility as next target
- Start shale gas use
- Deregulation and R&D for installing low-cost pipelines
- Extension of pipelines into TM surrounding area

Present: Safety & coverage as a primary target
- Gas production from homogeneous-grade LNG
- Gas supply by pipelines concentrated in TM area

Industry: City gas production & supply

2030–2050: Improvement of gas supply service by SGM
- Increased SGM market penetration
- Implementation of meter reading effectiveness by remote auto-reading meter technology
- Comprehensive energy supply service using SGM

Present–2020:
- Wide use of emergency-responsive gas meters with (NS) or without (NB) telecommunication function
- Technology demonstration and initial implementation of SGM

Technology: Gas meter

Overall trends (present–2050)
- Increasing need for GHG emission reduction
- Progress of EPMR & GMR

2030–2050: Growing GHG emission reduction demands
- Start H_2 import
- Expansion of smart grid network

Present–2020:
- Growing consciousness of energy diversity
- Initial phase of EPMR & GMR

Circumstances: Drivers, Constraints and Expected Social Change

Abbreviations:
EPMR: Electric Power system Market Reformation, GHG: Green House Gases, GMR: Gas Market Reformation, LNG: Liquefied Natural Gas, R&D: Research and Development, SGM: Smart Gas Meter, TM: Tokyo Metropolitan

Fig. 16 Road map for gas supply infrastructure

multiple services, such as remote meter reading, remote control shutoff valve opening and closing, security, safety, monitoring services, and others.

References

1. Energy white paper, website by METI. http://www.enecho.meti.go.jp/about/whitepaper/2014pdf/
2. Energy Supply and Demand Policy Office, General Policy Division, Commissioner's Secretariat, Agency for Natural Resources and Energy (2014) the New Strategic Energy Plan
3. Working Group for Gas Infrastructure Development (2011) Report on Working for Gas Infrastructure Development
4. Japan Gas Association (2014) Gas facts in Japan 2013
5. British Petroleum (BP) Statistics 2013 (Data for fifth meeting of the Strategic Policy Committee of the Agency for Natural Resources and Energy) (2013)
6. GIIGNL (2014) The LNG Industry 2013
7. Sumitomo Precision Products Co., Ltd.
8. The Japan Gas Association (2013) the Gas Industry handbook
9. Tokyo Gas (2014) Annual Report of Tokyo Gas
10. The Advisory Committee for Natural Resources and Energy, Coordination Subcommittee, and Subcommittee on the Establishment of Infrastructure for a Natural Gas Shift (2012) Report on the Advisory Committee for Natural Resources and Energy, Coordination Subcommittee, and Subcommittee on the Establishment of Infrastructure for a Natural Gas Shift
11. Kanto Bureau of Economy, Trade and Industry (2014) Forum of for energy infrastructure resilience
12. List of Officials of Agency for Natural Resources and Energy (2014) Investigation into the enhancement of trade and energy infrastructure resilience
13. HP of Oval Corporation: https://www.oval.co.jp/techinfo/keisoku/vortex.html
14. The Japan Gas Association (2012) Report on Earthquake Mitigation Program of supplying city gas based on lessons from the 2011 Great East Japan Earthquake