



Asia-Pacific
Economic Cooperation

APEC Oil and Gas Security Studies

Superiority of LPG A Disaster-Resistant Energy Source



Energy Working Group



Series **9**

May 2017





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A Disaster-Resistant Energy Source**

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FOREWORD

Following the instruction from 11th APEC Energy Ministers' Meeting (EMM11) held in Beijing, China in September 2014, APERC has started implementing the Oil and Gas Security Initiatives in November 2014. Among the overarching pillars of OGSI is the conduct and publication of the Oil and Gas Security Studies (OGSS). The first six reports of OGSS was published in November 2015, which were circulated to the Energy Working Group (EWG) members and uploaded in the APEC and APERC websites. OGSS continues to undertake research activity and produce reports including this one.

The primary objective of the OGSS is to provide useful information to APEC economies on significant developments and vital issues related to oil and gas security, including individual economy's policies to address and enhance oil and gas security measures. I am hopeful that APEC economies will learn something from these OGSS research studies and will serve as an impetus for them to re-examine their policies, plans and programs to further strengthen their respective oil and gas supply security measures. The information from these studies may offer plausible approaches and options which the APEC economies could consider as an individual member in addressing any magnitude of supply disruptions or emergencies, as well as how APEC could deepen cooperation for possible region-wide energy security framework.

I would like to express my sincere gratitude to the authors and contributors for the OGSS for spending time and efforts in doing relevant research studies. However, I would like to emphasize that the contents and views in these independent research projects only reflect those of the authors and not necessarily of APERC. The contents and information from these studies might change in the future due to unforeseen external events, and the changes or improvements in the individual economy's policy agenda and framework on oil and gas security.

Finally, rest assured that APERC will continuously conduct OGSS to serve its purpose of aiding the governments and policymakers in APEC in addressing the oil and gas security issues in the region.

Takato OJIMI

President

Asia Pacific Energy Research Centre

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Introduction

The use of LPG in APEC economies is expected to grow significantly in the coming years mainly as a result of increasing household consumption. Due to its cleanness and the disaster-resistance of its supply and distribution system, LPG remains an important source of energy in Japan, especially in geographic regions where the infrastructure for supplying city gas by pipeline network is not yet fully developed.

This study outlines the characteristics of LPG as an energy source including its usability and environmental impacts, and also illustrates how LPG is being used and managed in Japan, including the public LPG storage schemes to ensure supply stability, control schemes for ensuring safety and security, and disaster responses and preparedness for ensuring a continuous LPG supply. It is hoped that this information will be useful for ensuring the safe use of LPG in other economies.

1. Current situation of LPG use in Japan

1.1 Importance of LPG in Japan as an energy source

Liquefied petroleum gas (LPG) is a type of gaseous fuel, the main components of which are low hydrocarbons with a carbon number of 3 or 4. LPG is also commonly referred to as simply propane or butane.

LPG is gaseous at room temperature and atmospheric pressure but, as its name suggests, can be easily liquefied by pressurization or cooling. In the liquefied state, the volume of LPG is approximately 1/250th of that in its gaseous state. Due to this excellent compactness, the fuel can be easily and conveniently handled for transportation, storage and consumption. In terms of physical properties, LPG fuel lies between liquid fuels such as kerosene and gasoline and gaseous fuels such as city gas.

In Japan, LPG started to be sold commercially around 1955. This was mainly due to the increased availability of LPG, which is a byproduct of the oil refining process, as a result of the rapid growth in oil production and the petrochemical industry. In the early days, the only available form of LPG was propane in cylinders for household and commercial use, and demand swiftly grew as an alternative to traditional fuels such as charcoal, coal lumps and briquettes. Butane, which is produced by the same process as propane, has also become popular, though more slowly than propane, as an industrial fuel.

In 1961, LPG began to be imported from Middle East countries to Japan in its product form. In 1962, LPG started to be used as a fuel for taxis.

Currently, LPG is used for a wide variety of purposes in Japan, most significantly as a household and commercial fuel but also as an industrial or automotive fuel, and for city gas production and chemical manufacturing. LPG accounts for 4% of the economy's primary energy consumption (approximately 16.6 million tons in 2012). As a household fuel, it is estimated that 24 million homes in Japan, approximately half the total number of households in the economy, use LPG. In the commercial sector, the food processing industry is the largest consumer of LPG. As an automotive fuel, approximately 250,000 vehicles (according to Japan LP Gas Association statistics), mostly taxis, use LPG fuel. It is clear that LPG plays a very important role in the Japan's economy.

1.2 Characteristics of LPG

(1) Environmental characteristics

With a sulfur content of 0.0050 wt% or less in general, low NOX emissions during combustion and easy manageability, LPG is a very environment-friendly fuel. In terms of global warming effect, it is one of the two fuels (the other is LNG) that generate the lowest amount of CO₂ over the entire life cycle from production to consumption (Figure 1).

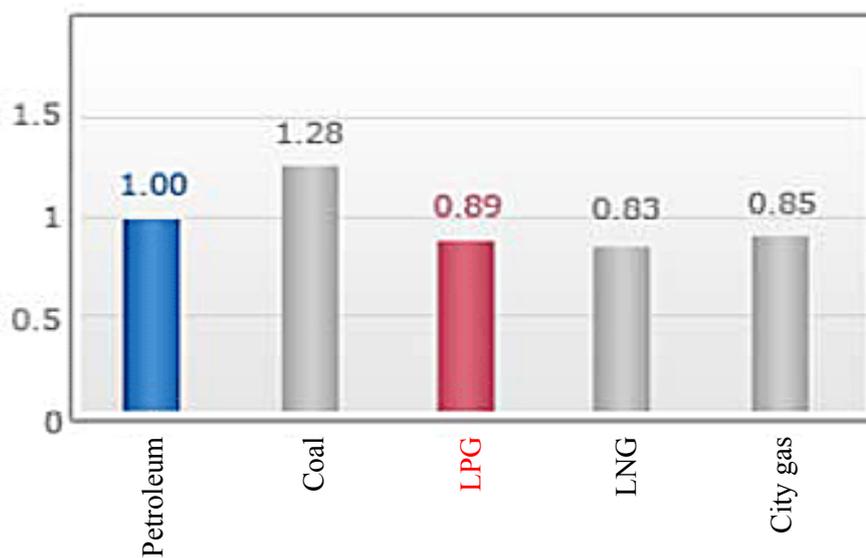
(2) Transportability

LPG is transported and stored in rigid cylinders and tanks in its liquid form (in the liquefied state, the volume of LPG is approximately 1/250th of that in its gaseous state), to be gasified later at the point of consumption. This excellent compactness leads to good transportability, which facilitates distribution and consumption in geographic regions without infrastructure for supplying city gas.

(3) Combustibility

LPG has a calorific value of approximately 99–128 MJ/Nm³, which is much higher than those of most other gaseous and liquid fuels. The good combustibility when gasified, in addition to easy conversion from the gaseous state (which is the state of the fuel at room temperature and atmospheric pressure) into the liquid state through pressurization or cooling, enables LPG to be used with a wide variety of readily-available equipment and systems, which is also advantageous for saving energy.

Figure 1. Comparison of CO₂ emissions of various fuels over the production-to-consumption life cycle



Note: Shown are emission factors per unit of heat, based on the crude oil value of 1.

Source: Japan LP Gas Association website

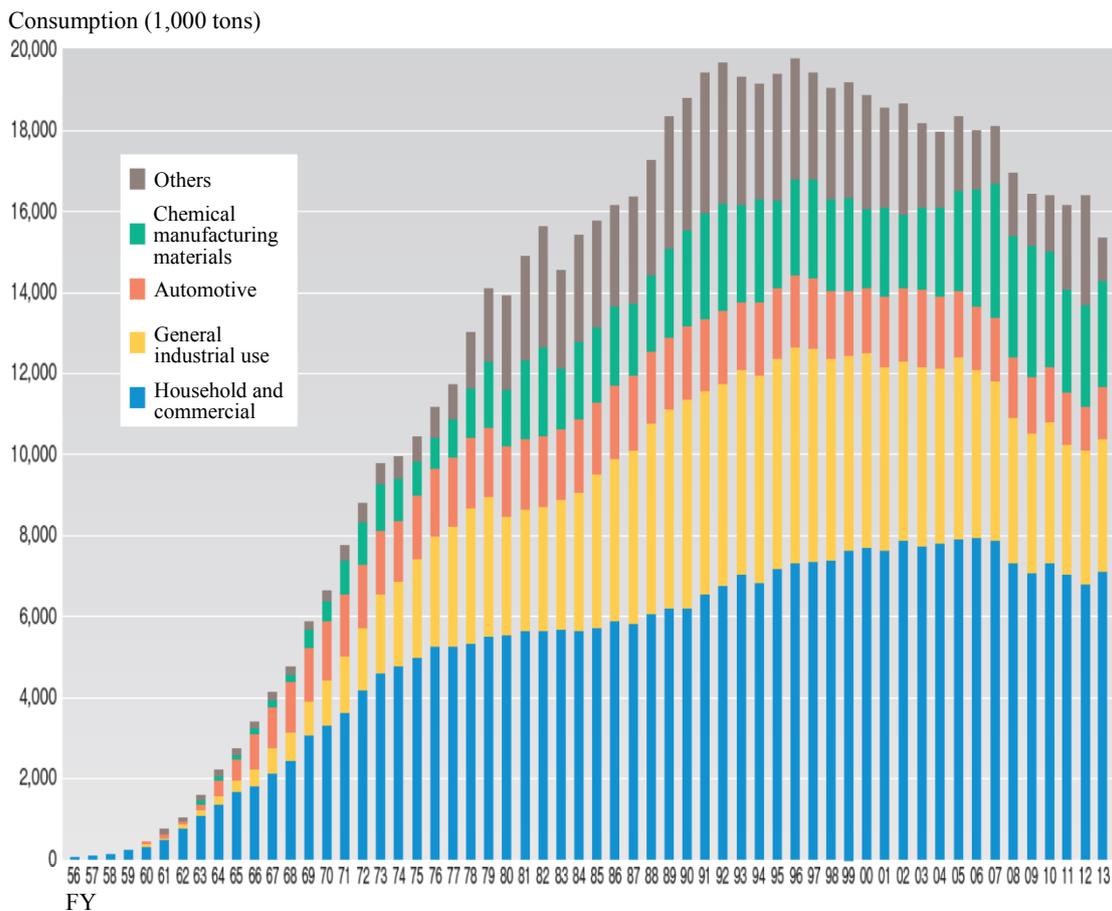
1.3 Supply and demand in Japan

The first recorded use of LPG as a fuel in Japan was in 1929, when the famous Zeppelin airship visited Japan. At that time, LPG was used as a fuel for the screw propeller engine.

Around 1953 LPG started to be used as a household fuel in the economy. Due to its easy manageability and high calorific performance, LPG use grew rapidly to replace wood and coal lumps and briquettes, which were the dominant household fuels at the time.

LPG consumption grew further with increased usage for industry and automobiles (the latter mostly as a fuel for taxis), while household and commercial use still accounted for the majority. After a temporary dip due to the oil crisis in the 1970s, LPG consumption reached a peak of 19.7 million tons in 1996. However, consumption decreased thereafter, most significantly in industrial sectors due to the economic slowdown of the economy. The current consumption stands at approximately 14.73 million tons (in FY 2015).

Figure 2. Consumption trend



(Source: Japan LP Gas Association)

Table 1

LPG supply and sales volumes

Unit: 1,000 tons

	Propane				Household and commercial (included in total sales)	
	Production	Import	Total supply	Total sales	1,000 tons	%
1990	2,221	8,001	10,222	10,111	7,538	74.6
2000	2,535	10,312	12,847	12,498	9,356	74.9
2010	2,505	9,315	11,820	11,948	8,847	74.0
2011	1,710	9,559	11,269	11,790	8,616	73.1
2012	1,688	10,012	11,700	11,867	8,266	69.7
2013	1,798	8,965	10,763	11,290	8,044	71.2
2014	1,720	9,179	10,899	11,431	7,901	69.1
2015	1,690	8,612	10,302	11,146	7,635	68.5

	Butane				Household and commercial (included in total sales)	
	Production	Import	Total supply	Total sales	1,000 tons	%
1990	2,273	6,280	8,553	8,832	3	0.0
2000	2,077	4,539	6,616	6,924	3	0.0
2010	1,502	3,012	4,514	4,540	8	0.2
2011	1,088	3,073	4,161	4,615	4	0.1
2012	1,036	3,177	4,213	4,704	2	0.0
2013	1,180	2,442	3,622	4,215	2	0.0
2014	847	2,331	3,178	3,963	0	0.0
2015	1,183	1,928	3,111	3,588	0	0.0

	Propane-butane blend				Household and commercial (included in total sales)	
	Production	Import	Total supply	Total sales	1,000 tons	%
1990	4,494	14,281	18,775	18,943	7,541	39.8
2000	4,612	14,851	19,463	19,422	9,359	48.2
2010	4,007	12,327	16,334	16,488	8,855	53.7
2011	2,798	12,632	15,430	16,405	8,620	52.5
2012	2,724	13,189	15,913	16,571	8,268	49.9
2013	2,978	11,407	14,385	15,505	8,046	51.9
2014	2,567	11,510	14,077	15,394	7,901	51.3
2015	2,873	10,540	13,413	14,734	7,635	51.8

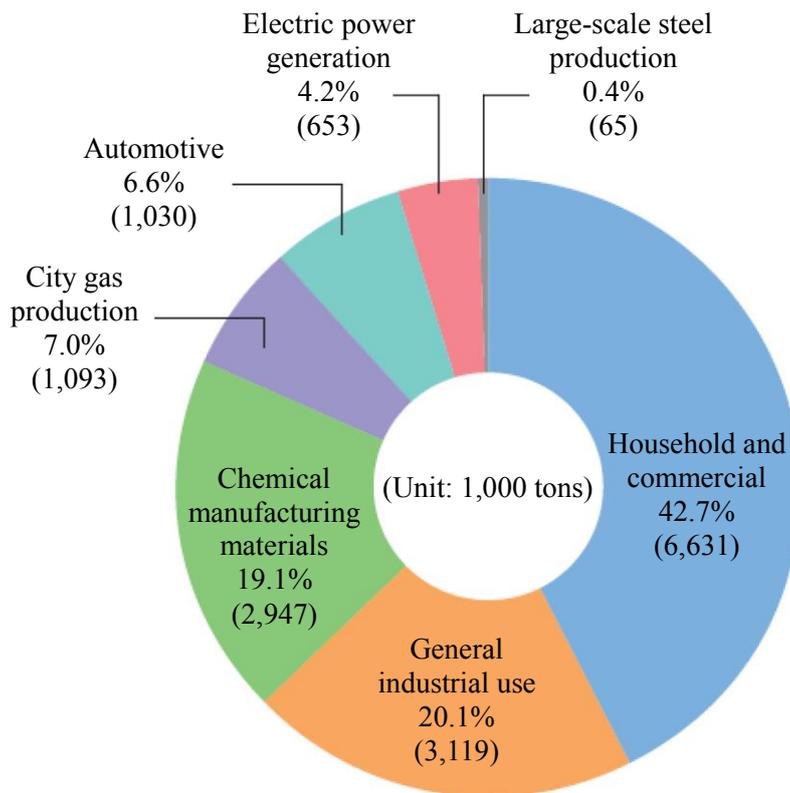
Source: Compiled by the Oil Information Center based on Ministry of Economy, Trade and Industry statistics

1.4 Uses of LPG

Currently, LPG is used for a wide variety of purposes in Japan, including as a household, commercial, automotive and industrial fuel, and for chemical manufacturing, city gas production and electric power generation. LPG accounts for approximately 4.6% of final energy consumption of the economy (2012 actual value).

Household and commercial use accounts for 42.7% of consumption, making it the largest category of consumption, followed by 20.1% for industrial fuel and 19.0% for chemical manufacturing. Most of the automotive consumption is as a fuel for taxis, while usage for chemical manufacturing is mainly for making ethylene, propylene and other chemical products. In city gas production, LPG is mixed in to adjust the calorific value. The electric power industry uses LPG as a backup fuel for electric power plants.

Figure 3



(Source: Japan LP Gas Association)

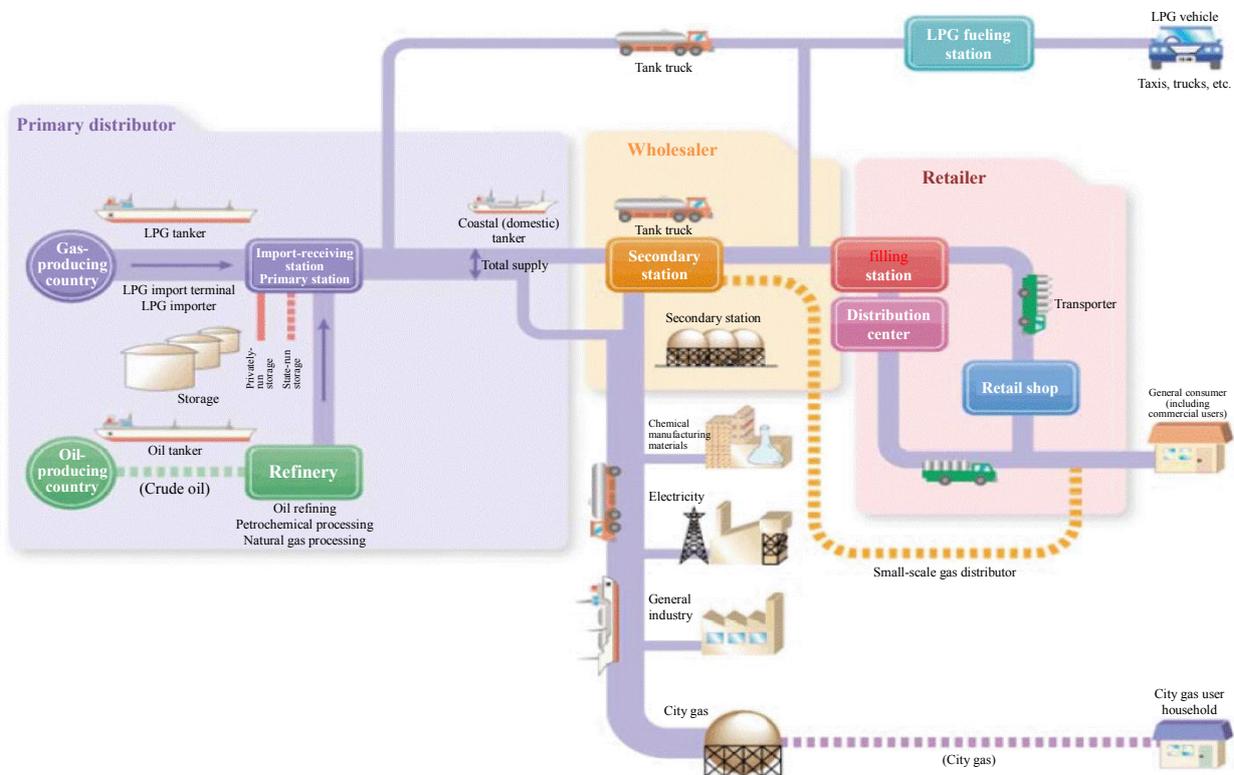
1.5 Logistics

LPG imports from overseas are transported by ocean tankers in the liquefied state at low temperature, to be delivered to and stored at import-receiving stations in Japan. Transportation from there to secondary stations located elsewhere in the economy is done by coastal (domestic) tankers, with the LPG stored in the pressure-liquefied state at room temperature. At the secondary station, LPG is loaded into tank trucks or other land transportation vehicles which then carry the fuel to local LPG-filling stations.

At the filling station, LPG is filled into smaller cylinders or tanks to be transported to end users. Alternatively, delivery to large-scale users may be done directly by a coastal tanker or tank truck.

The LPG supply chain in Japan is made up of primary distributors which import or produce LPG, wholesalers which fill LPG into cylinders and tanks, and retailers which deliver the filled cylinders and tanks to households and other end users. In recent years, there have been ongoing efforts to streamline the logistics to shorten and simplify this supply chain as much as possible. As a result, some households are now even receiving LPG cylinders filled at and carried directly from import-receiving stations.

Figure 4



Source: Japan LP Gas Association website

1.6 Sales chain

The LPG supply and sales chain in Japan is generally made up of three layers: producer-importers (primary distributors), wholesalers, and retailers.

1) Producer-importers (primary distributors)

A “producer-importer” of LPG may refer to an LPG branch or subsidiary of an oil company or oil alliance, or importers or traders specializing in the LPG business. These LPG producer-importers together form the Japan LP Gas Association (15 members as of May 2014). With approximately 75% of domestic demand supplied by product imports, any change in the LPG import volume and pricing can have a significant effect on the Japanese market. The remaining 25%, which is supplied by domestic production from crude oil, is also easily influenced by production volume fluctuations in the oil production and petrochemical industries.

2) Wholesalers

It is estimated there are about 1,100 LPG wholesalers in Japan. Each of these wholesalers typically has a dozen to several hundred affiliated local retailers.

3) Retailers

There are approximately 21,000 LPG retailers operating in the economy. All the LPG retailers in each prefecture form a prefectural LP gas association/society. There used to be three different national LPG trading associations: Japan LP Gas Federation, National LP Gas Wholesalers’ Association, and National LP Gas Station Association. The three associations merged in April 2009 into the present Japan LP Gas Association.

1.7 LPG sales transition from weight-based system to volume-based system

In the early days, sales of LPG in Japan were mostly weight-based, but consumers often complained that the sales system was confusing and should be changed to make it clearer and easier to understand. While the law required that the weighing of LPG in a weight-based sales system must be performed in the buyer's presence, consumers questioned whether the weighing was being done accurately and fairly, and whether or not and how any fuel remaining in the cylinder was checked. Many also complained that cylinders had been changed in their absence and they could not check the remaining fuel in the cylinder. Some were also skeptical about the quality of gas with new gas being added to the old gas remaining in the cylinder, or were critical of the whole system as being outdated compared to that for city gas.

These consumer opinions were a major factor leading to the mandating of gas meters. The LPG trading associations eventually gave in to strong consumer pressure and publicly announced their agreement to legislation mandating the use of gas meters (January 1972).

In parallel with these moves in the industry, the government, having completed a feasibility study, published on December 6, 1972 a "Ministerial Ordinance for LP Gas Law Amendment Concerning the Requirement for Gas Meter Use" to take effect in February 1973 with a grace period through March 31, 1975. With this, a volume-based, meter-controlled LPG sales scheme started in Japan.

With exceptions specified for small-volume users, sales in small cylinders of 20 liters (5 kg) or less in capacity, sales and supply to portable cylinders and tanks fitted to cars and moving retail vehicles, and other cases which the International Trade and Industry Minister deemed appropriate and harmless not to provide a gas metering mechanism, the whole economy became covered by the meter-based LPG sales system.

1.8 Differences between LPG and city gas

While LPG is a gaseous energy source like city gas, there are a number of important differences in their properties. The main component of LPG (household fuel type) is propane (C_3H_8) while that of city gas (13A) is methane (CH_4). Propane's calorific value per unit volume is more than twice that of city gas.

Due to this significant difference in calorific value, it is impossible to use the same cooking stoves or water heaters for both LPG and city gas; each fuel must be used in equipment specifically designed for it.

As propane can be easily liquefied and containerized and thus moved anywhere (non-rigid supply system) as described above, it is available throughout the economy. As shown in Figure 5, all of Japan is fully covered by the propane supply network.

On the other hand, city gas, which cannot be liquefied at room temperature, is distributed in the gaseous state primarily through permanently installed supply lines (rigid supply system). This limits the availability of city gas to urban areas where supply lines can be laid relatively easily (5% of the land area of Japan) while LPG can be transported and delivered to anywhere in the economy.

It should be noted, however, that there are more city gas users in the economy than LPG users. Currently, there are approximately 24 million LPG users served by about 20,000 distributors, while there are 29 million city gas users served by 203 distributors.

Table 2

	LPG	City gas (13A)
Main component	Propane (C_3H_8)	Methane (CH_4)
Calorific value	102 MJ/m ³	45 MJ/m ³
Specific gravity	1.5	0.6
Boiling point	-42°C	-162°C
Supply system type	Non-rigid supply system	Rigid supply system

Figure 5

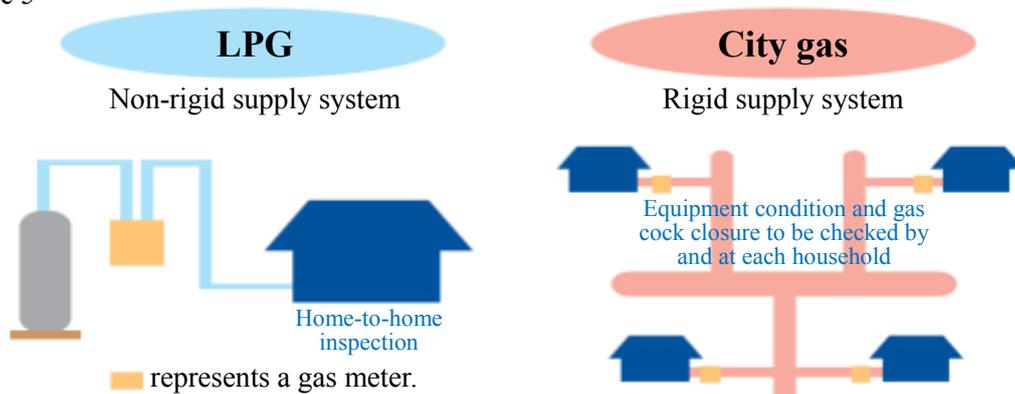
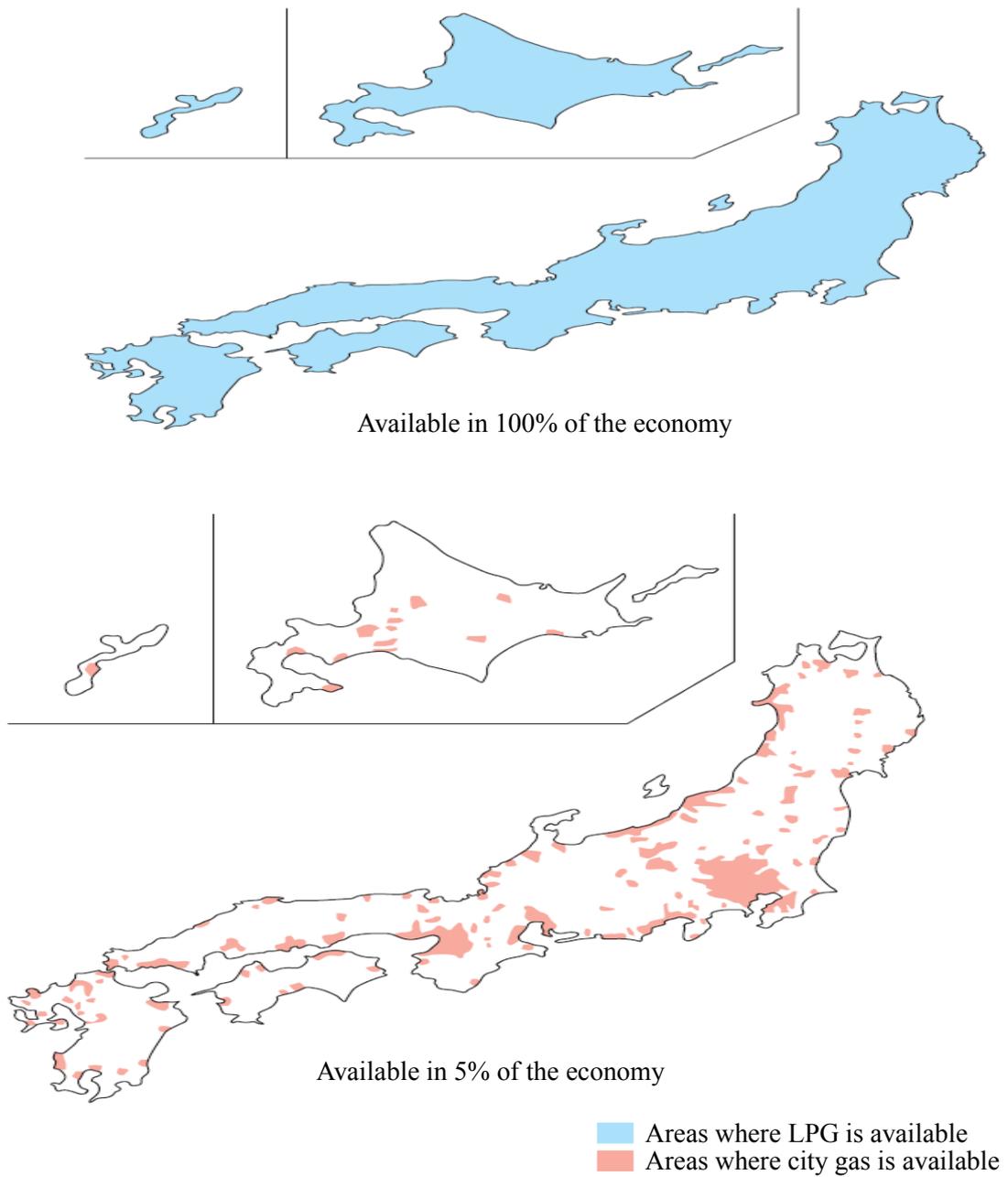


Figure 6. Availability by area



Source: Japan LP Gas Association

1.9 LPG storage

Currently, the law of Japan requires only two types of energy stockpiling —petroleum and gasoline—to be stored. This is mainly due to their almost complete dependence on supply from Middle East countries. Storages operated and maintained by private companies (but under legal obligation) are called “(statutory) private storages”, while those run by the government are called “government storages”. Japanese law requires that there shall be a total private storage volume equivalent to 50 days of imports.

In addition, five state-run LPG storage stations, located in various parts of the economy, were completed in March 2013, with LPG storage volume gradually being increased over a period of several years. When all of those stations are fully loaded, the total government LPG storage will be approximately 1.5 million tons. Added to existing private storages, the economy will then have a total of 3.1 million tons of LPG storage, equivalent to 90 days of imports. These storages are intended for use in emergencies, such as a disruption of supply from producing economies or after earthquakes and other major disasters.

After the Great East Japan Earthquake, the supply of LPG that had been stored in the Kamisu Station significantly helped stabilize the fuel supply in the economy.

Figure 7. State-run storage stations

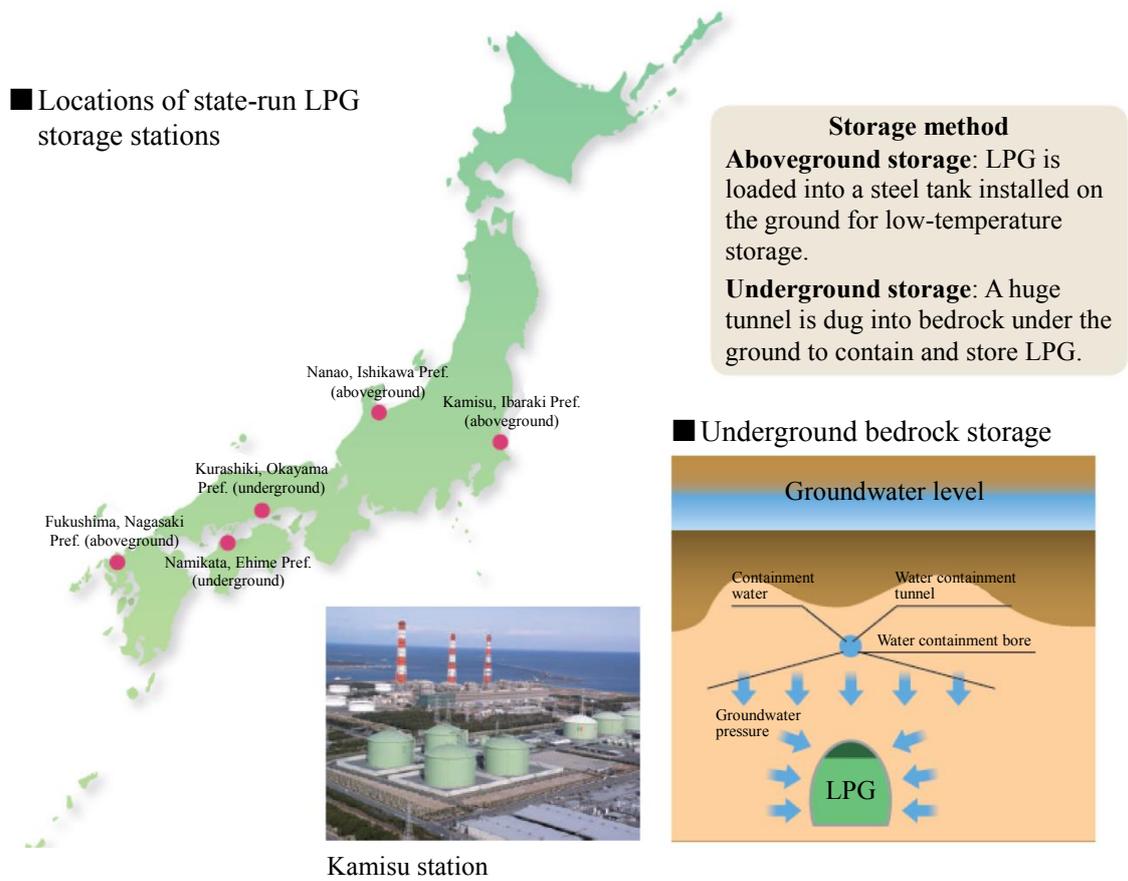
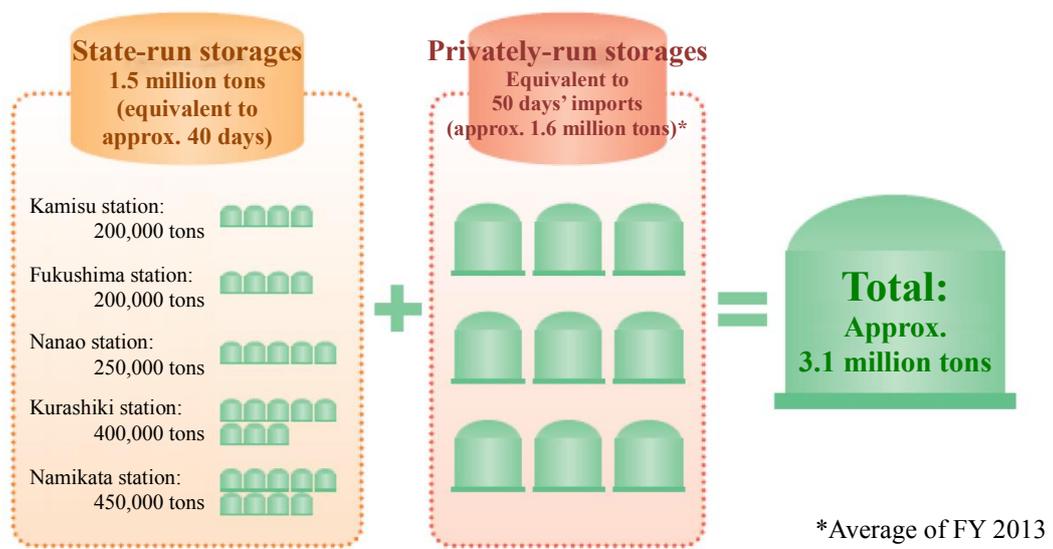


Figure 8. State- and privately-run LPG storage volumes



2. Safety measures

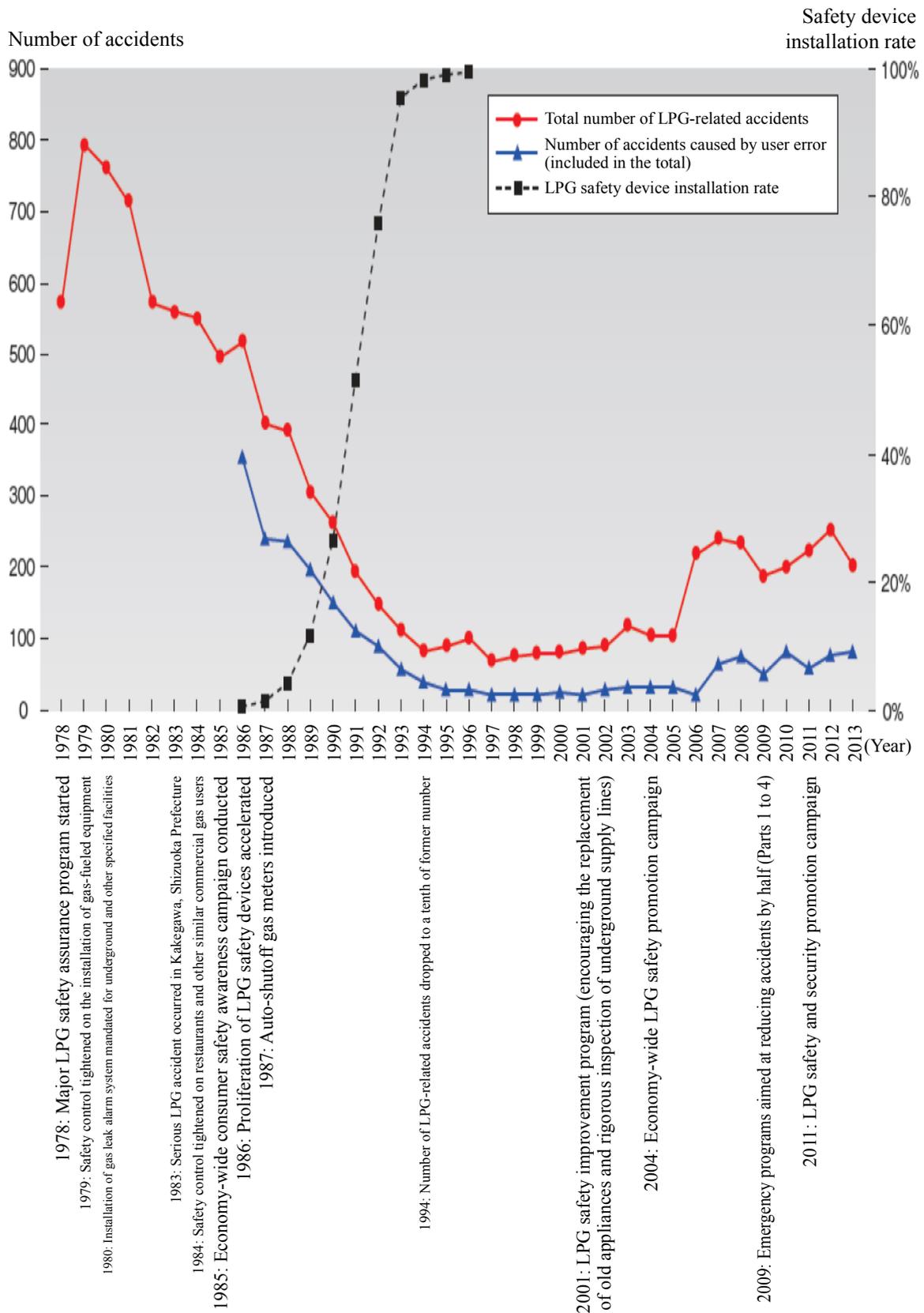
2.1 Overview

LPG started to be widely used as a household fuel in Japan from around 1952. The use of LPG has continued to spread ever since, and is now used by approximately 24 million homes in the economy.

Factors contributing to the widespread use include the 1967 enactment of the “Act on the Securing of Safety and the Optimization of Transaction of Liquefied Petroleum Gas”, voluntary safety assurance efforts by distributors since the beginning of LPG commercialization, and the economy-wide proliferation of safety devices including auto shutoff gas meters^{*1} and gas-fueled appliances with advanced safety protection features. These factors are all building blocks of the comprehensive LPG safety assurance system that is in place in Japan today.

The current LPG accident rate is 0.82 cases/100,000 households, with only 0.015 deaths per case (2013 actual values). This is a very low figure compared to the number of deaths due to “general accidents at home”^{**2}, which stands at 27 deaths per 100,000 households (2013 actual value, based on a Japan LP Gas Association survey).

Figure 9. Number of LPG-related accidents vs. proliferation of LPG safety devices



Source: Japan LP Gas Association

2.2 History of LPG safety assurance efforts

1969: LPG Accident Prevention & Safety Assurance Committee formed

This Committee was formed jointly by LPG gas trade associations, governmental bodies and consumer groups to accelerate the proliferation of technical safety assurance knowledge and safety awareness among LPG users.

1978: Economy-wide LPG equipment inspection program commenced

This major safety assurance program was started under a joint initiative of the government and LPG industry. The target of the program is to fully inspect all households and other LPG-fueled equipment used throughout the economy in a two-year period, and to remedy the identified problems in the following year.

To support this program, the then Ministry of International Trade and Industry (now Ministry of Economy, Trade and Industry) amended part of the “Act on the Securing of Safety and the Optimization of Transaction of Liquefied Petroleum Gas (LPG Act)” and also introduced subsidies for safety measures.

With the amendment of the LPG Act, distributors became obliged to fully inform consumers of important knowledge concerning the safe use of LPG and also to duly inspect all gas supply and consumption equipment. In addition, governmental notices were issued specifying a voluntary inspection checklist for distributors. These moves were all part of an economy-wide drive toward improved LPG safety.

1979: Safety control tightened on the installation of gas-fueled equipment

To reduce accident risks due to gas emissions and other hazards, the “Act concerning Supervising Installation Work of Specified Gas Appliance”, intended to tighten the safety control on the installation of and other works on city gas, LPG and other specific gas-fueled equipment, was enacted.

1980: Installation of gas leak alarm system mandated for underground and other specified facilities

In response to a major city-gas explosion that occurred in an underground shopping mall near Shizuoka train station, new safety standards were introduced governing fuel gas safety in underground and other specific locations.

These standards made it mandatory to install a gas leak alarm system in underground and other commercial facilities as well as in apartment buildings. At the same time, LPG started to be supplied with stronger odorants to make it easier to notice gas leaks.

1981: Installation of tip-over gas shutoff device mandated for open-type gas-fueled heaters

1983: Serious LPG accident occurred in Kakegawa, Shizuoka Prefecture

In 1983, which was around the time when the number of gas-related accidents started to decrease, a major LPG explosion and fire accident occurred at a recreational facility in Kakegawa, Shizuoka Prefecture, resulting in 14 deaths and 27 injured.

This accident occurred because a facility staff member opened an intermediate gas supply valve without fully checking all of the downstream terminal valves. As a result, gas leaked from a partly open terminal valve and caught fire, resulting in an explosion and blaze.

1984: Safety control tightened on restaurants and other similar commercial gas users

Based on the lessons from the above-described accident of the previous year, the LPG Act was further amended in 1984.

With the new amendment, restaurants and other similar commercial gas users were now required to use terminal gas cocks with an overflow protection mechanism (fused gas cocks) and to have a stronger connection for rubber hoses and the like. In addition, restaurants and other similar commercial gas users larger than a certain scale were required to appoint a designated safety/security contact person. Safety monitoring and guidance by government authorities were also strengthened.

1985: Economy-wide consumer safety awareness campaign conducted

In response to recommendations by the LPG Consumer Safety Measure Study Group, which was a private advisory body to the Director of the Industrial Location and Environmental Protection Bureau under the Ministry of International Trade and Industry, the LPG industry designated October as the “LPG Consumer Safety Promotion Month”, thereby starting a nationwide campaign to promote safety awareness among consumers.

In parallel with these consumer awareness efforts, a major publicity and education program regarding safety technology was commenced targeting LPG retailers as well as commercial and industrial users.

1986: Proliferation of LPG safety devices accelerated

In response to a series of new recommendations for specific safety device promotion measures and accident reduction target date proposal by the LPG Safety Device Proliferation Advisory

Body (a private advisory body to the Director of the Industrial Location and Environmental Protection Bureau under the Ministry of International Trade and Industry), a joint initiative between the LPG industry and the government was launched aiming to spread nationwide the “Three LPG Safety Devices (auto shutoff gas meter, fused gas cock, and gas leak alarm system)”.

While the official accident reduction target was set to reduce the number of LPG accidents to a fifth after five years and then to a tenth after ten years, the LPG industry, in a stronger push to improve safety, voluntarily moved up the target date for a 100% proliferation of the safety devices by three years, thereby aiming at 100% proliferation in seven years.

1987: Auto-shutoff gas meters introduced

In this year, a series of auto-shutoff gas meters with built-in microcontroller, which was a technology jointly developed by the safety device manufacturing industry and the High Pressure Gas Safety Institute of Japan, was commercialized. These new auto-shutoff gas meters significantly improved the safety of LPG users.

1989: Installation of incomplete combustion prevention device mandated for open-type gas-fueled compact water heaters

1997: LPG-fueled appliances and underground supply lines inspection program

In January 1996, the High Pressure Gas and Explosives Safety Council issued a “Safety Improvement Target” recommendation, which targeted eliminating all fatal LPG accidents by the end of 2000 and providing an environment where consumers can use LPG with no safety concerns. As part of the efforts to attain the target, the then Ministry of International Trade and Industry (now Ministry of Economy, Trade and Industry) adopted a “Comprehensive Safety Program for Preventing CO Poisoning”.

In line with the ministerial program, the LPG industry launched a full-scale inspection campaign for gas combustion equipment (water heaters, bath heaters, etc.) as well as a voluntary inspection and survey program of underground supply lines for better maintenance and management.

In 2001, the combustion equipment inspection program was replaced with a new program to promote the replacement of equipment with newer, safety device-fitted models.

2001: LPG safety improvement program

In December 2000, the Liquefied Petroleum Gas Subcommittee under the High Pressure Gas and Explosives Safety Council proposed a new “LPG Safety Improvement Program”, which, by

taking the ongoing safety efforts and the recent accident trends into consideration, promoted the renewal of combustion equipment and underground supply pipe inspection projects.

2003: Installation of incomplete combustion prevention device mandated for open-type gas-fueled compact room heaters

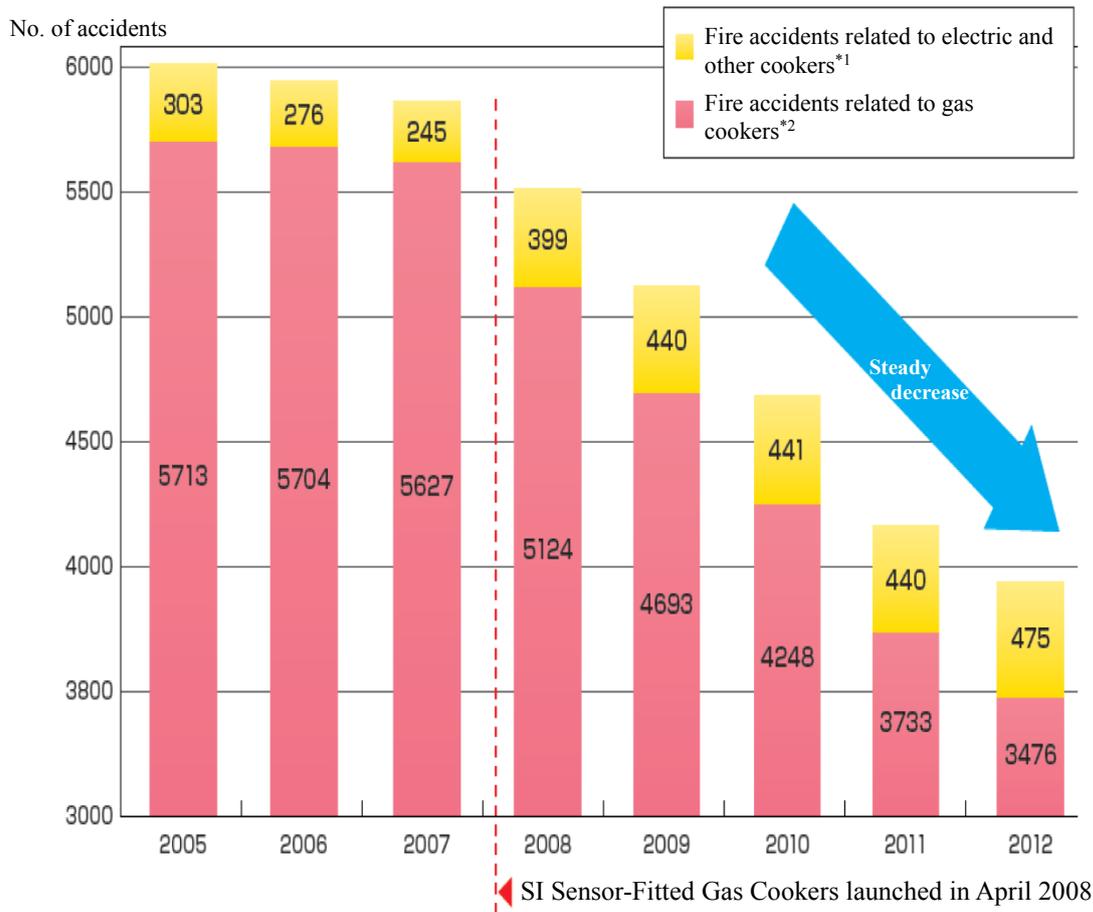
2004: Economy-wide LPG safety promotion campaign

The number of LPG accidents, after reaching an all-time low of 68 in 1997, which was only one tenth of the peak value, gradually increased again to 120 in 2003. To improve this situation and also to promote disaster preparedness against future earthquake risks such as the Tonankai and Nankai mega-earthquakes, the LPG industry, with governmental assistance, launched a voluntary nationwide LPG safety promotion campaign, which was planned and implemented over a period of six years.

The main themes of this campaign included the monitoring and controlling of the service life of LPG supply equipment (LPG pressure regulators, high- and low-pressure hoses and gas leak alarm systems), promotion of appliance renewal to models with built-in safety functions such as incomplete combustion prevention, misfire safety protection and tempura oil overheat protection, and promotion of voluntary underground pipe inspection.

A new legal amendment in October 2008 mandated the provision of specific built-in safety devices, such as cooking oil overheat prevention and misfire protection devices, on gas-fueled cooking heaters. At around the same time, the cooking equipment industry launched a family of “SI (Safety and Intelligence) Sensor-Fitted Gas Cookers”^{*3} that offered significantly better safety and greater convenience than existing gas cookers. The introduction of these innovative cookers to the Japanese market has greatly contributed to the reduction of gas-cooker-related fire accidents in recent years.

Figure 10. Number of gas cooker-related fire accidents



*1 Number of fire accidents related to electric or oil-, wood-, charcoal- or coal-fueled cookers

*2 Number of fire accidents related to gas-fueled cookers (including SI sensor-fitted models)

(Source: Fire Service White Paper” published by the Fire and Disaster Management Agency under the Ministry of Internal Affairs and Communications)

*1 Auto-shutoff gas meter with a built-in microcontroller

These gas meters will shut off gas supply upon detecting any of the following events:

- 1) An excessively high gas discharge rate
- 2) Gas appliance continuously left on for an abnormally long time (protection against users forgetting to turn the appliance off)
- 3) An earthquake
- 4) An abnormal drop in gas pressure



*2 The term “general accidents at home” refers to all kinds of accidents that occur on a household premises (including both indoor and outdoor areas).
(Source: “National Demographic Survey” published by the Ministry of Internal Affairs and Communications)

*3 Collectively refers to gas cooker models with, among others, the following functions:

- 1) Cooking oil overheat prevention
- 2) Misfire protection



2.3 Safety of household and commercial LPG supply equipment

The section of LPG equipment installed at a user site from the storage cylinder to the secondary side of the gas meter is generally called “LPG supply equipment”. The LPG Act requires LPG retailers to monitor and control the safety of LPG supply equipment installed at their user sites, and specialized and authorized monitoring and control organizations perform the following tasks.

Table 3. Safety monitoring and control tasks

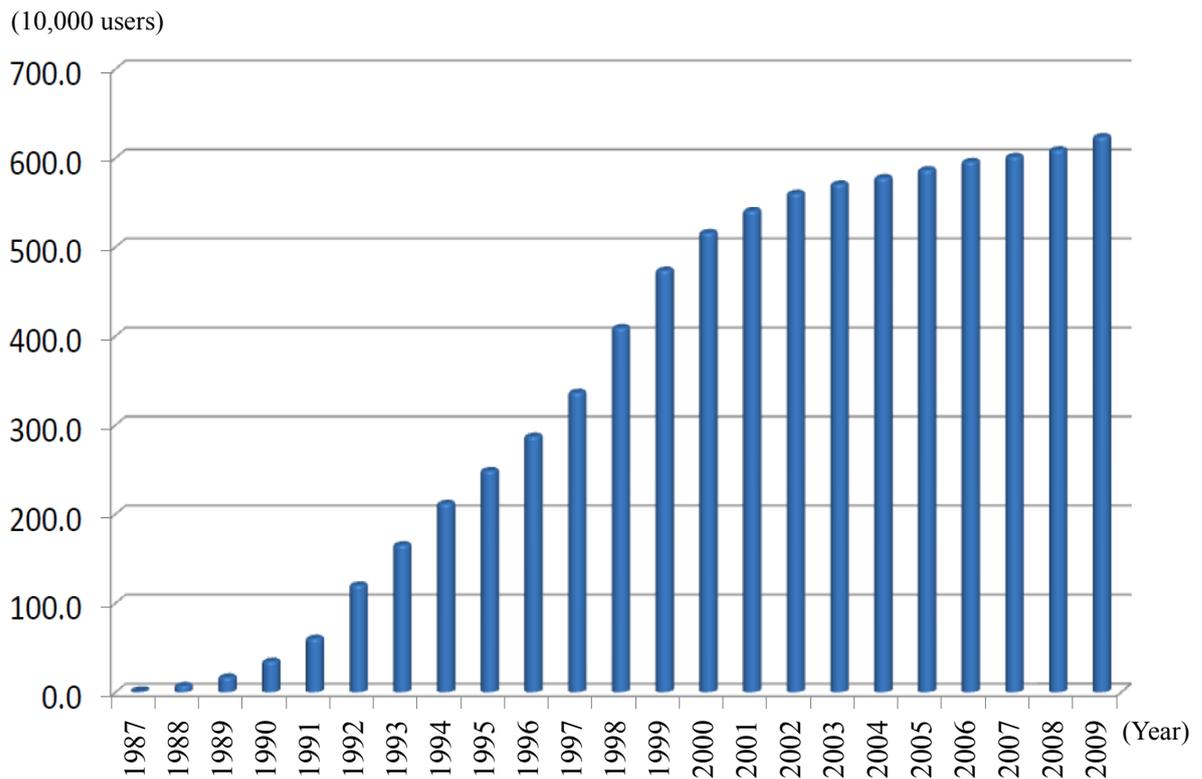
Task	Description	Frequency
1) Information service	Provide the user, periodically in writing, with important safety precautions and useful information on preventing accidents.	Once a year (or once every two years)
2) Inspection service upon starting gas supply	When starting gas supply to a new user, the LPG retailer must inspect and check all the LPG gas equipment installed, including gas-fueled appliances.	When starting gas supply to a new user
3) Periodic inspection of supply equipment	Inspect the supply equipment, from the regulator to the gas meter, to check for gas leak and any other irregularity.	At least once every four years
4) Receiving and giving information and responding in the event of emergency	Respond to gas leaks or other emergency situations and take actions promptly.	The retailer should be available to receive and respond to emergency reports even during the night and on weekends and holidays. The retailer must provide free-of-charge assistance within 30 minutes of receiving an emergency report.
5) Cylinder change and supply equipment inspection	Check the LPG cylinders and their accessory equipment to make sure that the cylinders are adequately secured against tipover and other risks.	Perform the inspection upon every cylinder change or at least once a month.
6) Periodic consumption equipment survey	Check the consumption equipment including gas appliances, air supply and exhaust systems, hoses and piping, etc.	At least once every four years

As it is difficult for LPG users to accurately determine how much gas is remaining in their storage in order to place timely orders, many users are now covered by a centralized LPG usage monitoring system connected to their distributor for efficient transportation and supply management.

A typical monitoring system has a network control unit (NCU, a data transmission device), fitted to the gas meter at the user site to send gas usage information to the central monitoring station. In addition to assisting the automated meter reading, the monitoring system enables the distributor to quickly detect gas leaks and also to deliver gas in a timely manner before the user's supply runs out (streamlined delivery).

Currently, 6.24 million users, or 24% of the total number of LPG users, are covered by such central monitoring systems.

Figure 11. Number of users covered by a central monitoring system



Calculated based on the estimated sales volume of NCUs (network control units).

2.4 Safety inspection of charging station equipment

Safety control at filling stations and other industrial facilities where a large volume of LPG may be handled is subject to the High Pressure Gas Safety Act. These facilities must undergo more intensive equipment tests and inspections, such as piping and storage tank airtightness tests and fire extinguisher operation checks, than ordinary gas users.

Piping airtightness test



Piping airtightness test
Piping sections are inspected for gas leak.

Storage tank airtightness test



Storage tank airtightness test
Storage tanks are inspected for gas leak.

Open-tank wall thickness measurement



Open-tank wall thickness measurement

The thickness of the tank wall is measured from inside the tank for safety verification.

Source: Japan LP Gas Association

2.5 Long-service life product safety inspection scheme, etc.

In response to reports of deaths and other serious accidents in recent years related to old oil-fueled FF fan heaters^{*1}, gas-fueled water heaters and other similar heating equipment, where the main cause was product deterioration as a result of aging, a “Long Service Life Product Safety Inspection Scheme” was established on April 1, 2009, under the Consumer Product Safety Act.

This scheme requires the seller or distributor of equipment or a device that cannot be adequately maintained by the user and that could potentially cause a serious accident if it deteriorates due to aging (“specified maintenance product”) to, for the benefit of the user, appropriately assist the user with required inspections and other maintenance services so as to eliminate the risk of serious accidents. This is to ensure the safe use of gas-fueled equipment for consumers over a long period of time. Specifically, the seller or distributor of a “specified maintenance product” must perform the following tasks.

Figure 12. Overview of the long service life product safety inspection scheme



Source: Japan LP Gas Association

^{*1} A room heating appliance where outside air is sucked in through an air intake/exhaust duct and into the unit by a built-in combustion fan and air warmed by combustion is blown into the room by a blower fan, while the combustion exhaust gas is discharged back into the atmosphere through the air intake/exhaust duct. “FF” stands for “Forced draught balanced Fuel type”.

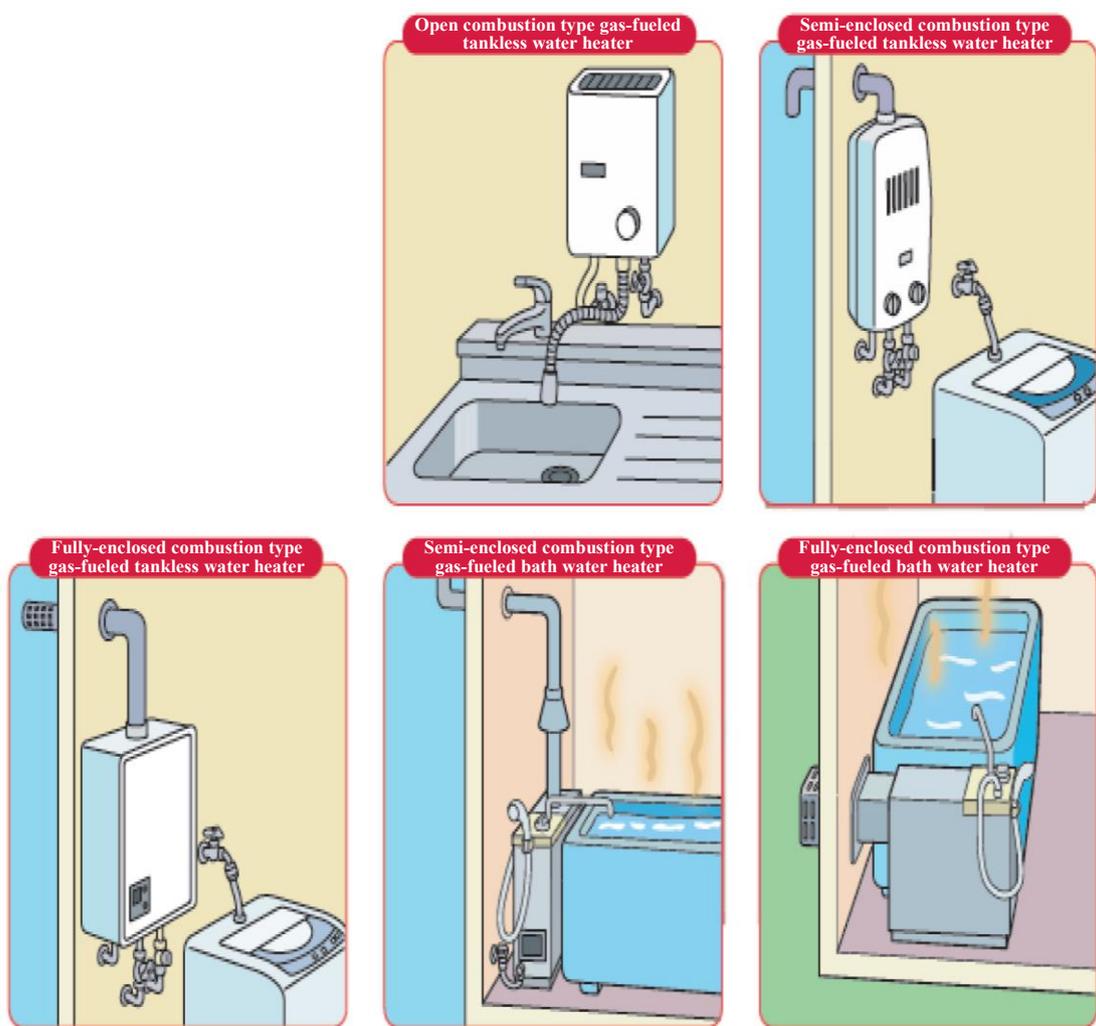
User obligations under the scheme include, upon purchasing a “specified maintenance product”

(gas-fueled indoor tankless water heater, gas-fueled indoor bath water heater, etc.) which require legal inspection, completing the user registration card contained in the product package and returning the card to the seller/distributor to become a registered user.

This registration information will be used to notify the user of a legally required inspection date or to issue recall notifications in the event that a serious defect is found in the product.

For the scheme to function properly, it is critical to collect user registration cards from as many users as possible. To attain full and complete registration of the user base, the revised Inspection Scheme Guideline published by the Ministry of Economy, Trade and Industry in 2012 allows and actively recommends retailers to fill in the registration card on behalf of the user to ensure that all eligible users are registered.

Figure 13. Products subject to legal inspection requirement (gas appliances)



Source: Japan LP Gas Association

3. LPG service situation after the Great East Japan Earthquake and the 2016 Kumamoto Earthquake

3.1.1 Overview of the Great East Japan Earthquake

The 2011 earthquake off the Pacific Coast of Tohoku occurred at 14:46:18 (Japan Standard Time) on March 11, 2011, with the epicenter located under the bottom of the Pacific Ocean 130 kilometers east-southeast of the Oshika peninsula, Miyagi Prefecture, and 70 kilometers east of the city of Sendai.

The size of the earthquake was a moment magnitude 9.0 (Mw), much stronger than that of the 1995 Great Hanshin-Awaji Earthquake, which at the time was the most powerful earthquake ever recorded to have hit Japan.

The hypocentral region of the earthquake spread over a huge area, running from off the coast of Iwate Prefecture to off the coast of Ibaraki Prefecture and spanning approximately 500 kilometers in the north-south direction and approximately 200 kilometers in the east-west direction, covering an area of about 100,000 square kilometers. The greatest seismic intensity (JMA intensity scale) recorded was 7 in Kurihara, Miyagi Prefecture. An Upper 6 intensity was also recorded in 36 municipalities of the four prefectures of Miyagi, Fukushima, Ibaraki and Tochigi and also in one ward in the city of Sendai.

The earthquake triggered powerful tsunami waves that in some areas reached a wave height of over 10 meters and a run-up height of 40.1 meters, causing devastating damages along the Pacific coast of the Tohoku region and part of the Kanto region. In addition to the huge tsunamis, various effects of the earthquake, such as severe shaking, soil liquefaction, subsidence, and dam failures, inflicted damages over a vast expanse of land from the south coast of Hokkaido, through Tohoku, to southern Kanto including Tokyo Bay. Various public infrastructures such as water, electricity and gas services were disrupted.

As of October 10, 2014, 18,487 people were reported dead or missing and a total of 401,306 homes were officially confirmed “completely collapsed” or “half collapsed”. After the earthquake, the number of evacuees during the worst times exceeded 400,000, more than 8 million households were left without electricity and more than 1.8 million without water. According to the Reconstruction Agency, 243,040 people were still living away from home as of September 11, 2014, indicating that many people have remained in an evacuation status for a long time.

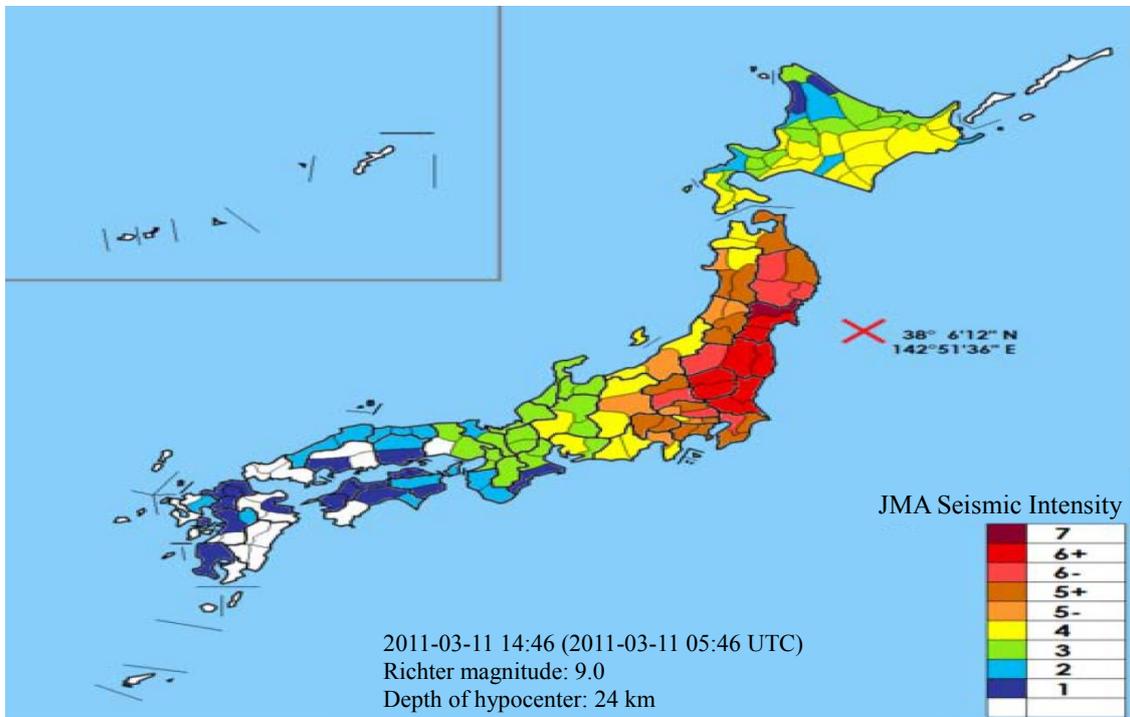
The government of Japan estimates that the direct financial cost of damage caused by the earthquake amounts to 16 to 25 trillion yen. This figure is approximately equivalent to the total gross prefectural product of Iwate, Miyagi and Fukushima, which are the three prefectures most

severely hit by the quake (in comparison, the direct damage caused by the Great Hanshin-Awaji Earthquake was only half the gross prefectural product of Hyogo Prefecture alone). According to a World Bank estimate, this is the greatest economic loss ever caused by a natural disaster.

Table 4. Overview of the Great East Japan Earthquake

Date	14:46 on March 11, 2011
Epicenter location	Off the Sanriku coast
Hypocenter depth	24 km
Size of earthquake	Magnitude 9.0
Highest seismic intensity	7 (Kurihara, Miyagi Prefecture)
Tsunami	Powerful tsunami waves occurred after the quake, reaching a wave height of over 10 meters and a run-up height of 40.1 meters in some areas
Type of earthquake	Reverse-fault-type subduction zone earthquake
Fatalities	18,487 reported dead or missing (as of October 10, 2014)
Housing damages	401,306 homes completely or partly collapsed
Nuclear power plant damage	In the Fukushima No. 1 Nuclear Power Plant complex, a cooling system breakdown resulted in a series of accidents that discharged large amounts of radioactive materials into the atmosphere.
Direct financial damages	16 to 25 trillion yen

Figure 14



Source: Japan Meteorological Agency

3.1.2 LPG service disruption and resumption after the Great

East Japan Earthquake

The six quake-hit prefectures (Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba) had approximately 4.04 million households using LPG. Of those, about 160,000 households had to evacuate their homes, either because their houses completely or partly collapsed, or as a result of the nuclear power plant accident, disrupting their use of LPG service.

Of the approximately 5,200 LPG retailers and distributors operating in the six prefectures, 331 had to also evacuate from their place of business, because their buildings completely or partly collapsed, or as a result of the nuclear power plant accident, disrupting LPG supply in the region.

Also, tsunami waves washed away an estimated 200,000 LPG cylinders.

Table 5

LPG service disruption after the Great East Japan Earthquake

	Before the quake		After the quake	
	Number of LPG users	LPG retailers and distributors	Number of LPG users who evacuated (home completely or partly collapsed or due to nuclear plant accident)	LPG retailers and distributors who evacuated (place of business completely or partly collapsed)
Aomori	480,014 homes	610 businesses	940 homes	14 businesses
Iwate	449,436 homes	500 businesses	22,104 homes	79 businesses
Miyagi	578,724 homes	756 businesses	88,000 homes	165 businesses
Fukushima	630,767 homes	917 businesses	30,000 homes	70 ⁵ businesses
Ibaraki	898,728 homes	1,301 businesses	16,877 homes	1 businesses
Chiba	1,002,161 homes	1,149 businesses	200 homes	2 businesses
Total supply	4,039,830 homes	5,233 businesses	158,121 homes	331 businesses

(Based on Japan LP Gas Association statistics)

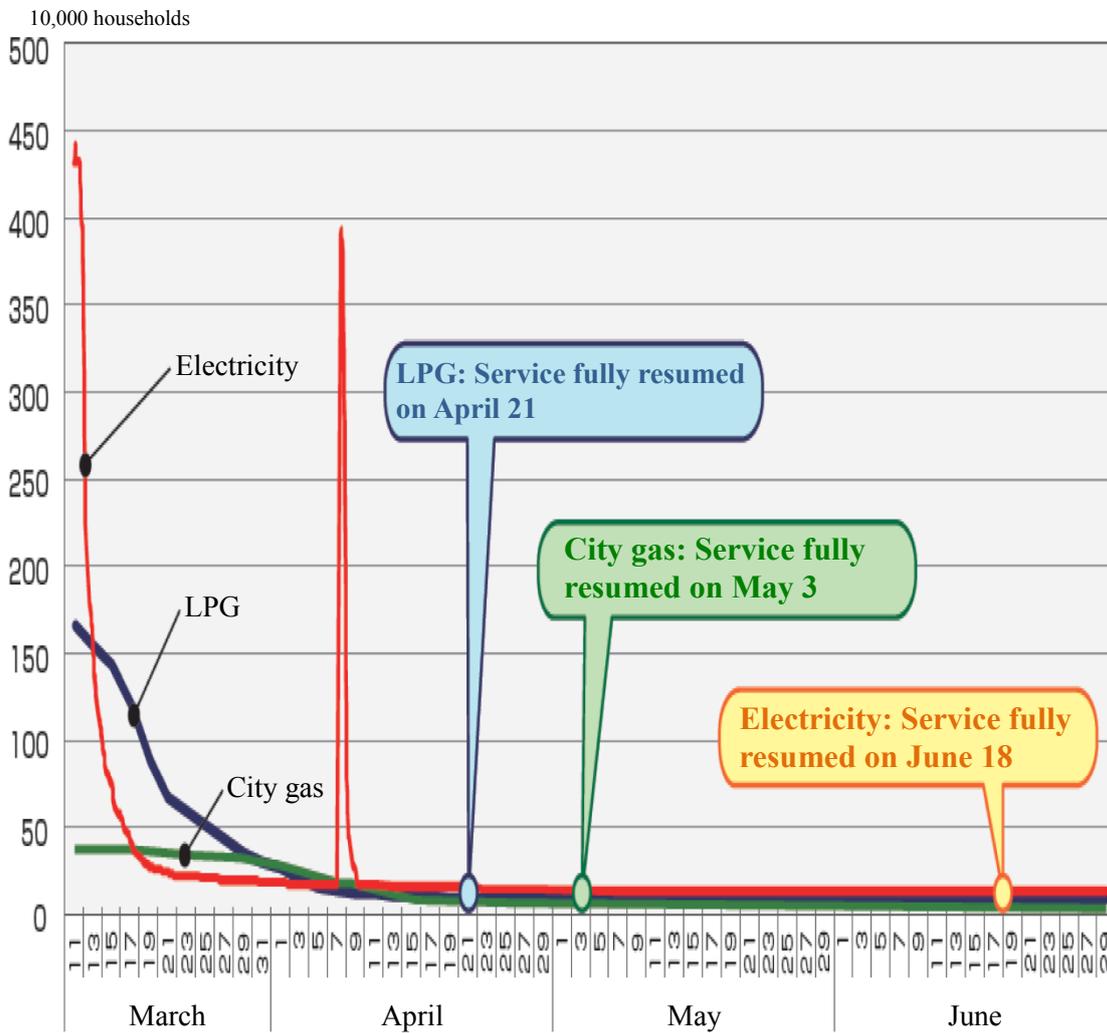
In Iwate, Miyagi and Fukushima, which were the prefectures hardest hit by the quake, most LPG retailers and distributors, except for those with their place of business completely destroyed or washed away, resumed operation within about three weeks after the earthquake, restoring full services much faster than city gas or electricity.

From users' point of view, having gas in cylinders at their homes ensures that they can keep using fuel for some time even without deliveries.

For example, a household having two 50 kg cylinders at their home has sufficient fuel to last approximately one month until deliveries are resumed, if one of the cylinders is at least half full. Due to their storability, LPG is an especially useful backup energy source in case of disaster.

Figure 15. Public service disruption in the three quake-hit prefectures and the number of

households affected



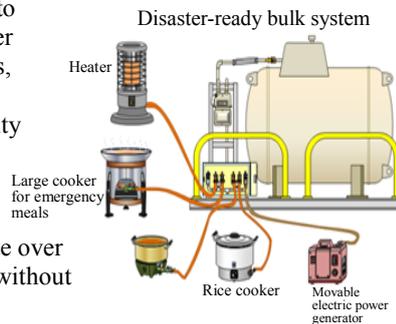
(Source: “Survey concerning LPG supply stability in the future with lessons from the Great East Japan Earthquake” published by the Ministry of Economy, Trade and Industry in February 2012)

Figure 16

Disaster-resistant petroleum gas service

As petroleum gas (LPG) is delivered in cylinders, which is a non-rigid form of supply not dependent on permanently installed supply lines, it can be a very useful alternative source of energy when electricity or city gas supply lines are cut due to natural or other major disasters.

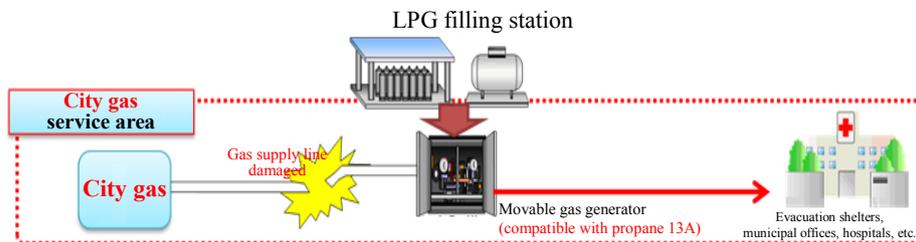
- 1) At-home storage: Each LPG user household normally has two LPG cylinders at their home, which will keep the family supplied with fuel for an average of at least one month in the event of delivery disruption.
- 2) Speedy recovery: As LPG is individually delivered to each household, service can be resumed even for one household at a time, allowing flexible and speedier recovery.
- 3) Use for emergency meal services: In addition to supporting existing users with at-home cylinder storage and disaster-ready bulk supply systems, LPG can also be very useful for heating and cooking at local evacuation shelters (community centers, etc.) in the early days following a disaster, maintaining the quality of life for evacuees.
- 4) Non-deterioration: As LPG does not deteriorate over time, it is an efficient source of stored energy without costs incurred for discarding due to aging.
- 5) Usability of LPG vehicles: Even when gasoline is not easily available, taxis and other LPG-fueled vehicles can still run.
- 6) Alternative energy source to back up city gas: With the use of movable gas generator units, gasified LPG can be supplied to hospitals and evacuation shelters located in an area with city gas.



50 kg cylinders kept at user homes

Percentage of LPG user households in the total number of households in each prefecture (as of the end of 2012)

Iwate	79%
Miyagi	73%
Fukushima	75%
Chiba	33%
Kanagawa	37%
Tokyo	13%
Niigata	31%
Aichi	36%
Osaka	11%
Fukuoka	50%



3.1.3 Active use of LPG at the time of disasters

When people's homes are damaged or collapse due to earthquake or other natural disasters, evacuees often have to stay at evacuation shelters or in a temporary housing project. LPG can be easily delivered to such facilities for cooking, heating, hot water supply and even for electric power generation, helping maintain quality of life for evacuees.

LPG cylinders at a temporary housing project



LPG being used at an evacuation shelter



Emergency meals (Ishinomaki)



Source: Japan LP Gas Association

3.2.1 Overview of the 2016 Kumamoto Earthquake

Table 6

Date	1:25 on April 16, 2016
Epicenter location	Kumamoto area, Kumamoto Pref.
Hypocenter depth	12 km
Size of earthquake	Magnitude 7.3
Highest seismic intensity	7 (Nishihara Village and Mashiki Town, Kumamoto Pref.)
Type of earthquake	Inland intra-core earthquake
Fatalities	50
Housing damages	38,594 homes completely or partly collapsed
Direct financial damages	4.6 trillion yen

3.2.2 LPG service situation after the Kumamoto Earthquake

Of the 434 LPG retailers and distributors operating in Kumamoto Prefecture, four suffered damage or collapse of their place of business. However, there were no service disruptions.

Table 7

	Full service recovery	Extent of damage
Electricity	April 20	Up to 477,000 homes were left without electricity
City gas	April 30	Up to 105,000 homes were left without gas
Water	July 28	Up to 446,000 homes were left without water
LPG		No service disruptions reported

Source: Cabinet Office

4. Lessons learned from field surveys (conducted by Kumamoto LP Gas Association)

4.1 Details of the Kumamoto Earthquake

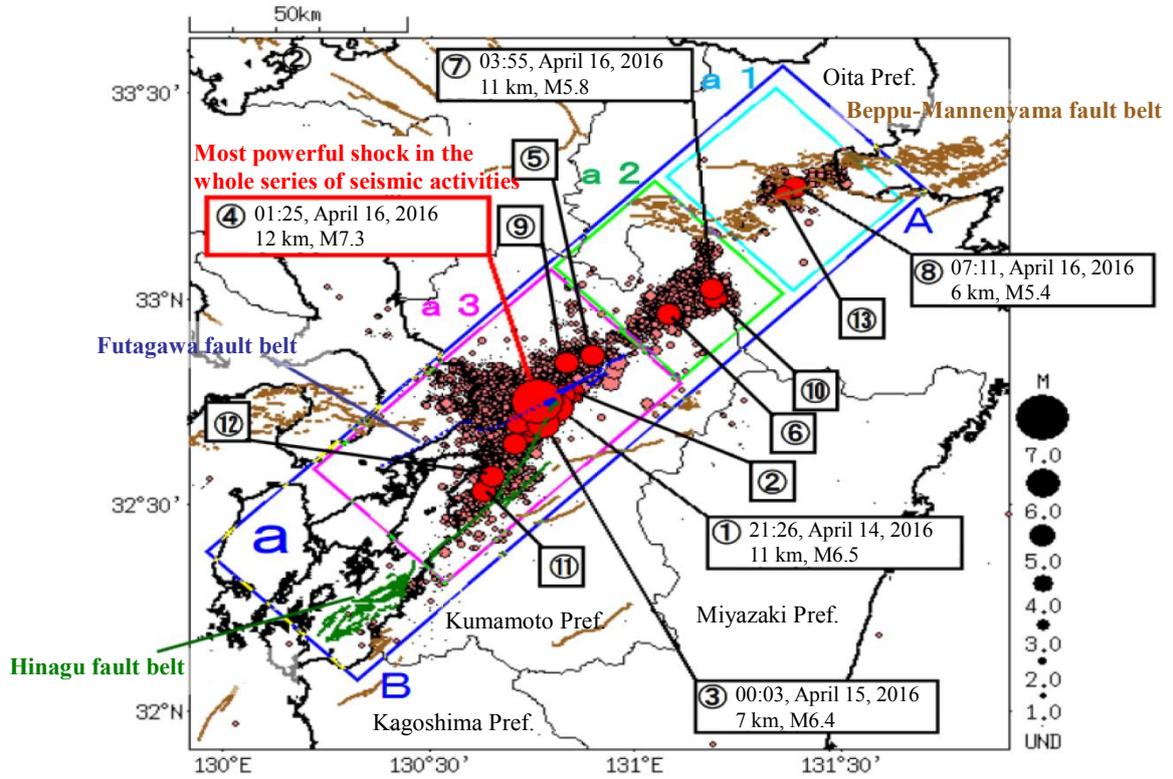
- Foreshock at 21:26, April 14 (Thur), magnitude 6.5, Kumamoto area, hypocenter depth approx. 10 km (highest seismic intensity recorded: 7 in Miyazono, Mashiki Town)
- Main shock at 1:25, April 16 (Fri), magnitude 7.3, Kumamoto area, hypocenter depth approx. 10 km (highest seismic intensity recorded: 7 in Miyazono, Mashiki Town and also in Komori, Nishihara Village)

Table 8

Order	Time of shock		Epicenter location	Depth	M	Highest seismic intensity
1	21:26	April 14	Kumamoto area, Kumamoto Pref.	11	6.5	7
2	22:07	April 14	Kumamoto area, Kumamoto Pref.	8	5.8	Lower 6
3	00:03	April 15	Kumamoto area, Kumamoto Pref.	7	6.4	Upper 6
4	01:25	April 16	Kumamoto area, Kumamoto Pref.	12	7.3	7
5	01:45	April 16	Kumamoto area, Kumamoto Pref.	11	5.9	Lower 6
6	03:03	April 16	Aso area, Kumamoto Pref.	7	5.9	Upper 5
7	03:55	April 16	Aso area, Kumamoto Pref.	11	5.8	Upper 6
8	07:11	April 16	Central area of Oita Pref.	6	5.4	Lower 5
9	09:48	April 16	Kumamoto area, Kumamoto Pref.	16	5.4	Lower 6
10	20:41	April 18	Kumamoto area, Kumamoto Pref.	9	5.8	Upper 5
11	17:52	April 19	Kumamoto area, Kumamoto Pref.	10	5.5	Upper 5
12	20:47	April 19	Kumamoto area, Kumamoto Pref.	11	5	Lower 5
13	15:09	April 29	Central area of Oita Pref.	7	4.5	Upper 5

Source: Meteorological Agency

Figure 17



Source: Meteorological Agency

4.2 Damages in Kumamoto Prefecture

- 98 dead

Breakdown of the death toll:

- 1) 50 confirmed dead on site by the police
- 2) 43 died after the quake due to injuries inflicted during the quake or earthquake-induced illness or other health problems
- 3) 28 deaths deemed by the municipalities to be earthquake-related
- 4) 5 deaths due to rainstorm damages of June 19 to June 25, but deemed to be related to the April earthquakes

- Number of people severely or lightly injured

- 1) Kumamoto Earthquake: 2,353
- 2) Number of injuries caused by the rainstorm damages of June 19 to June 25, but deemed to be related to the April earthquakes: 2

- Extent of housing damages

- 1) Completely collapsed: 8,151 homes
- 2) Half collapsed: 29,072 homes
- 3) Partly damaged: 129,624 homes
- 4) Not classified; 21 homes

Total: 166,868 homes (from Fire and Disaster Management Agency statistics)

- Fire damages: 15 cases

Breakdown: Kumamoto City: 9, Kamimashiki: 1, Yatsushiro: 2, Aso: 1, Kikuchi: 2
... No fire where LPG was determined to be the cause

- Number of evacuees

183,882 evacuees staying at 855 shelters (highest figure recorded at 9:00, April 18, 2016)

- Sediment-related disasters

Debris flows: 54 cases, landslides: 10 cases, cliff collapses: 94 cases (from Ministry of Land, Infrastructure and Transportation data)

In the Kumamoto Earthquake, Mashiki Town, which was closest to the hypocenter, suffered the severest damages. However, no LPG-related accidents or damages were reported even though almost all households in the area were LPG users. This may be due to the fact that the earthquake did not occur during the hours when usually people cook meals, that in areas where people evacuated after the foreshock on April 14 the LPG valves were already closed before the main shock, and that auto-shutoff meters, which are designed to cut off gas supply when a seismic intensity of upper 5 or greater is detected, dependably shut off the gas flow.

Photos from quake-stricken areas

•Houses in Mashiki Town

(Photo taken on April 15, 2016)



• Road in Mashiki Town



Source: Kumamoto Prefecture LP Gas Society

4.3 Damages suffered by LPG retailers and distributors

- 434 LPG retailers operating in the area (513 shops)
 - 41 filling stations (one central station in Yatsushiro City)
 - Damages suffered by LPG retailers
 - Fatalities: No employee or member reported dead
 - Property damages: 4 LPG shop buildings completely collapsed, 21 half collapsed, 118 partly damaged
 - Employee or member homes: 7 completely collapsed, 27 half collapsed, 108 partly damaged
 - Charging station damages include cylinder tipover, station floor/wall cracking, partial piping damages, water spray system cracking due to subsidence, etc.
 - Number of LPG user households: Total number of households in the prefecture: 710,300
Of those, LPG user households: 498,049 (70.11% of the total)
 - LPG equipment damages at user sites: Gas leak at 3,887 households
 - *Non-gas-leak damages reported at 15,656 households
 - (As of June 30, 2016) Cylinder fastening chains damaged at 14,089 households
 - Piping damaged at 5,718 households
 - LPG shop in Mashiki Town (the first floor is completely crushed; the photo shows the second floor of the building)
- (Photo taken on April 20, 2016)



Source: Kumamoto Prefecture LP Gas Society

4.4 Steps taken after the earthquake

Date and time	Event occurred/step taken
21:26, April 14 (Thur)	A magnitude 6.5 earthquake occurred (foreshock) in the Kumamoto area.
22:00	The Kumamoto Prefecture LP Gas Society set up its own Disaster Information and Response Headquarters.
22:10	The prefectural government set up a Disaster Response Headquarters.
23:10	Each block leader of the Society was requested (via fax) to check and report the damage.
03:30, April 15 (Fri)	Mifune Police reported a gas smell in Kiyama, Mashiki Town. Society officers and other members went to the site. (Temporary repair completed at 5:31 am)
06:30	Mashiki Fire Department reported a gas smell in Kiyama, Mashiki Town. A Society member (local gas cooperative employee) provided the first on-site response.
08:00	Later, a full member arrived at the site to conduct further inspection and investigation.
14:00	Members of the Society's coordination office surveyed the quake-stricken parts of Mashiki Town.
17:20	Collected information about the extent of damage to the 41 prefectural filling stations.
19:40	Collected information about charging stations near Mashiki Town, including the extent of damage and whether or not they are operational.
01:25, April 16 (Sat)	A magnitude 7.3 earthquake occurred (main shock) in the Kumamoto area.
02:00	Employees arrived at the Society's coordination office, and checked whether electricity was available, telephone lines were working, etc.
04:30	Power supply and telephone service resumed at the office. Started collecting information from Society members and other sources.
06:00	Checked the status of other utility services and social welfare facilities.
09:00	District No. 8 issued a letter of recommendation asking that a petroleum gas supply coordination plan for petroleum gas disaster be drawn up.
12:00, April 17 (Sun)	Under the existing disaster response agreement, the prefectural government requested the Society to provide fuel assistance to shelters for emergency meals.
April 18 (Mon)	Started supplying LPG to evacuation shelters. Free-of-charge supply to eight schools including Kumamoto

<p>07:00, April 19 (Tue)</p>	<p>City's Isshin Elementary School. In addition, 29 member retailers voluntarily assisted more than 80 shelters. The Amakusa unit of "Team LPG" (a disaster response/assistance organization formed under the initiative of Kumamoto Prefecture LPG Gas Society) transported water, rice, waterproof sheets and other emergency supplies to the Society's Ukishi block.</p>
<p>April 24 (Sun)</p>	<p>Team LPG started collecting gas cylinders from collapsed homes in Mashiki Town (29 team members collected a total of 608 cylinders).</p>
<p>April 25 (Mon)</p>	<p>Except for homes that had collapsed or where family members were still evacuated and away from home, LPG equipment repairs and safety checks were completed at all LPG user households in earthquake-stricken areas. Full LPG service resumed for user households.</p>
<p>April 26 (Tue)</p>	<p>Kumamoto Prefecture's Disaster Information and Response Headquarters requested the Society to help provide LPG service to the proposed temporary housing projects. The Society assured the prefecture that it would provide centralized supply and management of LPG for the projects.</p>

Source: Kumamoto Prefecture LP Gas Society

4.5 Lessons from the Kumamoto Earthquake

(1) Information collection

Issues immediately after a disaster strikes:

- How to assess the extent of damage? (How to check whether members and employees are safe and how much damage has been suffered by users, etc.?)
- How to respond to user inquiries and emergency assistance requests? How to reply and in what order of priority?
- How to provide information? (Reports to block leaders, association/society office and municipal authorities, information and notices to users)

To improve preparedness:

- Keep the communication systems well-maintained and ready for operation during disasters, including fixed-line phones, cellular phones and satellite phones.
- Have alternative communication tools ready for operation during disasters, including fax, e-mail, SNS, etc.
- Develop and implement a business continuity plan (BCP).

When a disaster strikes, not only users but also retailers and distributors may suffer damage and need assistance. Work on building good disaster preparedness during normal times.

(2) Emergency responses and service resumption

Issues immediately after a disaster strikes:

- How to secure manpower (employees) to provide emergency response?
- How to provide on-site responses and service recovery quickly and flexibly in accordance with the damage situation?
- How to ask for external assistance when the disaster-stricken area is huge or there are too many assistance requests?

To improve preparedness:

- Create a well-prepared Disaster Response Manual and be ready to implement it at any time.
- Have specific rules to prioritize inquiries and requests from users.
- Have a liaison mechanism for coordination with wholesaler assistance teams, etc.
- User data management (to be able to show assistance teams where individual users are located, etc.)
- Arrange in advance inspection equipment and repair tools that would be required in case of

disaster

(3) LPG equipment damage measures

Issues immediately after a disaster strikes:

- Cylinders slip from the fastening chains and tip over.
- Cylinders swing around due to earthquake shaking, hitting and damaging the piping and accessory equipment.
- LPG leak from damaged equipment

To improve preparedness:

- Make sure to secure the cylinders with appropriate devices and effective use of chains.
- Chains over the cylinders should be double-wound, to help prevent gas from escaping.
- The gap between cylinders and wall, and between cylinders, should be kept as small as possible. Chains should also be wound tightly with minimum slack.
- For protection against cylinder tipover, consider using high-pressure hose connections designed to prevent gas escape, to help prevent massive leaks from cylinders.

To improve disaster preparedness from normal times, always remember to double-wind the chains over the cylinders, and also consider using high-pressure hose connections designed to prevent gas escape.

4.6 Evaluation of LPG as an energy source in Kumamoto

Prefecture

Currently, approximately 70% of households in Kumamoto Prefecture use LPG. After the earthquake, LPG and its non-rigid supply system are now highly acclaimed for continuing to provide service without interruption during difficult times.

5. Conclusions - superiority of LPG

1. Disaster-resistant supply system

With the non-rigid delivery system not dependent on permanently installed pipes, service can be resumed much more quickly after a disaster than with the natural gas system.

2. Easy and inexpensive storage

Petroleum gas can be easily liquefied under pressure (1 MPa at room temperature) and its boiling point is much higher than that of natural gas (petroleum gas -42°C , natural gas -162°C), allowing LPG to be stored much more cheaply than other fuels.

3. Good transportability

LPG can be stored and transported in the liquid state to be gasified later at the point of consumption. This excellent compactness facilitates transportation, distribution and consumption in geographic regions without city gas supply infrastructure.

4. Combustibility

The calorific value of LPG is approximately $99\text{--}128\text{ MJ/Nm}^3$, which is at least about twice that of natural gas.