Opportunities for LPG

LPG EXCEPTIONAL ENERGY

WORLD LPG ASSOCIATION
www.wlpga.org

WLPGA

The World LPG Association

The WLPGA was established in 1987 in Dublin, Ireland, under the name *The World LPG Forum*.

The WLPGA unites the broad interests of the worldwide LPG industry in one organisation. The WLPGA was granted Category II Consultative Status with the United Nations Economic and Social Council in 1989.

The WLPGA exists to provide representation of LPG use through leadership of the industry worldwide.

Acknowledgements

This report was originally developed by the *Innovation & Technology Network* of WLPGA in 2017. The report was updated and rewritten in 2022.

Key contributors:

George Nikolaou, Natco/AEGPL
Can Tıkıroğlu, Aygaz
Christian Steger, Scharr-Tec
Makoto Arahata, Japan LPG Association
Mauricio Jarovsky, Ultragaz
Michael Guth, Elgas
Neil Ormrod, ITO
Sean Guichon, Algas
Tucker Perkins, PERC

Nikos Xydas from WLPGA coordinated the original project.

Gary Eaton (consultant) was a key contributor to this update together with David Tyler from WLPGA.

All images used in this updated report have been taken from the original.

Contents

Chapter One

Introduction

The aim of this report is to promote the concept of Synthetic Natural Gas (SNG*) to users, policy makers and other key stakeholders. The term SNG is used to describe a precise mix of LPG and air, blended in specialised equipment to create a fuel with combustion characteristics that allow direct interchangeability with natural gas (NG). The report describes the mixing processes, market opportunities, applications, and examples of SNG being used to support NG markets.

(#*SNG is also referred to as LPG-Air, Propane-Air, Simulated Natural Gas, or Substitute Natural Gas)

The benefit of SNG is that it can be substituted directly for NG without requiring changes to the combustion equipment and without degrading the safety, efficiency, performance, or emission characteristics of the equipment burning the gas.

SNG is simply a blend of vaporised LPG with air, mixed to a ratio that simulates the properties of NG, in order that the two fuels can be readily interchanged.

This report describes some of the ways to produce SNG and some typical opportunities for it to be used. It also focuses on the mechanics of fuel interchangeability, an overview of the components required for an SNG system and the different applications for SNG. The SNG considered in this report is produced with LPG (propane, butane, or mixtures of the two).

The report includes fact sheets providing an overview of the current technologies, the main companies involved in providing SNG equipment, and the market status.

There is a section outlining a roadmap to explore the SNG market outlook on technology, market trends, market potential, and identifying the barriers and drivers for future growth.

There are some recommendations for all stakeholders on how to overcome the barriers and maximise the market opportunities for SNG.

In the Appendix there is information about the technologies used in the control and monitoring of SNG, and the key components utilised in SNG plants. The key combustion indicator, Wobbe Index, is also described. Finally, there are several examples of where SNG systems are being used around the world in different applications to benefit both the LPG and NG industries.

Chapter Two

Executive Summary

Liquefied petroleum gas (LPG), mixed with air in the correct ratio, provides a substitute to natural gas (NG). The common term for this replacement gas is synthetic natural gas (SNG). When mixed correctly, SNG is fully interchangeable with NG and requires no change of equipment or appliances. SNG provides an option when NG supplies are limited, unavailable, or at risk. SNG also provides a bridge fuel to the future arrival of NG. Government policy makers, NG utility companies and users of critical processes should be aware of SNG and consider SNG when NG supplies are threatened or where an energy option is needed.

The technique of blending LPG with air is not new. It has been used successfully in utility applications since the 1950s in all regions of the world (see Appendix 4.0).

There are four primary applications for using SNG as a substitute for NG:

- Backup fuel (when NG supplies are curtailed or interrupted)
- Base soad (in regions where there are no NG supplies)
- Peak shaving (supplementing NG supplies)
- Co-mingling (also including off-grid market development)

SNG allows LPG companies to market directly to some of the biggest energy users that are using, or considering using, NG in the future. For many large-scale manufacturers, a reliable supply of energy is essential with no risk of interruptions. A good example is the float glass industry. Other critical gas consumers include hospitals and military bases.

SNG systems exist in Argentina, Bangladesh, Brazil, Canada, China, Chile, Dubai, Finland, Japan, Hungary, Norway, South Korea, Pakistan, Turkey, Russia, Sweden, the UK, the USA, and others (see Appendix 4.0).

The opportunities for using SNG systems are often not recognised and exploited. SNG systems help NG utility companies efficiently manage seasonal demand swings and create the ability to guarantee a security of supply. SNG systems have long been proven to be an ideal bridging fuel in countries waiting development of a reticulated NG grid. South Korea and China are two examples.

NG interchangeability strategies can be a tangible investment in both the security and flexibility of a gas supply system. The growing reliance on NG, and the occasional vulnerability of supplies, has also added a new dynamic to the LPG market with the opportunities for SNG. Threats to NG supplies can be mitigated by using SNG.

Price fluctuation and seasonal volatility require the ability to strategically manage shortages of supply as well as pricing issues. Using LPG in the form of SNG to replace or augment NG provides additional stability to NG supplies while offering economic benefits to both gas consumers and gas providers.

Even though SNG systems have been around for decades, they still offer plenty of potential growth opportunities for the LPG sector. SNG systems provide additional stability to NG supplies, resulting in multifaceted economic benefits to businesses and other institutions.

SNG cannot be used in a process industry such as fertiliser manufacturing where methane or ethane is required as feedstock.

Key Markets

The following regions are identified as markets of high opportunity for SNG.

- **Asia**: one of the world's largest energy-consuming regions; possesses limited NG yet seeks to replace the use of coal with fuels of lower carbon footprints - priority markets include Bangladesh, China, Indonesia, Japan, Myanmar, Pakistan, Thailand, and Vietnam
- **South Africa**: depleting NG, and lack of a NG infrastructure; well-developed industrial NG consuming base
- **North America**: traditional well-established market; NG shortages during cold season; interruptible tariffs mandated shift to cleaner fuels
- **South America**: limited and depleting NG; well-developed industrial consumer base

2.1 Key Messages – SNG is not New

NG users, especially large ones, seek ways to mitigate threats to production and reduce energy costs. Using SNG can counter these threats and offer arbitrage opportunities to reduce costs.

LPG, the base ingredient of SNG, is an extremely versatile distributed energy source. It is reliable, portable and is an extremely efficiently distributed source of energy. As a reliable, portable energy, LPG plays an important role in disaster relief efforts - unlike grid-based energy services. When a tsunami or an earthquake occurs, infrastructure could be damaged. Sometimes electricity supplies are cut off and city life is suspended. SNG systems can ensure energy is restored quickly and reliably to assist in the recovery phase.

- Local distribution companies (LDC): *LDCs can supply SNG to customers who lose access to the city NG grid. An LDC can maintain an SNG facility as part of their disaster prevention equipment*
- Mobile SNG systems: *can ensure a continual supply of gas to essential services such as hospitals and schools in the event of an NG pipeline rupture*
- Supplies of SNG to temporary applications: *evacuee housing units can be provided with SNG in areas affected by natural disasters*

There are no significant technical barriers in adopting SNG. Standardised designs can be employed in standard process applications and specific designs can provide tailor-made solutions to suit process requirements (see 3.3).

The underlying principle of the efficient replacement of NG with SNG is based on matching the Wobbe Indices of the two fuels (see Appendix 3.0). Both combustion processes are similar, and burners do not require pressure adjustments nor orifice changes.

The United States is the leading supplier of SNG system technologies, followed by Europe and Asia. SNG systems are typically packaged, requiring minimal interconnects once located at the end user site. A variety of metering and monitoring options are available and are typically selected based on the type of gas consuming equipment and sensitivity of the manufacturing process to any thermal issues.

For large scale NG substitution projects, LNG may have an advantage over SNG, but it is not always available and accessible. LNG systems are also expensive, not easy to secure permits for, and are often difficult to source. LPG in the form of SNG holds a decisive advantage for small and medium sized applications, and regional city gas opportunities.

Argentina, Brazil, Bangladesh, Canada, Chile, Finland, Norway, Pakistan, Russia, Sweden, UK, and the USA, all have respectable penetration by SNG into their NG networks. This is either at the end-customer level, or the utility level. In Africa, the use of SNG is present but not widespread, but there are no technological barriers to employing it.

2.2 Key Messages – SNG Roadmap

NG and SNG have a linked relationship. SNG needs NG to maximise the benefits, and NG needs SNG when it is not available.

NG demand forecast data suggests global SNG use could increase up to 20% by 2025. SNG's role will vary by region and be linked to applications within specific emerging markets. SNG can play both a strategic and tactical role in meeting future energy needs.

For SNG market opportunities to expand, NG distribution networks must also expand. NG and LPG (SNG) work together rather than as competitors. Several SNG manufacturing and installation companies anticipate continued growth in Asia and the Americas over the next five years. Larger-scale SNG opportunities may also emerge in the Middle East and African regions.

An important opportunity for SNG technology is product adaptation into smaller scale systems designed for the residential and commercial sectors. These products will open new market opportunities globally. Continued refinement and standardisation of existing design concepts, and upgrading of their operating parameters, will enable SNG to be more accepted by potential end-users as well as being adaptable to existing opportunities.

There are several factors which support the opportunity for SNG systems:

- Pipeline delivered gas to the consumer, as with NG
- Guarantee uninterrupted supply even in peak periods
- Fully compatible combustion characteristics with NG
- Primary energy source, or as a backup to NG
- Secure piped gas infrastructure
- Competition and cooperation with NG systems
- Solution in natural and other disasters that cause NG grid failure
- Solution where supply continuity is at risk
- Applicable in remote off-grid locations
- Environmentally friendly (LPG is not a greenhouse gas)
- Safe and easy to operate and use
- Low capital investment with possible leasing offers
- LPG supplies are abundant and available globally
- Compact design and portable
- Can operate without electricity

Target markets for SNG:

- Limited NG availability or non-existent NG infrastructure
- Good availability of LPG product and infrastructure
- Expected growth in energy demand

- Expensive alternative fuel options (diesel, electricity)
- Policy/regulatory framework favouring clean fuels
- Where there are national clean energy goals

2.3 Key Messages – Recommendations

SNG is facing several barriers that need to be overcome:

- Customer economics: investment cost, this is perhaps the greatest challenge
- Policy/regulatory framework: SNG needs to be on a level playing field with competing technologies and fuels
- Technology development: Slow in some regions resulting in limited market growth
- Commercialisation and getting products to market: trained installers, servicing/maintenance networks and sales channels need to be in place
- Awareness/perception: SNG systems need to be considered by policy makers, energy users, installers, utilities, and the industry. The gas marketplace is very conservative and disinclined to change easily to new technologies and innovations rapidly
- Fear by LPG stakeholders of working together with NG and helping NG expand its network

All relevant market stakeholders need to work together in a coordinated way to overcome these barriers, develop new business models and maximise the market opportunities for SNG.

Key actions identified in the recommendations:

- Overcoming the economic challenge for SNG:
    - examples of ways to overcome this barrier could include economic support to end-users through financing packages and targeted incentives, or technology development which results in upfront cost-reduction and running cost savings
- Ensuring that the policy/regulatory framework creates a level playing field for SNG systems with competing technologies:
    - lobbying is one of the most important activities to ensure this. It is now more important than ever to develop and communicate a vision of the role that LPG can play in de-carbonised future energy
- Advancing or accelerating SNG technology development:
    - investment in R&D, and carrying out market research to identify which markets, market sectors & applications have most potential, and what R&D developments should be made to ensure that the technology is well-suited to these markets
- Facilitating commercialisation and getting products to market:
    - developing installer training schemes, providing support with developing distribution partnerships in new regions, and market research
- Raising awareness of SNG amongst policy makers, customers, installers, utilities, and the industry:
    - developing a consistent vision for SNG, which can be shared across the industry, identifying the end goal, and defining measures required to achieve this goal. Educate stakeholders and develop marketing and awareness-raising activities
- Publishing case studies of successful projects:
    - Creating a library of examples illustrating the range of use. Communicate successful SNG projects and emphasise the history SNG has with the NG industry

Chapter Three

Fact Sheets

These Fact Sheets provide a description of what SNG is, an overview of the various technologies, their major applications, market status; a snapshot of the main companies involved with SNG equipment on the global market, some important aspects on safety, training, and fuel quality - these companies can assist with aspects of SNG that range from safety to equipment selection to training.

3.1 What is SNG and how it works

3.1.1 Definition of SNG

SNG is created when LPG is blended with air in a pre-calculated ratio. The resulting fuel will have similar combustion characteristics to NG and provide an alternative to NG. The two fuels are fully interchangeable. This is achieved by ensuring the Wobbe Index – calculated by dividing the Gross Heating Value of a gas by the square root of its specific gravity – is the same for both fuels.

3.1.2 The SNG Principle

The calorific value of LPG (93.2MJ/m3) is more than double that of NG (38.7MJ/m3). When LPG is diluted with (around 45%) air to reduce its heat value and create a product with similar combustion characteristics to NG, it can be used in the same NG appliances (burners, heaters, cookstoves etc.).

The vaporised LPG is run through an LPG/air mixer (or blender) that mixes at the required ratio of vapour LPG and air, to create a mixture compatible with NG. The mixture can replace NG and be used by any NG equipment such as burners, heaters, stoves, furnaces, water heaters, etc., without any modification to the equipment. These systems can also be connected directly to NG pipelines. This makes operating the equipment easy, avoids lengthy and costly changeovers, and guarantees uninterrupted energy supply.

The simplified flow diagram (Figure 1) depicts a typical SNG system. Liquid LPG is stored in a tank under pressure. The size of the tank depends on the capacity of the SNG system, it's planned hourly usage, and the logistics associated with delivering the LPG.

During operation, LPG is transferred from the storage tank to the LPG vaporiser using an LPG pump. As the LPG liquid passes through the vaporiser, it is heated and transformed from the liquid to the vapour phase. The vaporiser provides sufficient super-heat to prevent re-condensation before entering the blender.

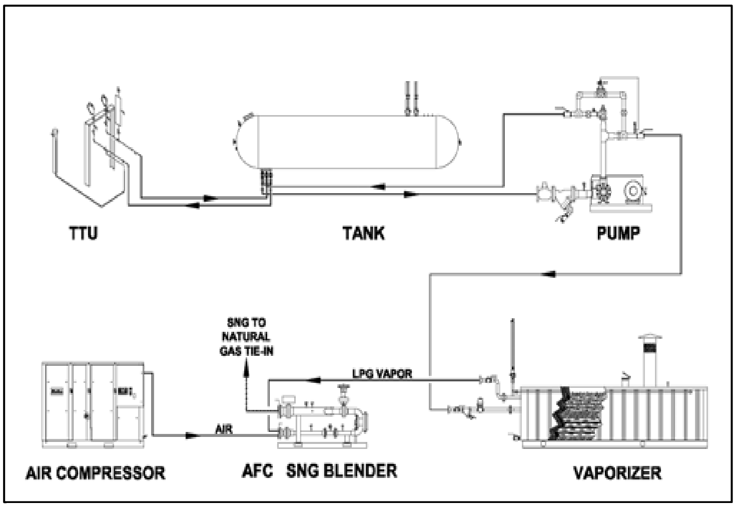


Figure 1 - Typical flow process of an SNG system

The super-heated LPG vapour then enters the SNG blender where the vapour and air, supplied from an air compressor, is mixed to a specific ratio to create the SNG. This system is called a proportional blending system. It is illustrated in more detail below (Figure 2).

The system's flow control system measures both the LPG vapour stream and the air stream while continuously measuring the Wobbe Index to ensure compatibility with NG. The SNG, at a pre-determined pressure and Wobbe value, then flows into the gas distribution grid as required.

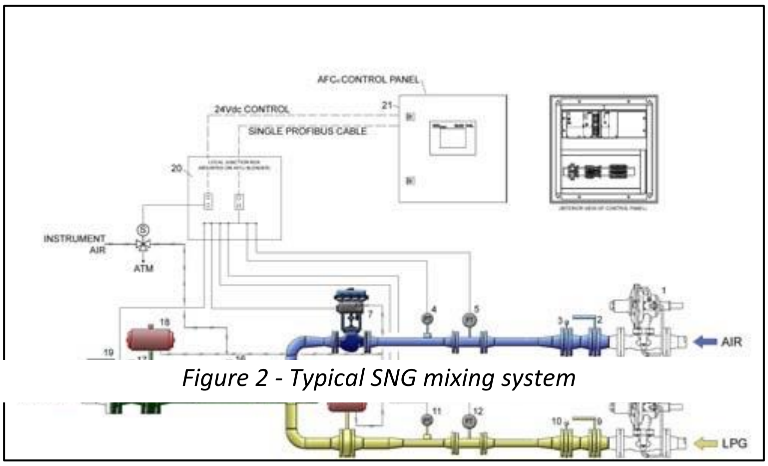


Figure 2 - Typical SNG mixing system

Smaller, simpler, and sometimes portable LPG/air mixing systems, use a venturi to induce atmospheric air. No air compressor is required. Each venturi has a nozzle specifically calibrated for the LPG being used. The pressure of the LPG vapour entering the venturi creates the SNG delivery pressure. These systems are limited to between 6 and 12 psig.

A simple cylinder fed venturi configuration is shown in Figure 3.

Benefits include:

- Requires no external power
- Requires no air compressor
- Is small, light and easily transportable
- Stable calorific value without adjustment
- Safety devices ensure total security

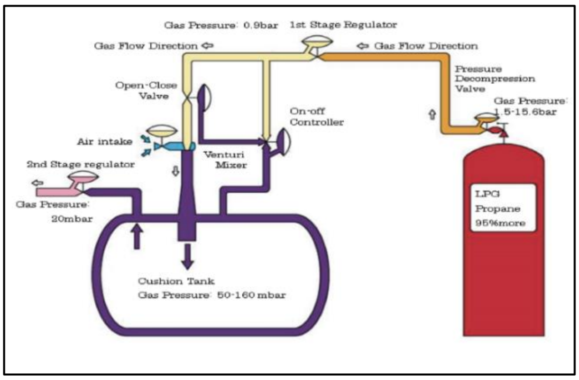


Figure 3 - Simple cylinder fed configuration

More information on the SNG system process is included in Appendix 1.0 and 2.0.

3.1.3 Fuel interchangeability

Replacing NG with SNG does not require changes to appliances or their fuel systems. The ease of using SNG offers significant benefits to end users who want to eliminate the challenges of using diesel, fuel oil or LPG to replace NG.

Replacement of NG with LPG would require changes in most of the burners and distribution equipment since those two gases have very different characteristics. The use of SNG systems however is a more suitable alternative for substituting NG and especially for industrial and utility companies.

Two alternatives to SNG are liquefied NG (LNG) and compressed NG (CNG). Both are more complex, demanding logistics to ensure a reliable fuel source, and both involve significant site approval challenges and capital investment. Unlike LPG, which can be kept liquefied indefinitely under ambient conditions, CNG requires costly compression and transportation. Similarly, LNG requires cryogenic temperatures to avoid boil off, which limits its storage time. Even when maintained at cryogenic temperatures, LNG still boils off with a negative impact to the environment.

SNG is the ideal solution for NG curtailments and as a bridging fuel to NG (see Appendix 4.0).

There are various quantitative techniques to measure interchangeability. These techniques include Wobbe, Knoy, Weaver and others.
The most common method used to confirm the interchangeability between two gases is based on their Wobbe index (see Appendix 3.0). The Wobbe Index is used to compare the combustion energy output of different composition fuel gases in

an appliance (burner, cooker etc.). If two fuels have identical Wobbe Indices, then for given pressure and valve settings the energy output will also be identical.

3.1.4 Benefits of SNG

An SNG system has the following benefits:

- Enables utility companies to ensure supplies to industry, homes, hospitals, schools, etc. and avoid costly shutdowns
- Small SNG systems can be erected quickly with low capita cost
- No adjustments required to NG appliances e.g., burners, cookers, heaters – avoids costly change-over expenses
- Process control systems automatically shuts the system down if a fault occurs
- LPG is a readily available fuel
- SNG produces a stable calorific value output
- Users can monitor and manage their fuel option (NG or SNG) to reduce costs
- SNG allows industrial consumers to take advantage of interruptible fuel tariffs when available
    - NG companies often offer two basic rates: firm rates - expensive but ensures gas availability, interruptible rate - allows for consumers with an SNG standby system to take advantage of rates which can be up to 50% lower than the firm rate
- SNG allows LPG companies to sell LPG into a NG market
- SNG has a lower dew point than LPG vapour and can be distributed without any re-condensation occurring (the temperature where SNG condenses from a vapour to a liquid). This allows SNG to operate at higher pressures and colder temperatures than LPG (Figure 4)
- SNG is typically cheaper than HSD (high sulphur diesel) and LSFO (light sulphur fuel oil)
- SNG is comparable to RFO (residual fuel oil) but is cheaper when capacity, availability, operational efficiency - leading to lower operating and maintenance costs - are considered
- The carbon footprint of SNG is the same as NG, i.e., significantly smaller than other liquid hydrocarbons

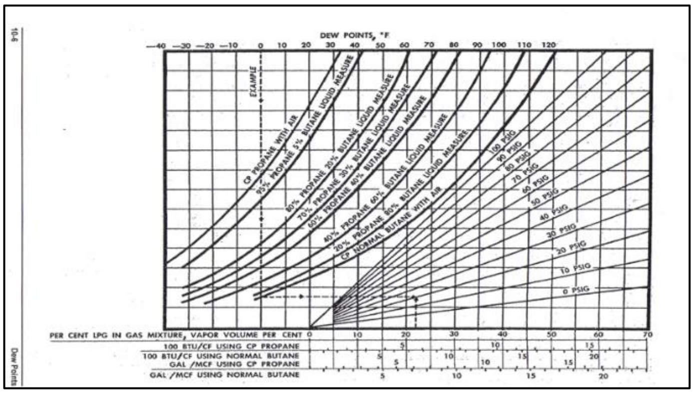


Figure 4 - Dew point chart

3.2 SNG Systems

SNG systems can be summarised into four major areas of use:

- **SNG Stand-by or Backup Systems**: Allowing NG customers to use SNG during curtailment periods and taking advantage of arbitrage opportunities
- **SNG Base Load Systems:** Providing a bridging fuel in regions where NG is planned to be available in the future but is not yet available. The SNG system may later revert to a peak shaving function
- **SNG Peak Shaving Systems:** Allowing distribution companies and consumers to supplement their NG during peak demand periods without adding grid/pipeline capacity
- **SNG Co-mingling Systems:** SNG replaces NG as required. The quantity of NG being replaced by SNG can be reallocated elsewhere in the grid to alleviate supply challenges

In emerging NG markets, the gas provision for anchoring industrial customers is based on restricted supply alternatives, which increase the risk and the concerns related to NG supply interruption. Very expensive equipment such as high temperature furnaces in glass works, steel mills, ceramic industries, or foundries, cannot run out of gas without the risk of expensive damages. The installation of SNG backup systems mitigates this risk. The four major areas are described here with their benefits.

3.2.1 SNG Standby or Back up Fuel Systems

The need for energy backup is related directly to the risk of supply interruption. With NG, the main causes of supply interruptions include political intervention, accidents, planned maintenance and distribution line failures. A drop in the NG line pressure can result in expensive results.

Photo by TransTech Energy

SNG system installed at a Pilkington glass factory in the USA

When an interruption occurs close to the end of a pipeline, line pressure can be lost in minutes. In this situation the use of an SNG backup system is essential. Depending on size and complexity, an SNG system can be brought online in less than an hour. An SNG system requiring a longer start-up time can be maintained in so called 'hot standby' position during times when it is most likely to be needed. Then it can be brought on-line in minutes.

Another reason to justify the existence of a SNG backup system is to allow an industrial consumer to improve its NG contracting strategy changing (totally or partially) from firm to interruptible contracts. Usually, interruptible gas contracts lead to fuel cost reductions, particularly under major gas price fluctuations, to justify the investment in a SNG system.

A standby or backup fuel system is imperative for maintaining steady operation both to supplement an inconsistent fuel supply or where there is risk of fuel supply interruption.

The SNG system enables the factory to continue normal operation and production even during curtailment periods. When NG becomes available again, the SNG plant deactivates and resumes its standby role.

Under an interruptible contract, a discounted tariff is available to the consumer year-round. When the gas demand placed on the utilities exceeds pipeline capacity the utility company can invoke all interruptible contracts. These customers are then told to switch to their SNG standby systems. Curtailments usually occurs only a few days throughout the year and happens with minimal advance notice. The savings from the use of the 'interruptible rate' are usually so significant, that most users recover the capital investment for a standby SNG system within 6 to 18 months.

Critical installations, such as hospitals, military installations, livestock farms, etc., often require backup systems for electricity and NG and SNG can provide the primary energy to a backup power generator.

Benefits

- Standby fuel systems provide the opportunity for large gas users to reduce NG costs by as much as 50%, by utilising 'interruptible service' gas savings rates, especially for large users (>2 million Btu/hr)
- NG shortages or interruptions can result in both production losses and damage of process equipment. Covering this risk with a back-up fuel system is an attractive option

3.2.2 SNG Base-Load Systems

SNG base-load applications typically address one of the following needs:

- Bridge system: where SNG is the bridge fuel to NG providing a local distribution network in anticipation of the imminent arrival of a secure and permanent NG supply. This system is commonly found in South Korea, and China where large-scale examples operate
- Critical NG supply for a utility: where demand exceeds supply on an existing NG distribution infrastructure the use of SNG by the utility to service a consumer is less expensive than pipeline expansion

For decades SNG base-load systems have been applied around the world in developing NG markets prior to the arrival of NG. An early example is when North Sea gas was discovered in the Groningen area of the Netherlands in 1959. In this model SNG is used as a 'bridging fuel' in preparation for NG availability later, either LNG or NG.

The following must be considered when using SNG for a large industrial user:

Photo by TransTech Energy

- System capacity must be carefully sized with a reasonable excess margin (~20%). This must be discussed and mutually agreed with the consumer
- Specialised equipment such as heat recovery units, regenerators, and dust collectors, must be evaluated to ensure SNG is an appropriate option for them following discussions with the consumer
- Heat transfer characteristics from the flame must be maintained in some sophisticated burners
- Flue gases may be needed to provide an oxidising, neutralising, or reducing atmosphere
- Careful coordination and communication with the client are needed for these types of applications

Base-load systems using SNG are one way to overcome base-load restrictions on NG supply, which may last a few years.

Benefits

- LPG for the SNG is easily transported via truck, rail, or pipeline, and requires less infrastructure and cost than CNG or LNG
- SNG base-load systems can be installed almost anywhere, regardless of location
- In developing countries, using SNG prior to the arrival of NG allows all NG infrastructure to be completed in advance

3.2.3 SNG Gas Peak Shaving Systems

Peak shaving systems (Figure 5) are primarily used to augment NG when NG supplies are insufficient to meet peak demand.

Utility Companies and large industrial users typically contract their supply agreements for a certain volume of NG to be available over a period (day, week, or month). Pricing is then established based on the contracted volumes and time periods.

Photo by TransTech Energy

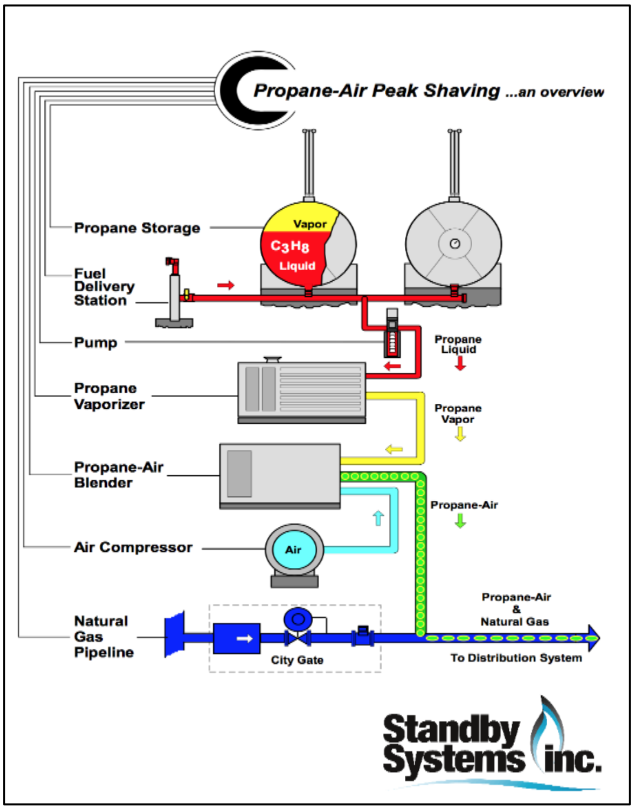


Figure 5 - SNG Peak Shaving Overview

The price to purchase additional gas will increase dramatically if the consumer exceeds their contracted NG volume. SNG systems can be designed, installed, and operated to replace a percentage of the total gas demand, avoiding penalties by using SNG when the NG allocation is reached.

The use of SNG for peak shaving must be understood from two perspectives, daily and seasonal.

Daily demand is when additional gas is required for just a few hours. This can arise when the flow rate in the NG grid reaches maximum capacity. If the pressure drops at the end of the distribution system, creating bottlenecks, it makes it difficult for the NG supplier to meet its commitments to end users. These scenarios become more critical if the gas grid is old or when the pipelines are under sized for current demand. The use of SNG peak-shaving stations, positioned at the end of the NG grid, is designed to maintain line pressure, and even allow new consumers to be admitted.

Peak shaving facility in the Midwestern USA - Photo Algas-SDI

In its seasonal role, an SNG peak shaving system would allow a utility or large gas user to maximise the use of their contracted NG and meet any peak demand that exceeds this amount by supplementing with SNG. This

avoids unnecessary investment in additional pipeline capacity or the expensive, spot market, purchases of NG.
To cope with the demand, SNG peak shaving systems generally operate when LPG is delivered to a peaking site via pipeline, truck or railcar and stored in LPG tanks. Very large storage capacities may involve refrigerated tanks or underground caverns.

SNG injection point

There are two common SNG injection methods used when peak shaving:

- Ratio Control (Figure 6)
  - The ratio of SNG to NG is fixed in the control system. SNG flow volume is controlled by a flow control valve
- Pressure Control
  - The desired NG line pressure is fixed in the control system. SNG flow to maintain the desired pressure is maintained by the control system and a flow control valve

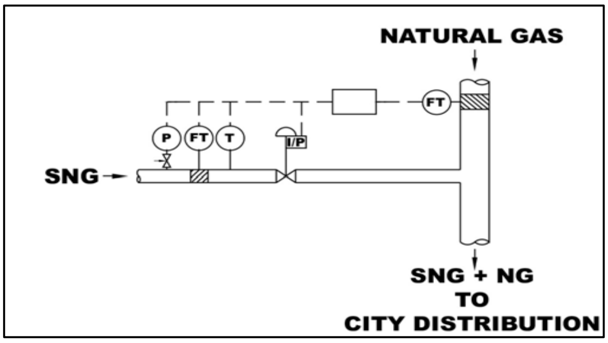


Figure 6 - Peak shaving using ratio control

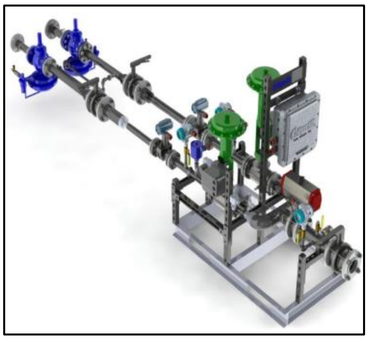
Benefits

- Peak shaving systems require lower capital investment, easier fuel storage, incur lower maintenance costs and manage NG supply restrictions in peak periods. The goal is to avoid using NG that exceeds the upper limits of the contracted volumes
- Peak shaving systems support NG utilities by minimising the impact of unpredictable consumption, as well as other unexpected supply constraints, by augmenting NG with SNG, during times of high demand, or high pressure drops in old and undersized gas pipelines

3.2.4 SNG Co-mingling Systems

Co-mingling is when SNG is injected into a NG distribution system to replace an adjustable percentage of NG on a part time, full time, or as required, basis. The process consists of injecting SNG into the pipeline to mix with NG. Flow meters and chromatographs are available for the injected flow rate to calculate the equivalent energy provided.

The quantity of NG being replaced by SNG can be reallocated elsewhere in the grid to alleviate other supply problems.


Co-mingling SNG system

During periods of high NG demand the use of NG for industry is sometimes restricted. Thermal power plants may also be affected by restrictions on NG supply forcing them to use liquid fuels.

SNG has an advantage over traditional peak-shaving plants using LNG as it is easier and more economic to store liquid LPG (propane) at -42°C than LNG at -160°C.

3.3 SNG Equipment Companies

The companies listed in Table 1 below are some of the global SNG companies who design SNG plants and offer custom engineering and turnkey solutions for base load, stand-by, and peak shaving systems for clients who have the need to instantaneously replace, or limit their primary NG consumption. These companies carry out projects for government, utility and manufacturing or industrial applications.

Algas-SDI	**Algas-SDI** designs and manufactures a wide variety of LPG vaporisers, LPG-Air mixers for replacing or increasing the supply of NG as well as a variety of other related products. Algas-SDI, together with its partners world-wide, offers its customers an excellent single source for design, installation, and service for total system needs, supported by expert application engineering services (https://algas-sdi.com/)
SCHARRTEC bringt Energie ins Leben	**Scharr Tec**: Gas technology: LPG plants, gas-air-blending plants, technical gases PROLIMIX: the new generation of bio-methane mixer LPG plants: From the initial permit through to inspection and final authorisation, all from one hand. From small tanks and contain (https://scharr.de/tec)
I·T·O	**ITO** is a leading Japanese manufacturer of gas regulators for various gases. Founded in 1953 they have maintained a quality-first philosophy. ITO offers unique products and innovative products (http://www.itokoki.co.jp/english/products/product_lpg.asp)
ELGAS New Zealand	Elgas provides LPG and solutions for home, business and cars (https://www.elgas.com.au/)
KGE	**KGE** is growing into a global company, with strong endeavour that will continuously grow through ceaseless innovation. KGE has exported the gas equipment to the countries of ten or more nation of Southeast Asia. KGE offers the products of high quality, efficiency, and cost performance in all the countries (http://www.koreagaseng.com/main)
MACS	**MACS** is a leading organisation in the business of factory automation, industrial/commercial LPG/SNG systems, LPG Autogas stations, LNG gasification systems, heat exchangers, process filtration equipment, control cables and explosion proof LED ilghting systems and enclosures (https://www.macspk.com/)
TRANSTECH ENERGY	**TransTech Energy** is a leader in NGL and LPG storage and handling across all stages of oil and gas production, processing and distribution (https://www.transtechenergy.com/)
aether dbs	**Aether DBS** delivers the best value to its clients by providing practical, engineered modular systems for energy, gas, and environmental infrastructure projects (www.aetherdbs.com & https://sagebrushpl.com/)
cam	Since 1955, **CAM** has been designing, manufacturing, and installing gas mixing plants for industrial facilities and for gas distribution companies (http://www.camitalia.com/)
STANDBY SYSTEMS INC. (USA)	Since 1975, Standby Systems, Inc. has delivered SNG equipment and services to utilities and industrial/commercial gas consumers of every size. Standby also provides expertise in piping systems to provide complete solutions for clients. (https://standby.com)

Table 1

3.4 Regulatory Framework

Here are two typical applicable regulations and standards for SNG:

United States

In the USA the National Fire Protection Association publication NFPA59 (Utility LP-Gas Plant Code), a companion document to NFPA58, is applied as the minimum standard for utility-owned plants. This standard addresses materials of construction, installation distances, operational issues and more. Utility gas systems in the US are also affected by requirements of Federal, State, and local governmental agencies. The US Federal regulations in 49 CFR 192 *(Transportation of NG and Other Gas by Pipeline: Minimum Federal Safety Standards)*, as provided in eCFR (2012), are particularly applicable. The U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration has primary authority for administering these regulations. Factory Mutual and Industrial Risk Insurers also have specific requirements for SNG installations. Local code officials and fire departments must be consulted prior to construction and trained in the safety features of any system.

Germany

The 'DVGW-Regelwerk' contains a special code for gas mixing or SNG units: G 213, version 2013-10. The code addresses scope of application provides code references, definitions, componentry of gas mixing units, LPG plants, testing procedures and operation and maintenance. The code is available in the German language only.

3.5 Safety and Training

3.5.1 Safety

The development of any new technology, especially a technology that involves LPG, requires diligent attention and consideration of safety implications.

SNG equipment should hold an appropriate FM, UL, TUV or similar approval, providing assurance it is both designed correctly and has third party verification. Importance must be given to verification of materials and construction with attention to safety fittings. Equipment must be installed correctly, meeting all applicable country codes, and operated in accordance with the manufactures or designers' guidelines.

SNG system operators require a thorough knowledge of all potential safety risks associated with LPG and LPG systems. System operators must understand the basic properties and associated hazards of storing, handling, and distributing LPG. They should know the differences in properties between NG and SNG (LPG). This knowledge must include LPG tanks, pumps, vaporisers, SNG blenders piping and all other components that comprise the SNG system.

3.5.2 Training

Training of operating personnel for LPG and SNG equipment is critical and a prerequisite before any equipment is put into service. Training should be provided by the manufacturer of the equipment or their approved representative.

3.6 Quality of fuel

The quality and composition of the LPG being used in an SNG system must be understood. LPG composition (propane and butane percentages) may vary from country to country. This is needed to ensure the correct Wobbe Index matching to the NG has been properly calculated.

In Germany for example, and in other countries, propane and butane are sold separately. Quality is defined under DIN 51622.

For LPG to be used in SNG systems for residential and industrial applications, it is important to ensure a constant composition and quality of the fuel, together with controls in the distribution chain to maintain it free of impurities and contaminants.

When LPG is used in SNG blends for residential and commercial applications, a constant composition with a high propane content is preferred. SNG used in industrial applications or peak shaving systems are more forgiving on LPG composition. Mixed gas quality is typically maintained by a calorimeter which continually combusts samples and measures the energy content. The calorimeter sends a signal to the blender to control the correct LPG/air ratio to maintain the correct Wobbe Index.

3.7 Main Stakeholders

The various stakeholders in the SNG market must cooperate to drive market growth. They should raise awareness of the opportunities for SNG with both consumers and policy makers.

Key stakeholders include:

- LPG distribution companies
- NG utility companies
- Local and Federal Governments
- SNG systems manufacturers and installers
- Independent SNG system integration service companies
- National and international LPG associations
- Policy makers, regulators

They all have an important role to play.

Chapter Four

Roadmap

4.1 Market Outlook on Technology

LPG – and renewable LPG - will have an increasingly important role to play in the energy mix in the next 20 to 30 years. Global initiatives towards clean fuels, combined with the role of gaseous fuels with low carbon footprints, will become increasingly important. LPG as a clean, portable, flexible, available, easily transportable, and adaptable fuel, will continue to be an important fuel of the future.

The International Energy Agency (IEA) anticipates a 50% growth in the demand for NG in the period up to 2040 – with much of this growth associated with electricity generation.

If a gas pipeline network exists near the demand, NG will likely be the gaseous fuel of choice, particularly for residential, commercial, and industrial uses. However, many countries do not yet have an established network of NG pipelines. In such cases, there is a clear opportunity for SNG systems where LPG could provide a solution.

Though NG grid infrastructure is expected to expand in many countries throughout the world, in some countries, power shortages are becoming critical issues today. Governments either cannot afford to introduce NG to fuel new-build power plants, or they do not have access to NG.

Governments are increasingly considering the potential for using LPG as a 'bridging' fuel. In such cases, power plants using SNG for a short period are being built with a plan to convert to NG when the piped infrastructure will be in place. If this happens, the SNG (LPG) assets will not become stranded because they can either be used for future standby NG operation, or for developing traditional LPG cylinder and bulk off grid markets.

SNG mixing systems represent a mature technology with consensus around design concepts amongst manufacturers. There are unlikely to be any significant new conceptual developments but incremental improvements for components and systems are more likely to happen, including new types of valves which will lead to some efficiency improvements. Cost reductions should come as competition develops.

4.2 Market Trends

The following analysis identifies several high-level market characteristics which create strong potential for SNG systems with LPG. These characteristics were also used to determine the region to focus on. If a region has all these characteristics, the potential will be strong for SNG systems using LPG. Each global region is assessed based on these inherent characteristics listed in Table 2 below.

Market Characteristic	Ingredients for success
Limited NG penetration or non-existent NG infrastructure	Countries with limited or no access to NG supply grids but have plans to develop NG infrastructure in the future are of high interest
Local production of LPG and infrastructure	Countries with an abundance of LPG supply or domestic production. These countries can control the cost of LPG and are not exposed to risks of global price fluctuations, transportation costs or shortages of supply etc. These countries have an LPG infrastructure in place improving the ability to strategically manage shortages of supply as well as pricing.

Expected growth in industrial activity which creates energy demand	Significant use/growth of NG by both the residential and commercial sectors. Economic growth strongly influences energy consumption. As countries develop energy demand tends to grow rapidly. LPG can act as a 'bridging fuel' solution for power plants intended to operate on NG. If NG is being used for power generation SNG can help avoid blackouts.
Fuel price advantages	In off-gas grid areas, diesel is often the primary fuel of choice for power generation. LPG and SNG creates an opportunity as a lower cost alternative.
Policy/ regulatory Framework	Political and public pressure to reduce global carbon emissions from the energy sector. LPG has a lower emissions profile compared with NG, LNG, or diesel. Countries seeking to lower carbon emissions may consider LPG, especially as a bridge fuel to NG grid development. Some governments may reduce subsidies for diesel to encourage switching to gas, including LPG in SNG systems

Table 2

4.3 Market Potential

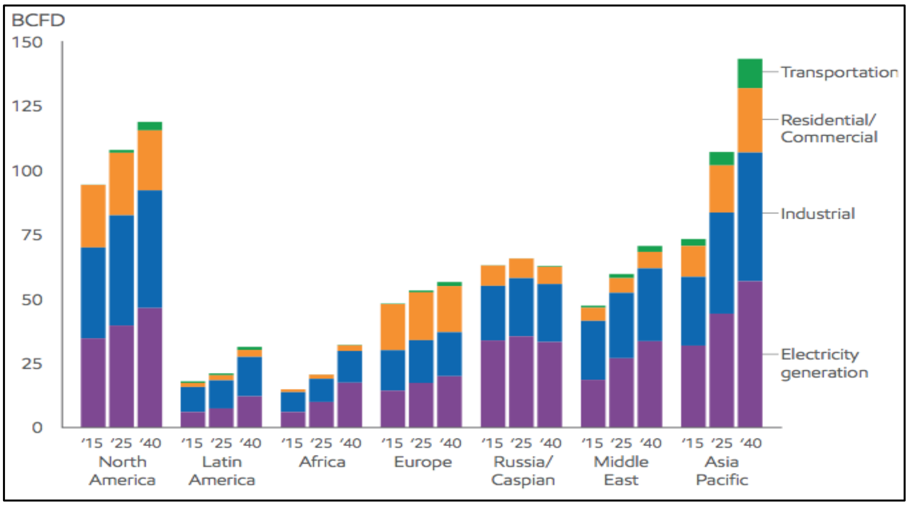
4.3.1 Target Regions

For countries and regions looking for an abundant availability of low-cost, more environmentally friendly NG, but lacking a NG infrastructure, the use of SNG, until NG infrastructure can be built, is an option.

NG – projections

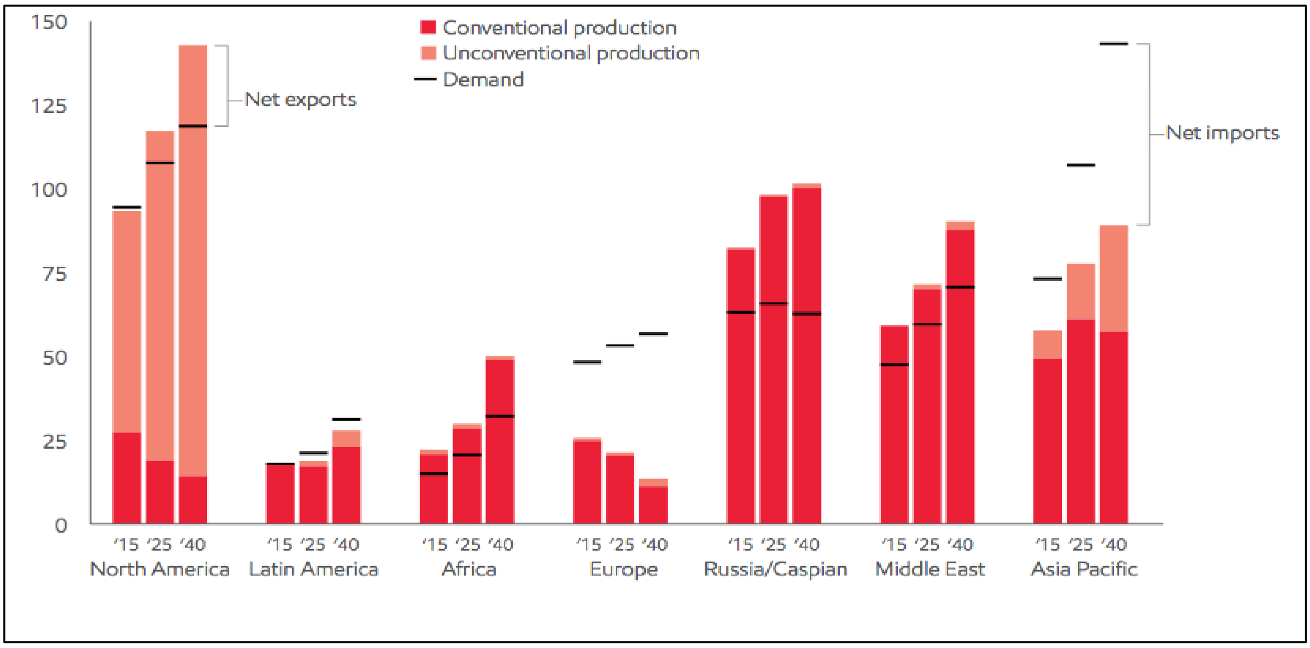
Regional gas demand highlights growth and end-use versatility. Global gas demand is forecast to grow by 50% by 2040.

- Gas demand grows in all major sectors led by electricity generation
- North America shows strong growth as energy choices shift to lower carbon fuels
- African gas demand more than doubles as local supplies increase, and economies develop
- Asia Pacific gas demand rises the most accounting for 45% of global growth



NG – projections

Gas supply highlights regional diversity



According to P & GJ's (Purvin & Gertz) 2017 Worldwide Pipeline Construction survey, figures indicate 83,802 miles of pipelines are planned and under construction worldwide. Of these, there are 38,390 miles of pipeline in the engineering and design phase, and 45,412 miles in various stages of construction.

The following is a breakdown of new and planned pipeline projects by region:

Africa
Some 43 crude oil and NG projects are expected to start operations in Sub-Saharan Africa by 2025, of which 31 are crude oil and 12 are NG, according to available Global Data. Nigeria leads the region in number of planned projects with 11, followed by Angola with eight pipelines.

Sub-Saharan Africa needs additional power generation capacity to provide energy to the 600 million people on the continent who have no access to electricity. Demand for energy is driven mainly by a growing middle class, urbanisation, increased household consumption, and infrastructure projects linked to power generation, transmission, and distribution. The region's proven NG reserves of more than 496 trillion cubic feet (tcf) offers a major driver for countries in the region to achieve energy security.

The 2,600-km, large-diameter main pipeline will link Rovuma Basin gas fields in northern Mozambique to South Africa's industrial region of Gauteng. It will also deliver gas to towns along the pipeline route, stimulating industrial demand. SacOil Holdings announced that it has signed a cooperation agreement with various firms for the construction of a US$6 billion NG pipeline in Mozambique. The US$12 billion Trans Saharan Gas Pipeline is a 4,401 kilometres NG project to be constructed from Nigeria to Algeria via the Niger Republic, and from Algeria to Spain. These projects, when completed, will enhance the outlook for SNG systems in the region.

Asia

World energy consumption is expected to increase by 48% over the next three decades. Growth will be led by Asia which accounts for over half of the projected increase in global energy use through to 2040 according to the US Energy Information Administration (EIA).

In India, GAIL initiated a major step toward construction of the Jagadishpur-Haldia-Bokaro-Dhamra NG Pipeline (JHBDPL), by approving orders for the 133-mile section from Phulpur to Dobhi (under phase-IB/Two section) to be constructed simultaneously by JSIW Infrastructure Pvt. Ltd. and IL&FS Engineering & Construction. Once completed, the 1,578-mile pipeline will connect homes in major cities and towns along the route with piped NG.

Australia

Australia accounts for several pipeline projects. Jemena was selected by the Northern Territory Government to build and operate the North-East Gas Interconnector, which will be known as the Northern Gas Pipeline (NGP).

Europe

The North Sea will account for 36 crude oil and NG projects by 2025, according to Global Data. The UK is expected to account for 25 while nine will be in Norway and two in Denmark.

North America

USA - North America accounts for 31,814 miles of new and planned pipelines but several major projects have been delayed causing industrial gas supply problems in the coming peak demand period.

Mexico - Mexico is a potential growth area in North America. A 75% increase in demand for NG is estimated over the next 15 years. Mexico's economy remains robust with the country continuing to switch to NG powered power generation.

Canada – Delays in major pipeline construction are seen in Canada. These include TransCanada's Energy East project and Enbridge Energy's $7.9 billion Northern Gateway project. The delays may enhance prospects for SNG.

Middle East

The outlook for the Middle East also remains positive. Pipelines under construction and planned in the region total 9,217 miles.

South America

In 2014, only the United States, Canada, Argentina, and China were producing commercial volumes of either NG from shale formations or crude oil from shale or other tight formations. Since 2014, Argentina has drilled over 275 shale gas and tight oil wells with the potential to significantly increase production. Colombia and Mexico are beginning to explore and produce hydrocarbons from shale and other tight resources but are short of reaching commercial production. There is a limited NG pipeline construction programme but that could be a great opportunity for SNG systems.

Based on an analysis of the inherent market characteristics across major global regions the figure below identifies core regions where potential could be strongest.

4.3.2 Market Potential for SNG systems

There is no size limitation for SNG systems, but they are probably not economically feasible for loads of less than 1-2 million Btu/hr (300kWh). Table 3 provides a summary of how the market for SNG systems could develop in different regions of the world over the next five years.

Africa	South Africa has great potentiality. The future of Southern Africa's gas market, for example, could lie along a 2,600km pipeline linking the gas fields of Mozambique to South Africa's Gauteng Province.

Asia Pacific	Asia is expected to become the largest energy-consuming region in the world. Countries that have limited NG infrastructure and having a strategy to replace coal, are of high priority. This includes China, Japan, Vietnam, Thailand and Myanmar and Indonesia. China used SNG as a bridge fuel for cities with no access to NG. In Japan small SNG systems are positioned as 'disaster-resilience' projects. India is expected to increase NG consumption to 20% of its energy mix by 2025 compared to 11% in 2010. Expansion of the NG supply in the country involves additional LNG terminals, nationwide transmission pipeline networks and transnational pipelines.
Europe	Slow growth is expected
Middle East	Residential and commercial complexes could use SNG as a bridge fuel until NG arrives. Dubai and Qatar are good examples
North America	The market remains strong pushed in part by the drive towards cleaner fuels.
South America	The market remains steady. Argentina is facing constrained NG supplies during times of peak demand and there could be an opportunity there

Table 3

4.4 Barriers to Growth

The market characteristics mentioned above can make some regions more attractive to SNG use than others. Beyond the favourable characteristics, challenges exist which vary by region.

Key issues are highlighted below. In Chapter 5.0, some of these barriers are analysed.

4.4.1 Awareness/Perception:

Raising awareness of SNG, and promoting its potential, is the first major challenge. The use of SNG in North America, Japan, Middle East, and Asia is known, but it is not on the radar much elsewhere. The role for LPG stakeholders is to promote the SNG concept.

4.4.2 Customer Economics

Upfront cost and economics are the main drivers for anyone planning to invest in new technologies. LPG prices tend to be volatile, with a significant element of seasonality in year-round pricing associated with varying supply and demand profiles.

4.4.3 Policy/Regulatory Framework

Support for LPG technologies in policy and regulations is generally intermittent. LPG, as a fossil fuel, increasingly faces an image problem alongside other fossil fuels, and this will likely remain one of the biggest challenges facing the SNG (LPG) industry until bio-LPG becomes established. The support of LPG in the regulatory framework is critical for all types of systems where the environment, economics and security of supply are considered important. Receiving subsidy and tariff support for renewable LPG will support the uptake of implementation in different applications.

4.4.4 Technology Development

SNG is a niche market for LPG and NG. There is a perceived lack of opportunity associated with designing, manufacturing, and marketing products fuelled by LPG. The ability to identify application opportunities is ultimately the key to a larger market. Part of the market potential for SNG is based on the expected technology developments which will widen their applicability. These developments will likely occur in the controls, monitoring, and operational side, and in developing smaller residential and commercial type SNG systems.

4.4.5 Commercialisation and Getting Products to Market

New distribution networks and channels to reach the customer need to be developed - or acquired through partnerships with bigger companies. Developing sales channels and servicing/maintenance networks is a critical issue when entering new regional markets. The biggest opportunities for this are in the USA and Asia.

Chapter Five

Recommendations

5.1 Key Stakeholders with a Role to play

The roadmap (Chapter 4.0) identified barriers to growth that has restricted the market uptake for SNG systems. Recommendations are presented here on how each of these barriers can be overcome, and which stakeholders have a role to play.

In Table 4 each barrier is explained and differentiated between 'Lead Role' (the stakeholder is critical in overcoming the barrier), and 'Support Role' (the stakeholder can support but is not the critical element in overcoming the barrier).

Key: xx = Lead Role; x = Support Role

Barrier	Market Stakeholder			
	Industry Associations	Utilities/LPG Companies	Manufacturers	Government
Customer economics	X	xx	xx	xx
Policy/regulatory framework	Xx	x	x	xx
Technology development	X	x	xx	x
Commercialisation/getting products to market	X	xx	xx	x
Awareness/perception	Xx	x	x	xx

Table 4

5.2 Engagement to Drive Growth

The engagement of NG utility companies with SNG system manufacturers and LPG industry associations is instrumental in driving growth in the SNG market. This cooperation will help both commercialism and drive consumer and policy-maker awareness. The engagement of both the NG utility sector and government is particularly important with larger scale utility type SNG applications. The SNG market has demonstrated over many years that projects develop more quickly and easily when a NG utility and local authority support the project.

Coordinated engagement of stakeholders is important when working towards key objectives, for example:

- Working on new innovative applications
- Reducing costs and improving productivity for end users
- Cultivating LPG distributor, SNG end-user, and government awareness of LPG as a safe and adaptable energy.
- Industry stakeholders working together to create a high level of awareness regarding the benefits of LPG
- LPG companies working closely with local communities to identify and develop equipment, good industry practices, and the infrastructure needed to use LPG safely, economically, and reliably
- End users of NG understanding SNG as a tool to manage NG costs and security of supply
- LPG distributors seeing SNG markets as attractive sources of revenue and be aware of the opportunities
- Cultivating retailer, end-user, and government awareness of LPG as an exceptional energy source. The LPG industry working vigorously to create and maintain a high level of awareness regarding LPG's unique benefits among retailers, consumers, and policy makers
- Policymakers understanding the role of LPG within the NG market and ensure it is considered where appropriate

5.3 Awareness/Perception

SNG needs to be seriously considered as an option by policy makers, customers, installers, utilities, and the industry. This requires raising the awareness about SNG and addressing any negative perceptions.

- Developing a consistent vision for SNG which can be shared across the industry, identifying the end goals, and defining measures required to achieve these goals. One goal might be to reach a specified market penetration level for SNG. Interim measures could be to identify the national markets and market sectors with most potential, identifying the technology adaptations or developments which will support applications in these markets, and identifying the policy interventions required to facilitate this.
    - Role for LPG associations to communicate this vision to other stakeholders
- Marketing/awareness-raising activities such as information dissemination (showing the real technology performance, applicability, and potential), targeted marketing events for end-users, information/training events for installers etc.
    - Role for all stakeholders - Associations should be the primary driver of this activity but LPG companies/utilities could also play a role
- Collection of market data of SNG installations to prove the contribution that SNG is making to carbon saving goals etc., to be targeted at governments
    - Role for LPG associations

5.4 Customer Economics

- Offering financing packages via energy services companies, utilities, or other stakeholders, which could shift the upfront investment & risk away from the end-user. This approach could create significant market growth
    - Role for utilities
- Providing incentives to bring down either the upfront cost or running costs (depending on the structure of the incentive - a targeted grant or a tariff)
    - Role for government
- Considering mechanisms to reduce the risk of future LPG price volatility, and improve the confidence of end-consumers of the fuel
    - Role for government
- Lobbying to ensure that SNG systems ae evaluated on a level playing field
    - Role for industry/LPG associations
- Technology development to reduce costs and improve system efficiencies. Running pilots to demonstrate performance claims
    - Role for manufacturers

5.5 Policy/Regulatory Framework

SNG needs to be on a level playing field with competing technologies and other energy alternatives and ensure that policy makers are aware of the potential for SNG and that the evaluation of SNG as the solution is fair.

- Lobbying to ensure that SNG systems are included in regulatory framework and incentive schemes.
  - Role for LPG associations
  - Role for other stakeholders such as utilities

5.6 Technology Development

If the development rate of technology is slow, particularly in relation to competing alternatives, it will limit growth.

- Investment is required to support and accelerate the development of SNG technology to maximise its potential to market applications. For example, (i) investment in testing new system combinations to widen the operating parameters; or (ii) investment in pilot projects, and the development and testing of new larger or smaller SNG versions. Investment is also needed to develop a long-term vision of what the market requires.
  - Role for manufacturers
  - Role for other supporting stakeholders such as LPG utilities (e.g., to ensure LPG versions of the technology are made available)
  - Role for policy makers in making R&D funding available to research and develop new product concepts suited to their markets
- Market research to identify which markets, market sectors & applications have most potential, and what R&D developments should be made to ensure that the technology is well-suited to these markets (e.g., identifying the need to offer small, compact systems; or identifying the need to reach high throughput systems
  - Role for manufacturers (to lead development)
  - Role for LPG associations (to gather market information).

5.7 Commercialisation and Getting Products to Market

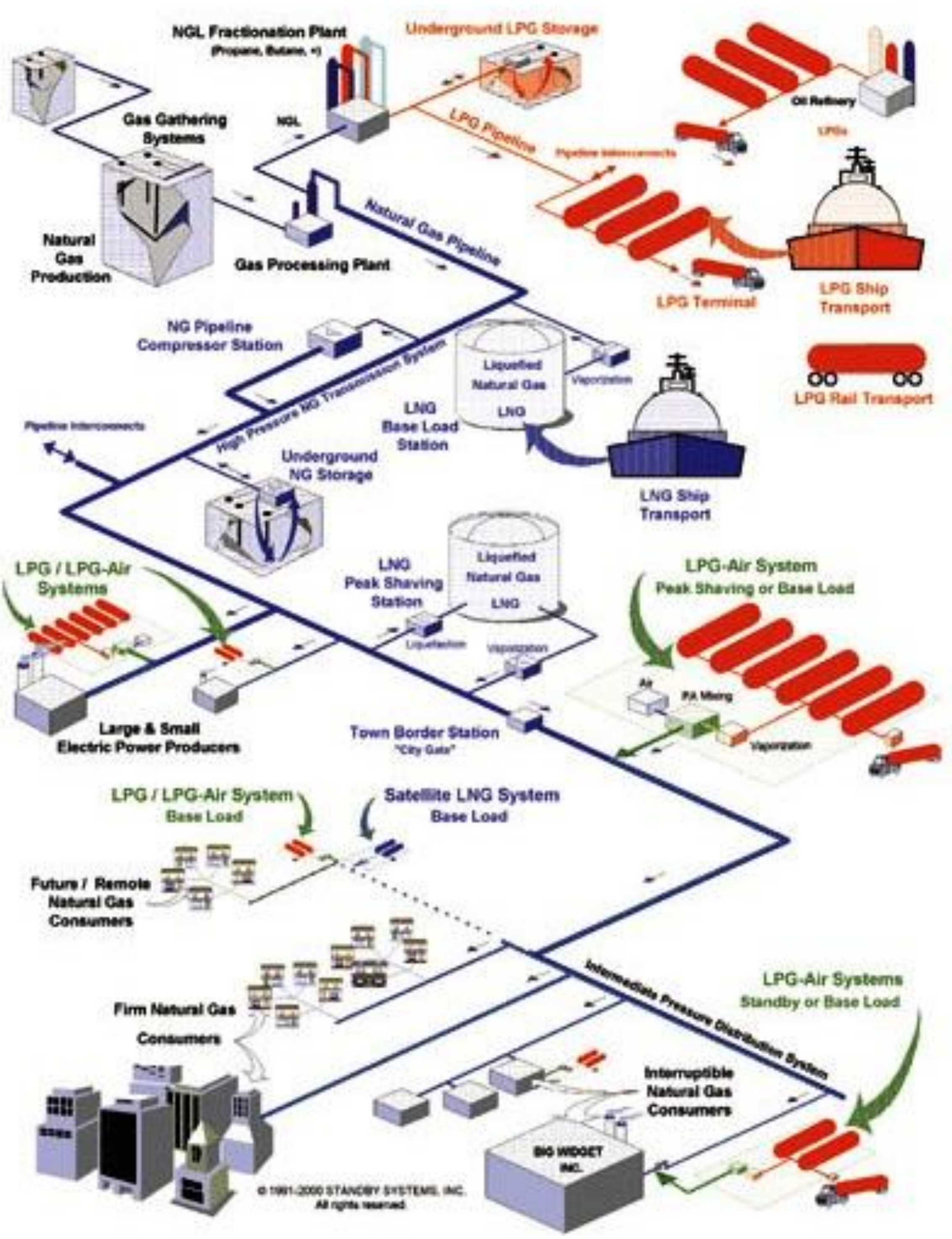
A key part of this is the requirement to train installers, develop servicing, maintenance networks and sales channels.

- Installer training schemes to ensure there is sufficient workforce to meet the demand for installation and maintenance
  - Role for policy makers (e.g., expanding government approved installer training schemes, identifying required competencies for LPG installations)
  - Role for manufacturers (to develop product-specific training)
  - Role for LPG associations (potentially developing and running training schemes – possibly with certification)
- Support with developing partnerships in new regions for the distribution and sales of SNG systems
  - Role for regional LPG associations to put their members in touch with local partners to develop sales channels and distribution networks
- Expanding offerings to include SNG systems via existing sales channels e.g. LPG system installation companies adding SNG using LPG to their product portfolios
  - Role for manufacturers and LPG associations to develop these new relationships
- Market research to identify which customer segments to target and what drives and motivates those customers in their decision-making process about installing a new heating/cooling system - this enables the technology and the sales techniques to be adapted to best engage the target market sectors
  - Role for LPG and manufacturers to educate distributors, installers and other customer-facing stakeholders

Appendices

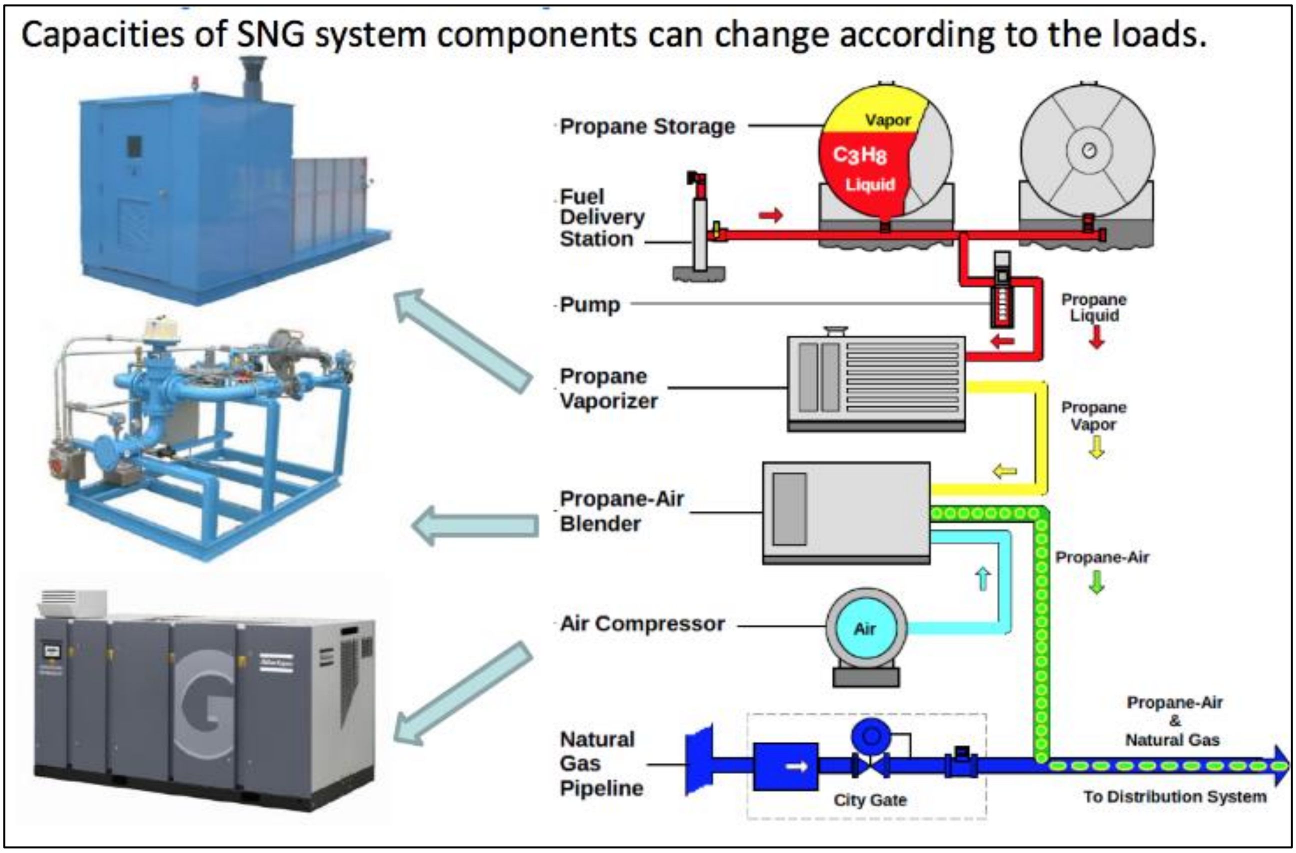
Appendix 1 - SNG Technologies and Components

GAS ENERGY GRID WITH APPLICATION OF LPG/AIR MIXING TECHNOLOGIES



Main components of a typical SNG system will include:

- LPG storage tank(s) or cylinder(s) (with associated loading facilities if needed)
- Vaporisers - if the natural vaporisation capacity of the tank or cylinder is not adequate
- Air compressor (high pressure only)
- Interconnected pipework
- LPG filter (optional)
- LPG pump
- SNG blender
- Pressure regulation
- Automated controls
- Calorimeter



Layout of alternative SNG systems depending on load required

SNG Plants in Pictures

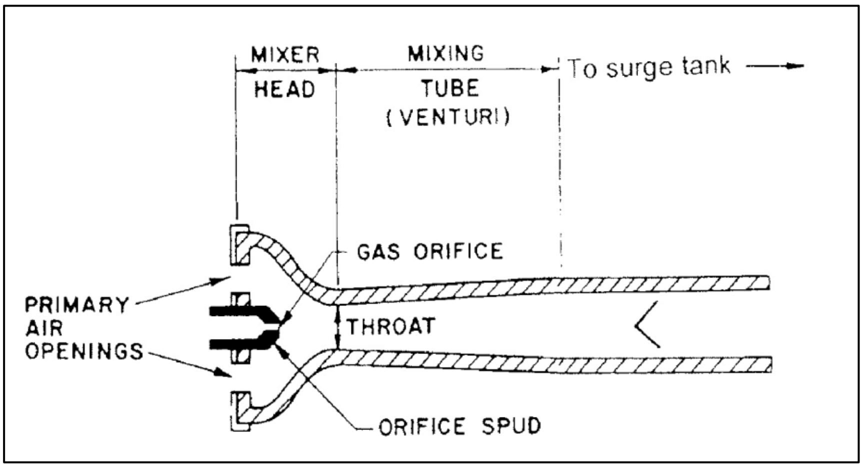
These photographs illustrate a modular approach to SNG system design

SNG Blending systems

There are two basic SNG blending processes used today.

- **Venturi Blenders (low pressure):** No air compressor is required; it provides 6 - 12 psig of SNG; atmospheric air is induced into the units' surge tank by use of a venturi
- **Proportional Blending (high pressure):** An air compressor is required; it provides the required SNG pressure

Venturi Blender:
The vast majority of all SNG systems worldwide are venturi type systems. These systems are simple, inexpensive and require minimal space for installation. Excluding the LPG storage tanks and piping, the basic system typically has three key components: LPG pump, LPG vaporiser and the SNG blender. The LPG pump elevates the liquid LPG pressure and feeds it into the vaporiser. High pressure LPG vapour then exits the vaporiser and enters the SNG blender where the vapour is regulated to a specific 'motive pressure' which is in turn matches to a specific venturi design.



For a general understanding of operation, the velocity of the LPG vapour increases as it passes through the throat of the venturi nozzle. Consequently, during the venturi 'ON' cycle, the LPG vapour gains kinetic energy. This energy allows the venturi to create a slight negative pressure in the venturi chamber. When atmospheric pressure *exceeds* the now reduced pressure in venturi chamber, atmospheric air flows into the venturi chamber. The LPG vapour and air now mix, forming SNG. The SNG then passes into the SNG surge tank. This tank is sized with sufficient volume to prevent undesirable short cycling of the venturi during in operation. The unique design of the SNG blender and it's on/off mode of operation, provides the system with 100% turndown making it ideal in applications where NG demand can change from high to low.

Proportional Blender:

Proportional blenders are more complex than venturi systems, provide more precise Wobbe index maintenance, and can delivery larger volumes of SNG at higher pressures. These systems are used for utility SNG peak shaving, large industrial SNG installations, and larger SNG base load grid applications. They are also more expensive as they require the addition of air compressors and well as more sophisticated controls and monitoring equipment.

Proportional blenders mix LPG vapour and air at a specific ratio to perfectly match the Wobbe characteristics of NG. Pressure and temperature compensated flow meters measure the regulated flow of both the LPG side and the air side of the system. The volumetric flow of each stream is then converted to a molar value with a sophisticated gas flow algorithm. The algorithm considers pressures, temperatures, and compressibility factors. The ratio of the two flow rates is then compared to the calculated air to LPG ratio required for the Wobbe Index of the SNG.

Appendix 2 – Design and Construction

The design and construction activities associated with an SNG facility can be sub-divided into discrete activity blocks. These include:

- Economic feasibility confirmation
- Site selection
- System design and specification
- Site permit/fire safety analysis completion
- Manufactured equipment ordered
  - Liquid LPG unloading facility
  - Liquid LPG storage facility
  - Liquid LPG transfer systems (storage to vaporiser)
  - Liquid LPG vaporisation system
  - SNG mixing system (i.e., LPG and air blending)
  - SNG flow control system
  - Control philosophy and hardware
- Field preparatory work
- Field concrete/foundations
- Tanks and manufactured equipment set
- Field interconnecting piping completed
- Field interconnecting electrical completed
- Field tie-in to NG grid completed
- Site security and landscaping
- Commissioning/training/handover to client

The amount of time required to design and construct a peak shaving facility depends on its complexity and size. Four to eight months are reasonable construction estimates for medium sized facilities. Larger facilities could require 18 months. These estimates include the design, manufacturing, field erection and commissioning activities.

The cost of an SNG System varies largely on system capacity and sophistication. The typical range lies between US$400,000 to US$7+ million including storage. LPG storage capacities, soil conditions and the amount of field pipework have the most direct impact on costs. The LPG storage costs are a major component, but should the SNG facility become mothballed, storage can be reallocated or used in another application.

Small systems, with capacities of 10MBTU per hour (approximately 10,000 cub ft per hour) can cost around US$10,000 (excluding LPG tanks, installation, and other costs). Larger systems can cost more than US$250,000, excluding LPG tanks, installation, and other costs.

When an interruptible NG tariff structure is offered savings will depend on the differential between the firm and interruptible rates. The differential can vary from negligible to up to 50%. The differential is a clear indicator of the challenges of fulfilling contract commitments during periods of peak NG demand.

Operational running costs of an SNG system depends on the cost of LPG, which fluctuates throughout the year. In the USA for example, customers typically purchase their LPG during the summer months when prices are traditionally lower than in winter.

Appendix 3 - Wobbe Index and Combustion

Wobbe Index is the commonly used indicator of gas interchangeability. Wobbe Index can be thought of as ‘energy flow’. It is a property of a gas that allows matching an original gas (e.g., NG) to a replacement gas (e.g., SNG). This table illustrates the basic characteristics of SNG when compared to NG.

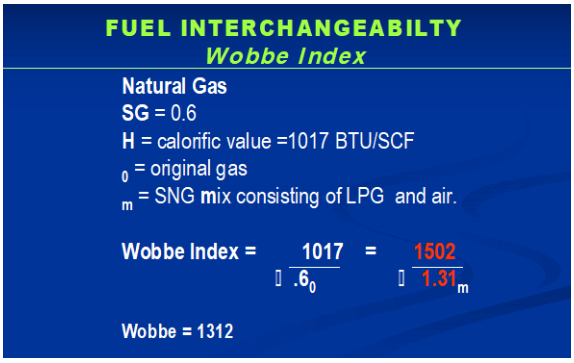
	CHARACTERISTICS				*INTERCHANGABILITY of NG and SNG*		
FUEL TYPE	COMPOSITION	TOXIC	SAFE	TYP. WOBBE	PRESSURE ADJUSTMENTS	BURNER ADJUSTMENTS	APPLIANCE'S SAME
NG	METHANE (~95%)	NO	YES	Same	NO	NO	YES
SNG	LPG + AIR	NO	YES	Same	NO	NO	YES

Comparison of SNG to NG

To obtain a Wobbe Index match between SNG and NG, the LPG must be around 51% of the mix and air around 49% of the mix. These indications vary by LPG composition and the NG composition.

If the Wobbe Index values of the two gases show less than a 5% differential, the gas consuming equipment will typically operate satisfactorily.

A Wobbe Index value is calculated by dividing the calorific value of a gas by the square root of its specific gravity as shown to the right.



Appendix 4 – Applications and Case Studies

Applications for SNG mirror those for NG. The following countries illustrate a few examples by sector of where SNG has been adopted in regions across the world. They are not exclusive but have been included here to illustrate the wide adoption of SNG around the world.

Country	Market Sector			
	Residential	Industry	Commercial	Utility
Alaska	X			
Argentina	X	x		
Australia	X		x	
Brazil	X	x		
Chile				X
China	X			
Hungary		x		
Italy				x
Japan				x
Pakistan	X		x	
Portugal		x	x	
South Korea	X			
Turkey		x		
UAE				x
Uruguay	X			
USA	X		x	

Case study – Alaska

Argonne National Laboratory assessed an SNG backup system to supplement NG use in the Anchorage, Alaska, area. The report, prepared for the U.S. Department of Homeland Security, examined the potential amount of LPG involved in installing a large capacity SNG system. The analysis looked at replacing 50% of the NG by SNG to the area's approximately 350,000 residents.

Case Study - Argentina

Argentina had been a large exporter of NG. However, increasing consumer demand, coupled with a decrease of gas field exploration, had led to a shortfall of NG. To meet demand, an SNG system was designed and commissioned by Ely Energy in 2008. Located in Buenos Aires, the system provides 1.9 million combined residential and industrial users with SNG.

Key features:

Capacity:	2,500 MMBTU/H
Injection Pressure:	330 PSIG (22 Bar)
User Base:	1.9m combined residential and industrial users
Vaporisers:	9 x WB 3,000H
Blenders:	1 Utili-PAK with 1x AFC A8
Storage:	1 x 30,000-gallon tank with LPG pipeline
Application:	Peak shaving

Case Study - Australia

Elgas manufactured a SNG plant, reticulating SNG through a pipeline network to customers in the town of Armidale, New South Wales, that also supplies the University of New England in Armidale.

Case Study – Brazil

Since 1995, NG use has increased dramatically in Brazil. The acceptance of NG by consumers has been expanding due to its availability, reducing consumer concerns regarding the security of supply. From 1995 to 2000, the Brazilian NG market expanded primarily based on industrial users. After a major electricity shortage in 2001, Brazil promoted an aggressive NG-fired power generation program, building up gas stations to supplement its dominant hydropower system. From 2002 to 2007, the share of NG fired power plants in the total power capacity increased from 4% to 7%.

Demand for power generation grew substantially faster than the demand for other uses (Brazil's Energy and Mines Ministry, 2008). However, NG-fired power station production fluctuated depending on the annual rain and the water availability in the hydropower system. NG availability for other uses also swung from long periods of excess supply to short periods of scarcity. The government imposed that power and residential sector had priority in receiving NG in case of any temporary shortage. This contributed to the perception of risk of lack of continuity in meeting the demand for NG by industrial users. Consumers then searched alternative solutions for a more reliable gas supply including SNG.

Large industrial SNG application in Brazil

Ultragaz in Brazil were replacing NG in an integrated steel mill. It was necessary to design and build two different SNG facilities: one for temporary delivery for the start-up of the coking plant, and other for permanent delivery to the steel mill for at least ten years. Both sites had to operate without interruption. The overall investment reached US$10m and more than 30kMT of LPG was consumed in the first year of operation. Gas quality, calorimeters and automatic standby systems were developed for the installation. The invoicing of LPG was done by Coriolis meters in real time.

Benefits

- High turndown ratio of SNG requiring automatic fine-tuning cascade LPG vaporisers, air compressors, dryers and several blenders
- Guarantee of non-interruption of supply even in case of force majeure
- Blending configuration to run 24/7 without any interruption

The replacement of NG by SNG was adopted in Brazil and proved to be a flexible solution to industrial applications overall. These include high temperature processes such as glass works, steel mills, foundries, and ceramic industry. The perception of NG supply insecurity was already high enough to justify the introduction of SNG. The experiences in Brazil have encouraged other countries, particularly in emerging gas markets dealing with similar risks of NG supply instabilities. The exchangeability between NG and SNG includes changes in the combustion control systems as well as monitoring Wobbe Index. The overall investment exceeded US$10m and the project consumed more than 30,000MT of LPG in the first year.

In 2011, Liquigas Distribuidora S.A., manufactured a SNG mixing system for ALCOA Company to replace diesel. Alumar received an award for environmental management in 2012 for this plant. This installation has used two mixing units in parallel, each one sized for the maximum consumption. This way, one unit is always available as full backup. The plant is also equipped with an automatic control system of the Wobbe Index, which may adjust the mixture composition in order to guarantee its accuracy and stability.

Key features:

Mixture Capacity Range:	0 – 3,200 Nm^3/h each unit
Mixture Outlet Pressure:	4.0 bar
Mixture Average Composition:	57% LPG + 43% Air
Mixture Wobbe Index:	11,800 $kcal/Nm^3$
Mixture HHV:	13,300 $kcal/Nm^3$

Case Study – Chile

Chile historically received 70% of Argentina's NG exports. Argentina's investment in exploration for NG did not keep pace with demand, which led to internal shortages. This is turn led to the curtailment of most gas exports to Chile.

SNG was selected as a short-term tactical solution in Chile. Two large-scale SNG facilities were supplied for the Santiago area. The first system was installed in 2005 in Maipu with LPG delivered via pipelines. The second system was installed in 2008 in Penalolen with LPG delivered via trucks. Together, they provide 3,900 million BTU/h of NG equivalent in Santiago.

A SNG base-load system solution was developed in Uruguay which operated with SNG before the Country started importing NG from Argentina. The SNG base-load system is planned to operate on a longer-term arrangement serving consumers off the NG grid.

Case study - China

In Liuzhou City, China, there are three SNG stations. Each station is designed to fuel 50,000 households, SNG is used as the baseload primary energy to fuel the city. They have spherical storage and a rail unloading station. They use 6,100 MT of LPG a month, per station.

Main features:

- Three Stations, 1100 MM BTU/hr each
- Each station designed for 50,000 households
- 30 psig
- Two x 1mn gallon spherical tanks, rail unloading station, three x positive displacement pumps
- Three x hot water vaporisers, three x proportional SNG mixers, three x air compressors, three x dryers, three x air filters, three x LPG filters, calorimeter and flare stack

Liuzhou City supplied with SNG

Case Study - Hungary

Suzuki, Hungary, had to limit NG consumption during the winter season, due to the constraints of their NG supply contract. They installed a stand-by SNG system which could supplement their NG demand during those peak periods. The solution to Suzuki's request given by CAM combines two units. The first is a mixing unit which feeds into the NG network an interchangeable mixture of LPG/air, during peaks of consumption. The second unit is an automatic flow control system, directly installed in the network, which limits the NG supply to a pre-set value.

- Mixture Capacity Range: 0 - 3200 Nm^3/h
- Mixture Outlet Pressure: 2.5 bar
- Mixture Pressure supplied to N.G. network: 1.5 bar
- Mixture Average Composition: 53% LPG + 47% Air
- Mixture Wobbe Index: 12000 kcal/Nm^3
- Mixture HHV: 14150 kcal/Nm^3
- NG Max Capacity: 4500 Nm^3/h
- NG Limited Capacity: 2500 Nm^3/h
- NG Regulated Pressure: 1.6 bar
- NG HHV: 9080 kcal/Nm^3
- NG Wobbe Index: 11995 kcal/Nm^3

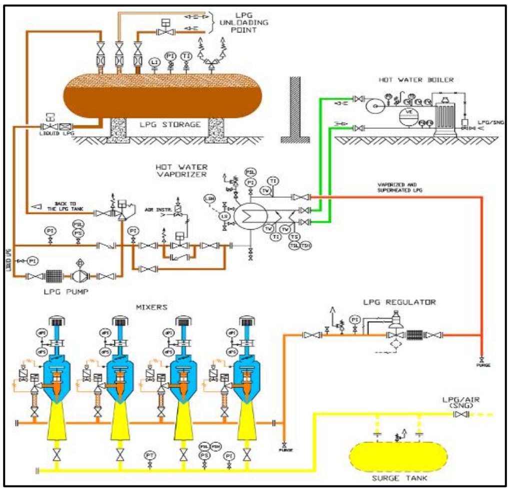
Case Study - Italy

Cagliari - Since 2000, SNG has been distributed to the town of Cagliari. Due to the size of the project, the SNG plant was divided into three modular SNG units. The units use boilers which provide hot water for both vaporisation and super heating. The systems are compact and use venturis to provide a constant flow of SNG. The venturi mixers operate on a simple ‘on-off’ strategy which provides a high (100%) turndown ratio. The system provides an ideal solution since the distribution network was both a low-pressure system and demonstrated highly variable consumption. The SNG feeds directly into the grid and then to all connected NG appliances. Liquid LPG is stored in nine 200 m^3 LPG storage tank with unloading compressors, pumps.

Key features:

- LPG storage: nine tanks, 200 m³ each
- LPG unloading compressors: Two units, 100 m³/h each
- LPG pump: Three units, horizontal, multi-stage, centrifugal type
- LPG pumps flow rate: 24 m³/h each
- LPG pumps head: 4.0 bar
- LPG vaporisers: Three units, horizontal shell BKU Type, hot water powered, 6000kg/h each
- LPG pressure regulating line: Two units, outlet pressure four bar
- Boilers: Three units, 800000 kcal/h each
- Mixers: Five x Compact Venturi
- Mixture Outlet Pressure: 300 mbar
- Mixture Average Composition: 53% Air + 47% LPG
- Mixture HHV: 12000 kcal/Sm³

Bagolino - More than one thousand end users in the small town of Bagolino are serviced with SNG despite the severe winter weather conditions. The low dew point of SNG makes the mixture particularly suitable for distribution, especially in cold climates.



Key features:

Mixture Capacity Range: 0-1000 Nm³/h
Mixture Outlet Pressure: 40 mbar
Mixture Average Composition: 53% LPG + 47% Air
Mixture HHV: 12,000 kcal/Nm³
Mixing Unit: Four x Compact venturi mixers
Two Pressure Regulators: set point 2.5 bar: 550 Nm³/h
LPG vaporiser, horizontal shell BKU Type hot water powered: 1000 kg/h
Two LPG pumping stations, horizontal, multi-stage, centrifugal type
Pumps flow rate: 2,100 litres/hr each
Pumps head: 2.5 bar
Two LPG Storage Vessels: 50 m³ each
LPG Average Composition: 50% Propane + 50% Butane

Case Studies – Japan

An architectural design firm developed a creative gas plant based on a 'disaster-resilience' concept. A citizen centre in Japan purchased two SNG systems. The first system provides back-up SNG to a small cogenerating unit that provides power and heat in times of disaster. The second system provides SNG for cooking and hot water. An SNG system was also installed in a fire station for to supply firefighters with hot water, meals, and showers in the event of an emergency.

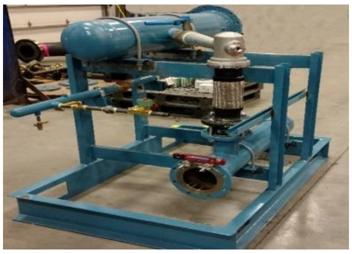
SNG system in Japan

Only 17 days after the 2011 Japanese earthquake and tsunami in 2011, 7,000 households in Kamaishi city were being supplied by SNG. An additional 60 days were required to reconnect 90% of the city's remaining population to NG. For the last three decades SNG has been a means of increasing the calorific value of very lean LNG delivered into Japan and Korea.

Following the Japanese earthquake and tsunami in 2011, it took two months for 90% of the city gas supply to be reconnected. After only 17 days following the disaster 7,000 households in Kamaishi city were being supplied by SNG. For the last three decades SNG has been used as a means of improving the calorific value of very lean LNG delivered into Japan and Korea.

Case Study – Pakistan

SNG technology has been successfully utilised in Pakistan for decades. SNG plants in Quetta, Larkana and more recently in Gwadar, Nushki, Mirpur Khas and Dalbandin continue this trend.



Skid mounted SNG system in Pakistan

Many companies in Pakistan in the textile and ceramic segment specifically, such as Azgard and Emco, have set up standby SNG plants to remain operational during shortages of NG.

Case Study - Portugal

The Hotel Vila Galé Porto Ribeira in Oporto, Portugal was connected to SNG while the NG supply was still being installed. The system produces SNG yet requires no electrical power. The system is small, portable, and self-contained. It provides 4m3/hr to 90m3/hr of SNG. Testing the SNG installation was accomplished using 45kg LPG cylinders. The allowed the hotel to have the gas it required and ensured its inauguration would occur on schedule.

Case Study - South Korea

South Korea evolved from naphtha gas to a complex mosaic of carefully planned City SNG grids. The country followed a comprehensive master plan that enabled it to become today, one of the most advanced LNG grids in the world. This could not have happened without the role played by SNG in initially feeding the City Gas grids prior to the arrival of LNG.

Case Study - Turkey

SNG is used in Turkey in many factory operations including Glass making and biscuits. It is also used in the headquarters of Aygaz for space heating.

Case Study – UAE

The Dubai Palm Jumeirah base load SNG system functions a bridge system until NG arrives. The distribution network is fed from a SNG central system connected to a distribution network constructed of polyethylene (PE) pipe. Scope of work included installation of all equipment and appurtenances including all appropriate valves, regulators and metering, and extends the inlet of the tank farm to the ultimate connection to the gas appliances. This network consists of 5.5km of lines that server over 2,500 residences, 9,000 apartments, 47 hotels and various commercial customers.

The concessionaire is obligated to a 30-year operation and maintenance contract; LPG consumption is around 1,400mt/month. The Discovery Garden Group project, also in Dubai, also uses SNG as a bridge fuel to later conversion to NG. Like the Dubai Jumeriah project, the contract award included all valves, regulators, and metering. This project consisted of an estimated 120km of polyethylene (PE) gas mains and six below ground 50MT LPG Tanks. SNG is served to around 75,000 customers.

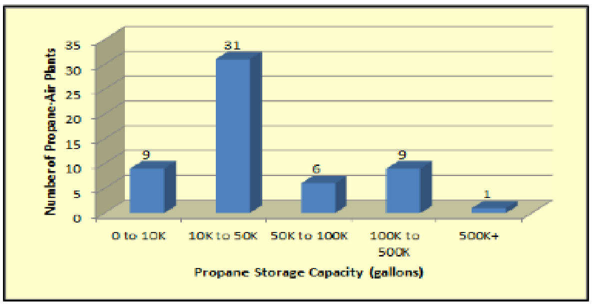
Jebel Ali Village by Lootah BCGas

Case Study - Uruguay

An SNG base-load system was installed by Conecta (owned by SEMPRA) in Montevideo to provide SNG before arrival of NG from Argentina. The SNG base-load system operated on a long term basis, helping to develop user subscription prior to arrival of NG.

Case Studies – USA

Over 50 SNG facilities currently operate in the United States (see chart). The majority are located along the east coast and in the upper mid-west primarily due to the cold winters in these regions. Most SNG system have LPG storage volumes of between 10,000 to 60,000 US gallons. We assume most are either 18,000 or 30,000 US gallon tanks.



LPG storage capacities at SNG projects in the US

As an example, Pinnacle Propane serves two customers (Mississippi) who lost their NG service because of a 90-year-old NG pipeline being decommissioned and subsequently rerouted. The new NG pipeline was re-routed to enable it to better serve more attractive new gas users. However, various old customers were left without NG. However, the NG company was responsible for providing these stranded customers with either NG or an alternate fuel. They obviously selected SNG. The NG utility selected Pinnacle Propane to supply, install and serve the new SNG system.

Abbreviations

AEGPL	European LPG Association
BCFD:	Billion cubic feet per day
LDC:	Local Distribution Companies
MMCFD:	Million Cubic Feet per Day
NG:	Natural Gas
OPSO:	Over Pressure shut Off
SNG:	Synthetic Natural Gas or Substitute Natural Gas
TcF:	Trillion Cubic feet
UPSO:	Under Pressure Shut Off
WLPGA:	World LPG Association

Copyright

Disclaimer

While the WLPGA has made efforts in good faith to ensure that the information and advice contained in this report is accurate, WLPGA offers no implied warranty of merchantability or fitness for any particular purpose, nor accepts any responsibility whatsoever for any damages arising from the use of the information contained in this report.

WLPGA

182 avenue Charles de Gaulle, 92200 Neuilly-sur-Seine, France
Tel: +33 1 78 99 13 30
association@wlpga.org
www.wlpga.org
@ExceptionalNRG

LPG EXCEPTIONAL ENERGY