



The 3rd APEC Oil & Gas Security Network Forum
Irkutsk, Russia, 29 June 2017

Superiority of LPG: A Disaster-Resistant Energy Source

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◆ Introduction

1. Current situation of LPG use in Japan
2. Safety measures
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◆ Introduction

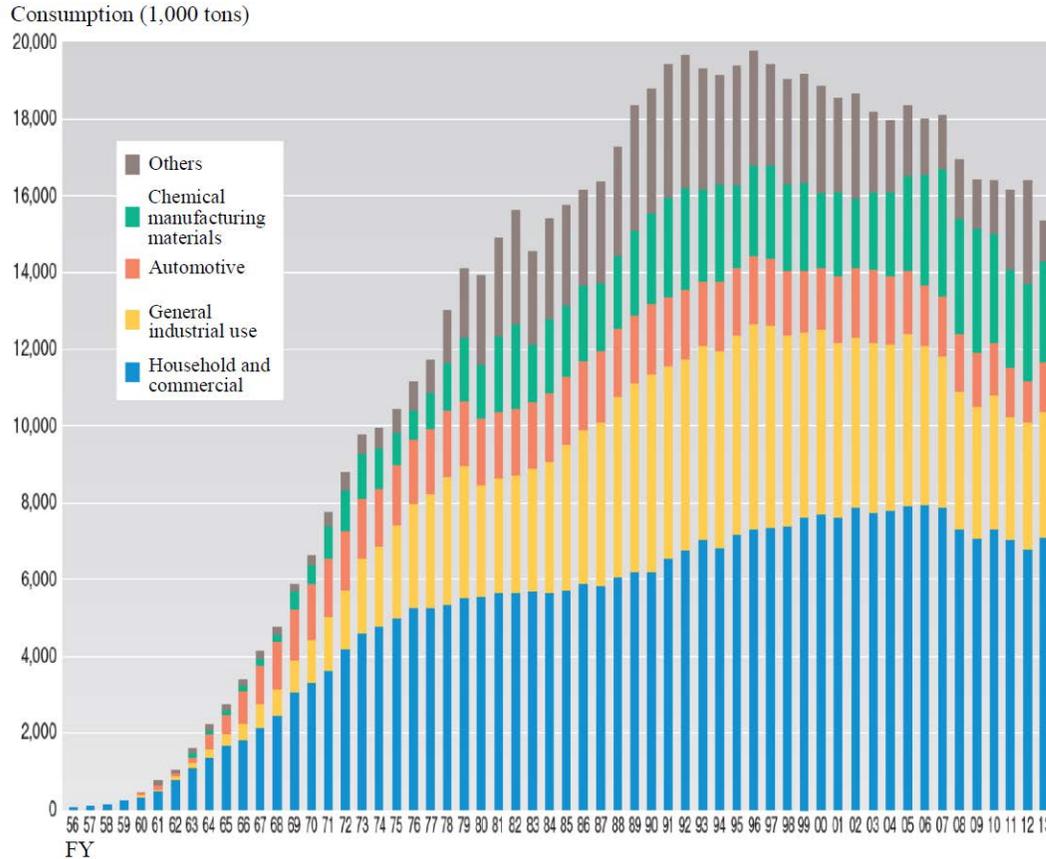
- The use of LPG in APEC economies is expected to grow significantly in the coming years mainly as a result of increasing household consumption.
- Due to its **cleanness** and the **disaster-resistance** of its supply and distribution system, LPG remains an important source of energy in Japan.
 - Especially 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;
 - **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**
 - ✓ **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

- Importance of LPG in Japan as an energy source
 - In Japan, **Liquefied petroleum gas (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 1961, LPG began to be imported from Middle East countries to Japan in its product form.
 - 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 Japan's primary energy consumption (**16.6 million tons** in 2012):
 - Household fuel; **24 million homes** in Japan (**half the total** number of households)
 - Commercial fuel; food processing industry is the largest consumer
 - Automotive fuel; **250,000 vehicles**, mostly taxis.

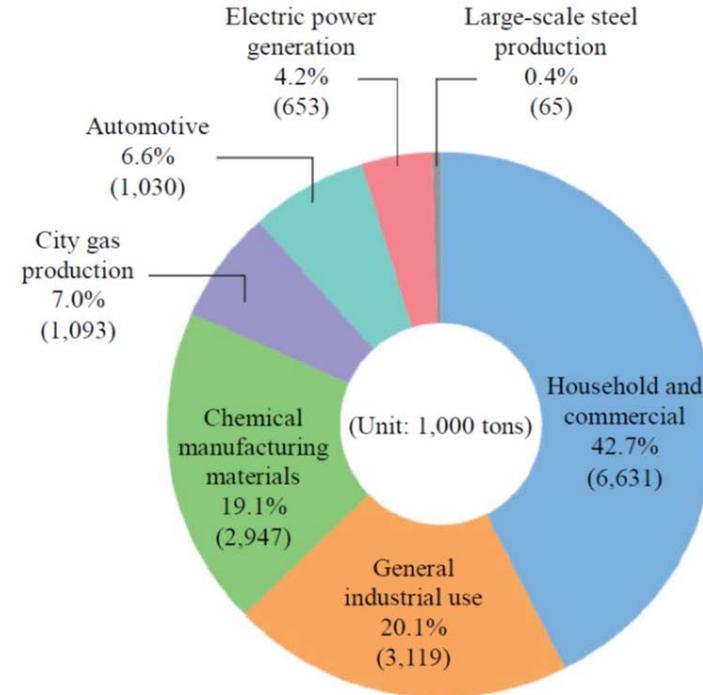
1. Current situation of LPG use in Japan

Figure 2. Consumption trend



(Source: Japan LP Gas Association)

Figure 3. Uses of LPG



(Source: Japan LP Gas Association)

1. Current situation of LPG use in Japan

□ Characteristics of LPG

(1) Environment-friendly

- A sulfur content of 0.0050 wt% or less in general, and low NOX emissions during combustion.
- Almost the lowest amount of CO2 over the entire life cycle from production to consumption

(2) Good 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).

(3) Good combustibility

- A calorific value of approximately 99–128 MJ/Nm³, which is much higher than most other gaseous and liquid fuels
- Easy conversion from the gaseous state into the liquid state through pressurization or cooling

1. Current situation of LPG use in Japan

□ Sales chain

1. Primary distributors (producer-importers) who import or produce LPG

- An LPG branch or subsidiary of an oil company or oil alliance, or importers or traders specializing in the LPG business
- Together form the Japan LP Gas Association (15 members as of May 2014)
- Approximately 75% of domestic demand supplied by product imports, while the remaining 25% is supplied by domestic production from crude oil

2. Wholesalers who fill LPG into cylinders and tanks

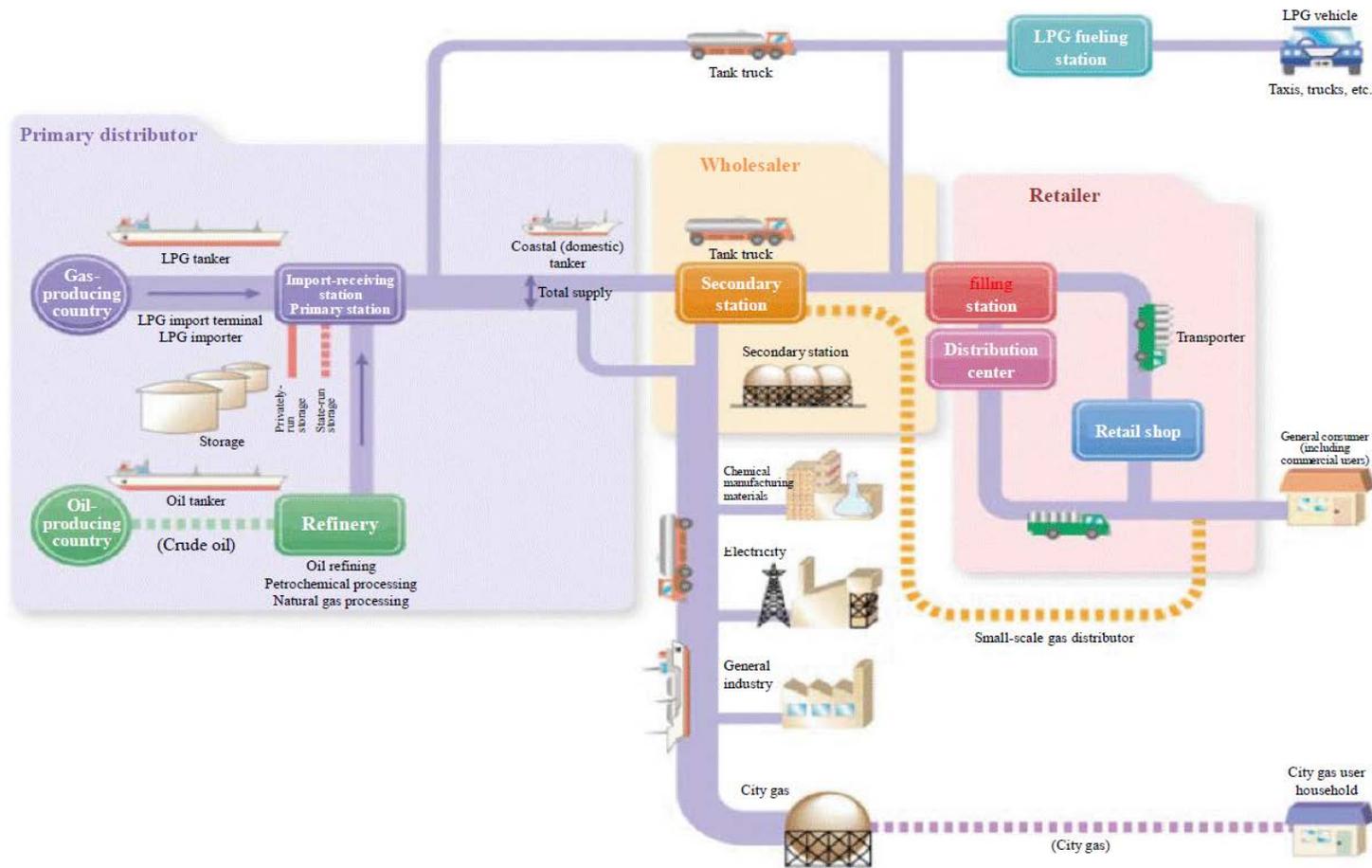
- Estimated about 1,100 LPG wholesalers in Japan
- Each wholesaler typically has a dozen to several hundred affiliated local retailers

3. Retailers which deliver the filled cylinders and tanks to households and other end users

- Approximately 21,000 LPG retailers operating in Japan
- All the LPG retailers in each prefecture form a prefectural LP gas association/society, which forms a national LPG trading associations: Japan LP Gas Association.

1. Current situation of LPG use in Japan

Figure 4. Logistics



Source: Japan LP Gas Association website

1. Current situation of LPG use in Japan

□ Differences between LPG and city gas

- The main component of LPG (household fuel type) is **propane (C₃H₈)** while that of city gas (13A) is **methane (CH₄)**. Propane's calorific value per unit volume is **more than twice** that of city gas.
- As propane can be easily liquefied and containerized and thus moved anywhere (**non-rigid supply system**), it is available throughout **Japan**
- 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**.
- 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**.

Figure 5

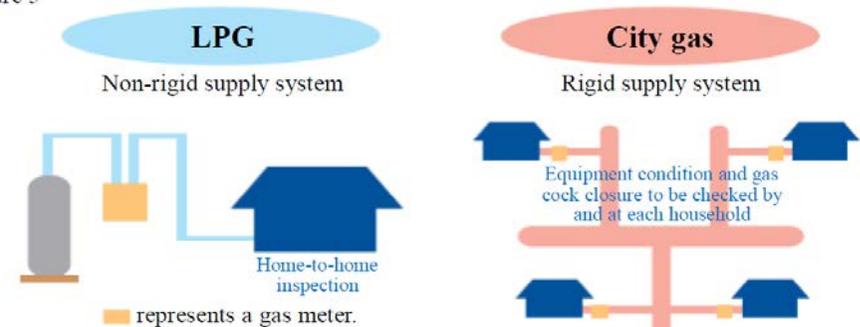
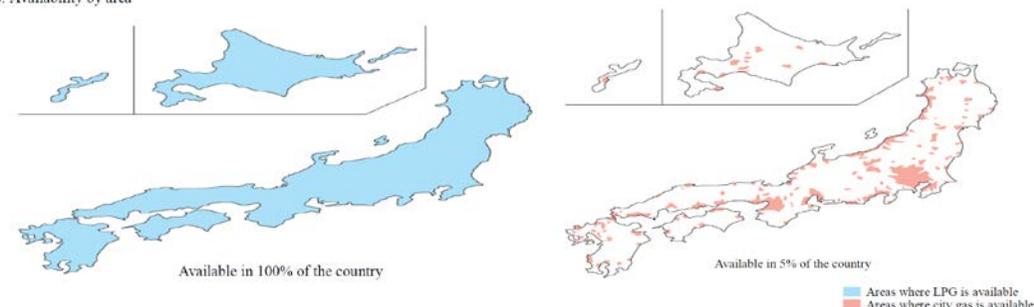


Figure 6. Availability by area



1. Current situation of LPG use in Japan

□ LPG storage

- **Five state-run LPG storage stations** were completed in March 2013, with LPG storage volume gradually being increased over a period of several years.
- 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**.
- 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

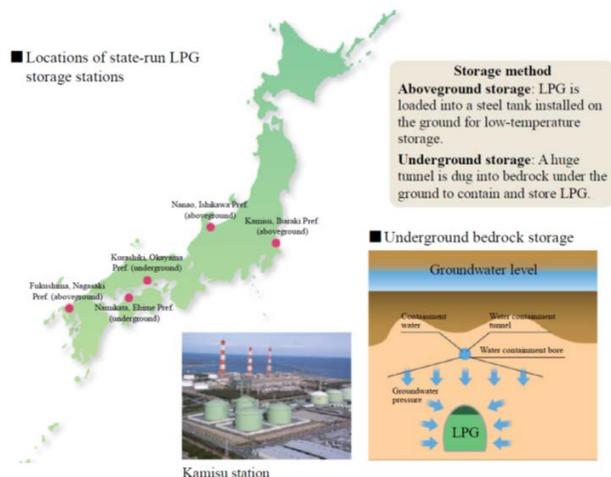
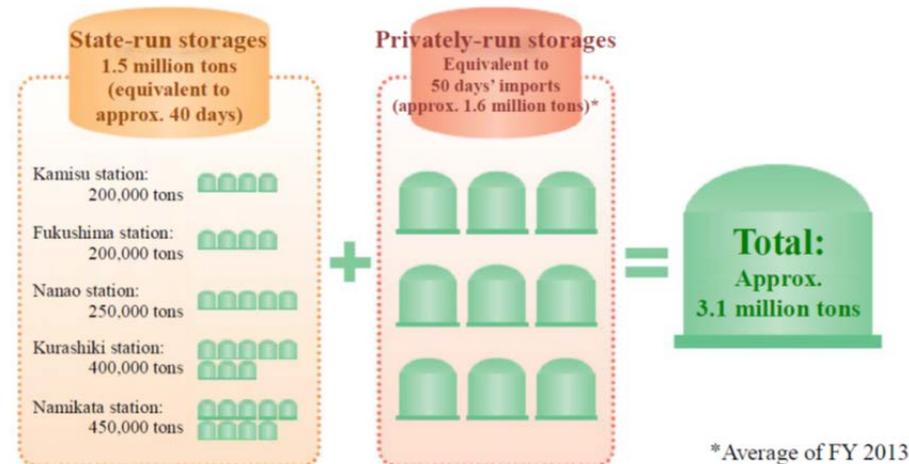


Figure 8. State- and privately-run LPG storage volumes



2. Safety measures

□ Overview

- Factors contributing to the widespread of LPG use include:
 - The 1967 enactment of the “**Act on the Securing of Safety and the Optimization of Transaction of Liquefied Petroleum Gas (LPG Act)**”;
 - **Voluntary safety assurance efforts** by distributors since the beginning of LPG commercialization;
 - The economy-wide proliferation of **safety devices** including **auto shutoff gas meters** and **gas-fueled appliances with advanced safety protection features**.

Auto-shutoff gas meter with a built-in microcontroller SI (Safety and Intelligence) Sensor-Fitted Gas Cooker



2. Safety measures

- The current LPG accident rate is 0.82 cases/100,000 households, with only 0.015 deaths per case (2013 actual values).

=Very low figure compared to the number of deaths due to “general accidents at home”, which stands at 27 deaths per 100,000 households (2013 actual value).

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

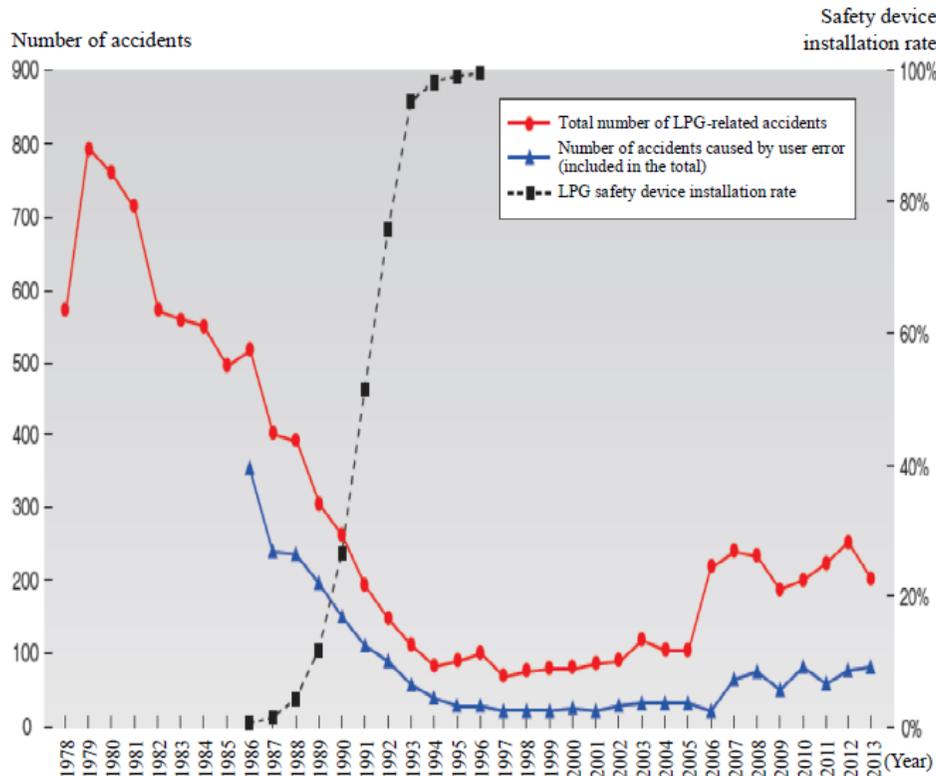
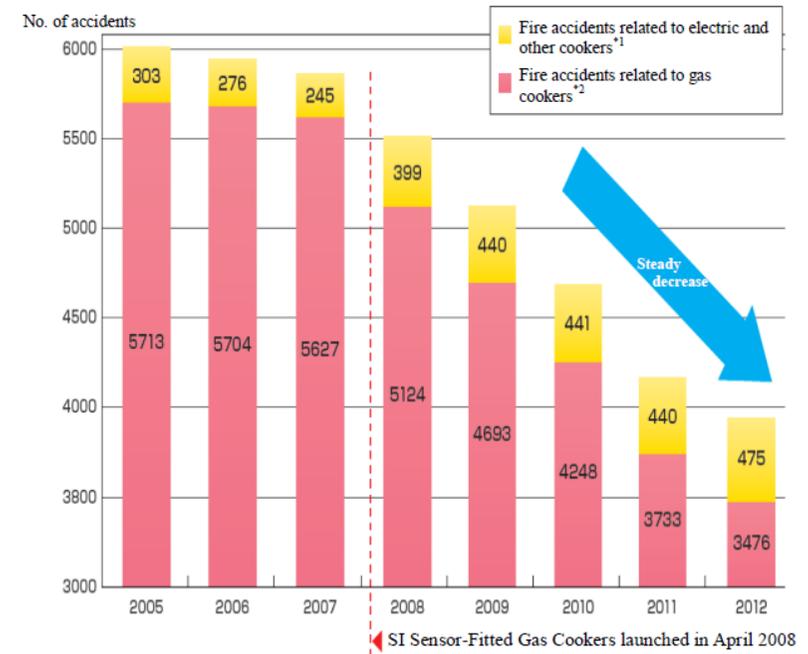


Figure 10. Number of gas cooker-related fire accidents



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 Paper² published by the Fire and Disaster Management Agency under the Ministry of Internal Affairs and Communications)

2. Safety measures

- Safety of household and commercial 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.

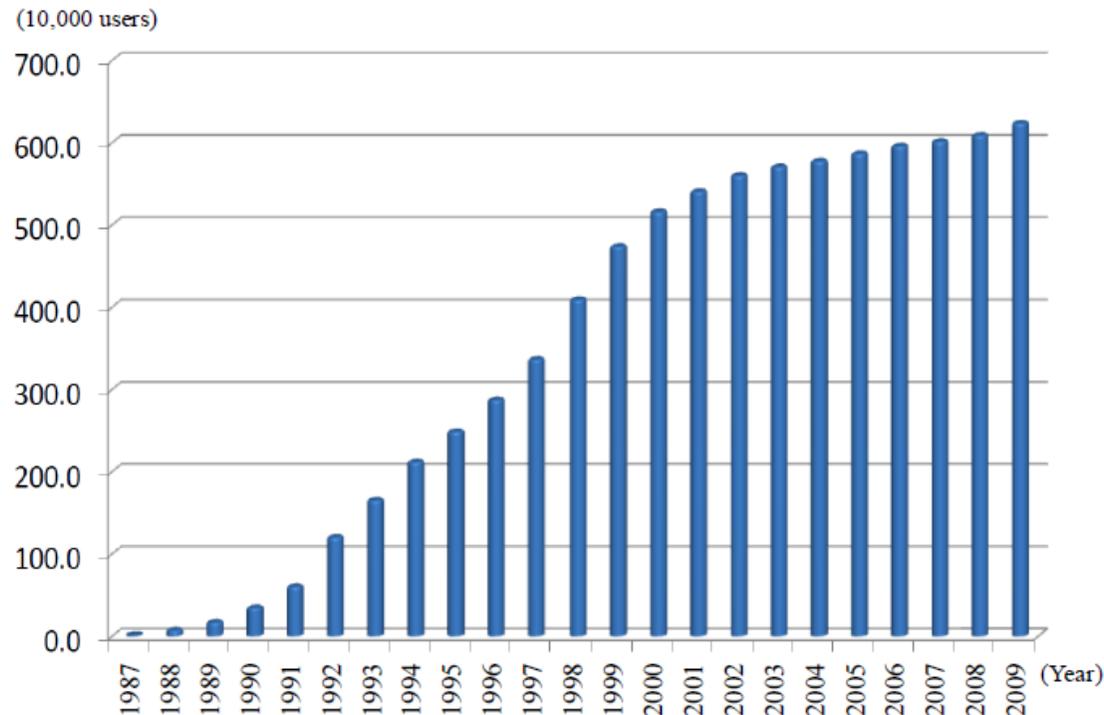
Table 3. Safety monitoring and control tasks

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

2. Safety measures

- Many users are now covered by a **centralized LPG usage monitoring system** connected to their distributor for efficient transportation and supply management.
- 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 NCU's (network control units).

2. Safety measures

□ 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.

Storage tank airtightness test



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

Piping airtightness test



Piping airtightness test
Piping sections are inspected for gas leak.

Open-tank wall thickness measurement



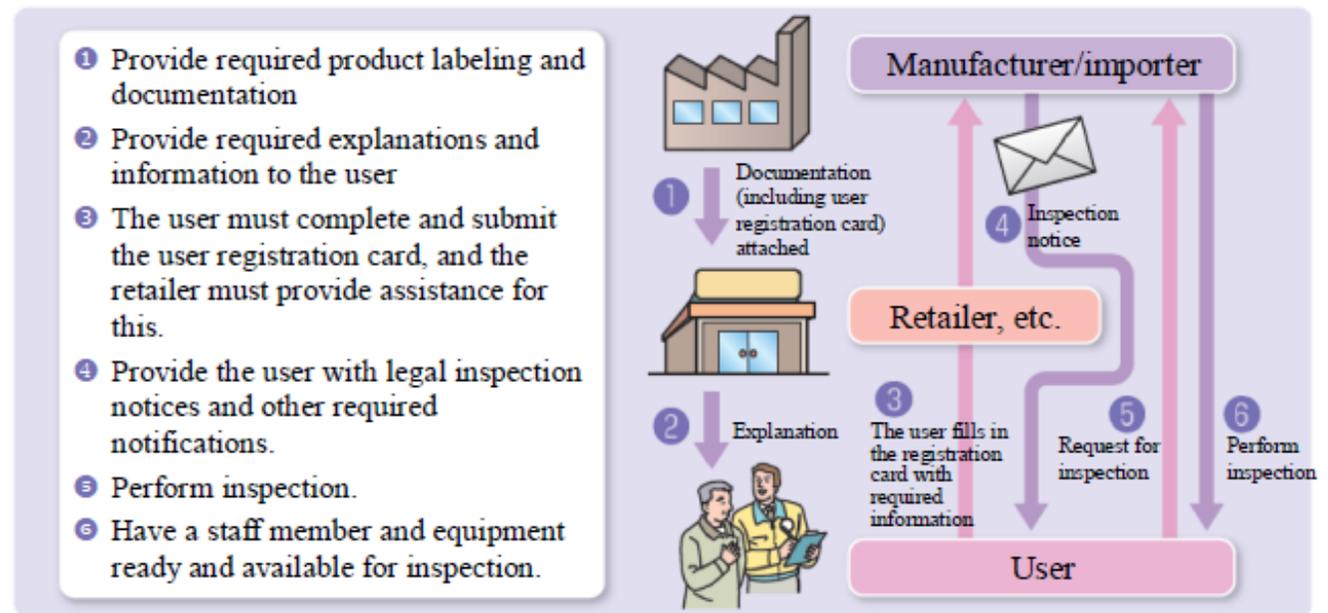
Open-tank wall thickness measurement
The thickness of the tank wall is measured from inside the tank for safety verification.

Source: Japan LP Gas Association

2. Safety measures

- Long-service life product safety inspection scheme, etc.
- In response to reports of deaths and other serious accidents in recent years related to 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 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

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

□ Overview of the Great East Japan Earthquake

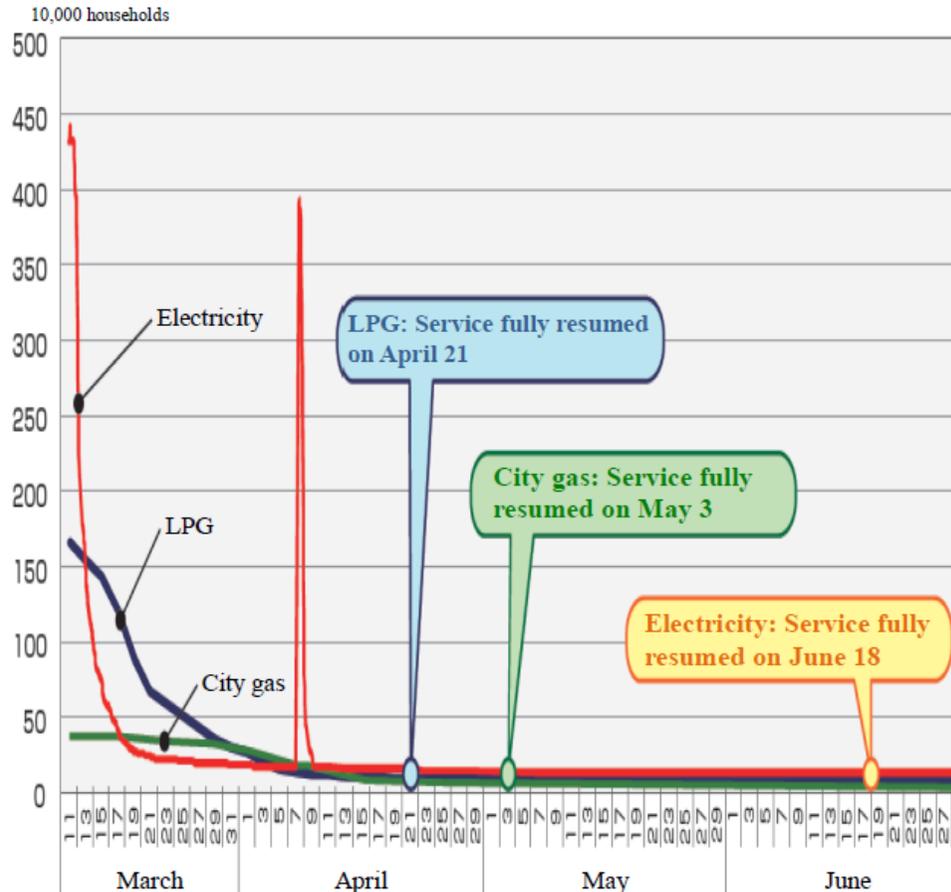
- **The 2011 earthquake** off the Pacific Coast of Tohoku occurred on March 11, 2011.
- The size of the earthquake was **a moment magnitude 9.0**.
- The earthquake triggered powerful **tsunami** waves, causing devastating damages along the Pacific coast of the Tohoku region and part of the Kanto region.
- 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.

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

- ❑ LPG service disruption and resumption after the Great East Japan Earthquake
 - Of the approximately **5,200 LPG retailers and distributors** operating in the six quake-hit prefectures (Aomori, Iwate, Miyagi, Fukushima, Ibaraki and Chiba), **331** had to 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.
 - In Iwate, Miyagi and Fukushima, which were the prefectures hardest hit by the quake, most LPG retailers and distributors 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.

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

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)

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

□ 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 being used at an evacuation shelter



LPG cylinders at a temporary housing project



Emergency meals (Ishinomaki)



Source: Japan LP Gas Association

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

□ Damages in Kumamoto Prefecture

- 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:
 - The earthquake did not occur during the hours when usually people cook meals;
 - In areas where people evacuated after the foreshock on April 14 the LPG valves were already closed before the main shock;
 - **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.

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

▣ Lessons from the Kumamoto Earthquake

- 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.

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 99–128 MJ/Nm³, which is at least about twice that of natural gas.



Thank you for your kind attention

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