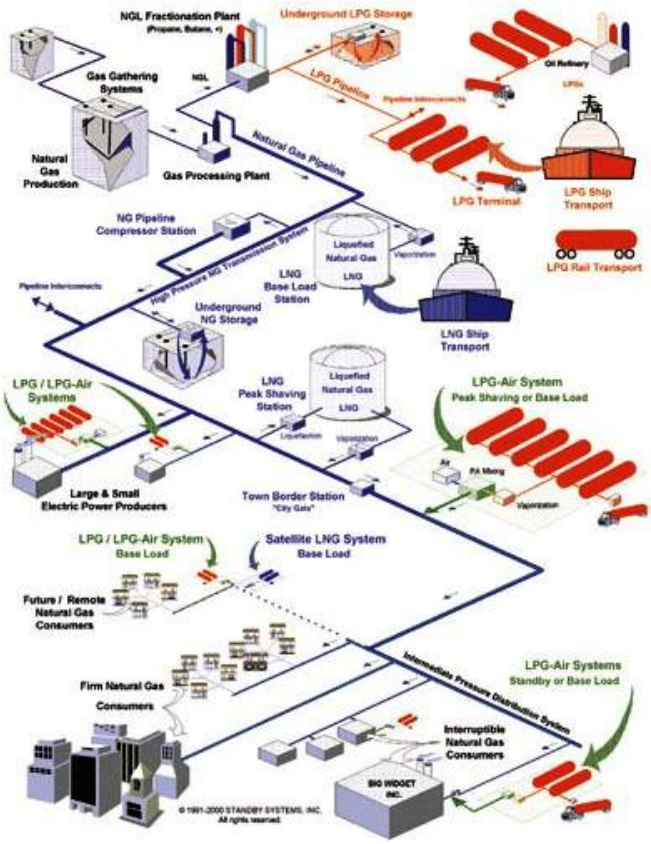
# SNG, LPG-Air, Propane-Air
# The LPG Opportunity


GAS ENERGY GRID WITH APPLICATION OF LPG/AIR MIXING TECHNOLOGIES




## Innovation & Technology

## The World LPG Association

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

It unites the broad interests of the vast worldwide LPG industry in one organisation. It 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 has been developed by the Innovation & Technology Network of WLPGA

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## Chapter One

# Introduction

The aim of this report is to **promote understanding amongst the LPG industry of the technical possibilities, applications and market potential of SNG, LPG-Air, Propane-Air.** SNG, also called LPG-Air, or Propane-Air can also be found as Simulated Natural Gas, Synthetic Natural Gas, or Substitute Natural Gas, even if some of this terminology is used also for gas created from goal. SNG is used as a replacement of Natural Gas (NG), without materially changing the safety, efficiency, performance or emission characteristics of the equipment burning the gas.

SNG can be produced in many ways, including also using LPG. When SNG is produced with LPG, which is the subject of this report, it is also called LPG-Air or Propane-Air and it is simply a blend of vaporised LPG with ambient air, mixed to a ratio that simulates the properties on Natural Gas. Ultimately this report is to inform the LPG community of the opportunities in this technology in the various related segments and provide recommendations on how to capture best these opportunities. 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. SNG can play a critical role in meeting the interchangeable energy requirements of the industry.

The SNG considered in this report is produced with LPG.

The report scope includes:

A scan of the market for **SNG** systems primarily in Asia, USA, Japan and other parts of the world.
Coverage of the commercial/industrial sector as well as developments in the utility sector.
Power generation as a specific application particularly suited to SNG.

This report contains:

**A 'fact sheet'** giving an overview of the current technologies, the main players, and the market status.
**A 'roadmap'** exploring the market outlook on technology, market trends, market potential and identifying the barriers and drivers for future growth.
**Recommendations** for the Association Members and other stakeholders on how to overcome the barriers and maximise the market opportunity.

## Chapter Two

# Executive Summary

SNG, a mix of LPG with air at a given ratio and burning with the same combustion characteristics as Natural Gas (NG), has been used in utility applications since the 1950s.

This report describes the different ways of using SNG as an effective substitute of NG. It can be used in backup, base-load, peak-shaving and commingling supply conditions, including also off-grid market development.

SNG allows LPG companies to market also directly to some of the biggest energy users, the NG users. Large scale manufacturers, city utilities, hospitals, military bases and even neighbourhoods need a reliable energy supply. SNG can be bulk-fed into the local gas distribution system, co-mingling and co-habiting without any technical problems.

The market of SNG could be characterised as a niche market with great potential. Several SNG systems are already installed in countries like Brazil, China, Chile, Dubai, Japan, Hungary, Korea, Pakistan, Turkey and others around the world.

The opportunities that LPG opens through SNG systems to the NG world have been largely underexploited. SNG systems are incredibly valuable in helping NG utility companies to efficiently manage load swings, guarantee security of supply and provide a bridge to a new community awaiting the development of a NG grid.

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

Natural gas interchangeability strategies can be a tangible investment in both security and flexibility of a gas supply. The growing reliance on NG has added a new dynamic also to the LPG market. Price fluctuation and seasonal volatility require the ability to strategically manage shortages of supply as well as pricing issues. Using SNG to simulate and replace NG can be a good option in many cases.

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

**Key Markets**

The following regions were identified during the research for this study as markets of high opportunity for SNG.

- Asia: It is expected to become the largest energy-consuming region in the world and countries that have limited NG infrastructure and having as strategy to replace high emitting fuel such as coal are of the strongest potential and high priority, as such are Bangladesh, China, Indonesia, Japan, Myanmar, Pakistan, Thailand and Vietnam.
- South Africa: Significant potential
- North America: It remains a strong market as there is a swift to cleaner fuels.
- South America: It is expected to remain a steady market.

## 2.1 Key Messages - Fact Sheet

SNG is not new, it has been around for about 75 years, being used to supplement existing NG needs, commingling of LPG and NG has been for many years a worldwide spread practice.
With the looming potential for NG, occasional shortages, cuts and price escalations, NG users especially large ones seek at times other alternatives. One of them is **SNG made with LPG**. It can provide an identical or nearly identical Wobbe Index, produce an equivalent amount of energy and require the same amount of combustion air as NG. Burners operating on SNG require no pressure adjustments compared to NG and the measured and observed combustion characteristics show essentially complete acceptance.

There are typically four main areas of use of such SNG systems:

- **SNG Stand-by or Backup Systems**: Allow industrial and other NG customers to use SNG during curtailment periods, and allow taking advantage of arbitrage opportunities.
- **SNG Base Load Systems:** Provide a "NG equivalent" bridge fuel in regions where NG is planned to be available in the future but is not yet available. In these cases, the SNG system will later revert to a peak shaving function.
- **SNG Peak Shaving Systems:** Allow both NG local distribution companies (LDCs) and industrial gas consumers to supplement their NG during peak demand periods. NG utilities inject SNG into their distribution grid to supplement the supply of NG thus allowing to satisfy increased demand without adding grid / pipeline capacity.
- **SNG Commingling Systems:** SNG replaces an adjustable percentage of NG on a “full time” basis or ‘as required’. Depending on the requirement SNG is co-mingled with NG, as for example when used for base load or peak-load, or used as is, as for example to provide Town Gas. The quantity of NG being replaced by SNG can be reallocated elsewhere in the grid to alleviate other supply problems.

There is a steadily growing SNG market in the industrial sector using SNG technology. Most systems are coming from American, and to a lesser extent European manufacturers. SNG systems are often ready-made configurations needing only connection at the factory after the NG metering and regulation stage.

Today SNG plants are being designed to be an ever more versatile component in the energy delivery matrix, being a testament to NG delivery system design ingenuity, one that continues to evolve to an ever-changing energy landscape.

There are no significant technical barriers to adopting SNG technology and specific designs can provide tailor-made solutions to suit specific process requirements.

For large scale NG substitution projects, LNG may retain the upper hand in terms of application, while however not being the perfect option for all scenarios as slower and more expensive to implement. For many small local markets as well as some regional city gas opportunities, LPG holds advantages.

Argentina, Bangladesh, Canada, Chile, Finland, Norway, Pakistan, Russia, Sweden, UK, USA, and other countries, see increase of their NG networks with SNG. In Africa, the use of SNG is not widespread yet, as well as in many countries in Europe, however there are no technological barriers to adapting the technology, and the market potential is gaining attention.

## 2.2 Key Messages– Roadmap

The overall SNG market could increase by 20% by 2025 based on NG market development. LPG will take a variable share in different regions (1-20%) and linked with varying applications to serve emerging markets. SNG can play both a strategic and tactical, albeit niche, role in meeting specific energy needs.

For SNG expansion, the challenge and opportunity lies in the development of marketing distribution networks, with sales and maintenance support. Several companies are taking the significant steps in Asia and the Americas, and the next five years could see a significant growth to continue in these markets.
The most important developments for this technology will be further technology improvements, and the step into smaller scale products for residential sector, which will open up large market opportunities globally.
Consolidation of design concepts is expected over the next five years, widening of operating parameters so make them more easily applicable in existing buildings.

Asia and USA will remain a very large market for SNG. The North American market has good growth potential for SNG. Within the next five years it is probably unlikely to see more than niche markets in Latin America, the Middle East and Africa, but in five years and beyond, Latin America and the Middle East and especially Africa could offer some larger-scale opportunities. SNG equipment sales will further expand outside USA, and the Asian market will stay strong.

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

- SNG systems deliver gas at the door step through pipeline, same as NG.
- They guarantee uninterrupted supply even in peak seasons.
- SNG has compatible characteristics with NG.
- SNG can be used as primary fuel source or as NG backup.
- SNG systems similarly to piped town LPG systems allow LPG distributors to secure and control complete housing development complexes, thus eliminating competition from oil.
- SNG helps LPG companies compete with NG for the largest energy consumers that otherwise would select NG.
- SNG provides solutions in natural disasters that often cause NG grids to fail.
- SNG can be supplied to remote / far flung locations.
- It is environmentally friendly.
- SNG systems are safe to operate and use.
- They require low capital investment and can often be obtained on attractive leasing offers.
- Its source gas LPG, is readily available globally.
- Many SNG systems come in compact designs and some are completely portable.
- Many systems require no electricity, just LPG supply.

**There are several inherent market characteristics that can create strong potential:**

- Limited NG penetration or non–existent NG infrastructure.
- Good availability of LPG product and infrastructure.
- Expected growth in industrial activity which creates energy demand.
- Expensive fuel prices such as diesel, other alternative fuels or electricity grid.
- Policy/ regulatory framework in favour for clean fuels.
- 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 the greatest challenge.
- Policy / Regulatory framework: SNG needs to be on a level playing field with competing technologies and fuels.
- Technology development: Slow rate 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 well considered by policy-makers, energy users, installers, utilities and the industry. The gas marketplace is very conservative and not inclined to change easily to new technologies and innovations rapidly.
- Fear by LPG retailers of working together with NG and helping NG expand its network.

**All relevant market players need to work together in a coordinated way to overcome the 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 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 LPG can play in a de-carbonisation of energy future.
- **Advancing or accelerating SNG technology development**: This could include 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 get products to market**: This means developing installer training schemes, providing support with developing distribution partnerships in new regions, and market research.
- **Raising awareness of SNG amongst customers, installers, utilities and the industry**: This means 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. It also means marketing/awareness-raising activities and collection of market data.
- **Publishing case studies of successful projects.**

## Chapter Three

# Fact Sheet

This Fact Sheet provides an overview of the SNG technologies, their major applications, market status, a snapshot of the main players on the global market, some important aspects on safety, training, fuel quality, stakeholders and includes also some case studies.

## 3.1 What is SNG and how it works

### 3.1.1 Definition of SNG

SNG (Synthetic Natural Gas or Substitute Natural Gas), also called LPG-Air or Propane-Air, is a gas created with the use of LPG, having nearly identical characteristics to Natural Gas (NG), thus providing an ideal alternative to NG. A constant percentage of air is mixed with the required amount of LPG to create it. Liquid LPG must first be converted to gaseous state with the use of a vaporiser.

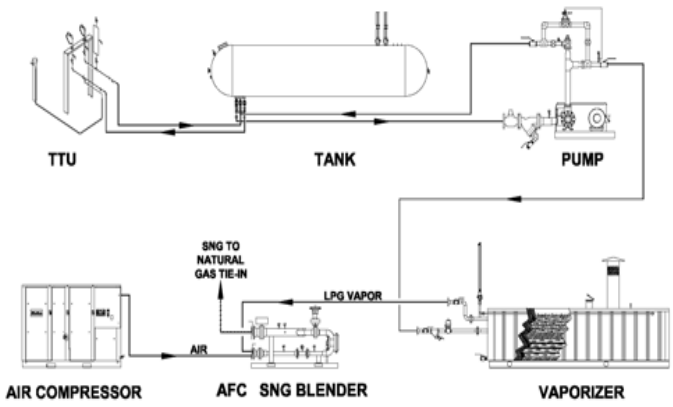
### 3.1.2 The SNG Principle

The principle of an SNG system starts with the conversion of liquid LPG into vapour, which is then mixed with air at a pre-set ratio (usually 53-57% LPG / 47-43% air). LPG can have a vapour BTU content of approx. 22500 Kcal's per cubic meter, compared to NG of approx. 9000 Kcal. Since LPG's BTU content is much higher than NG it has to be "diluted". The vaporised LPG is run through a LPG/air mixer that mixes at the required ratio of vapour LPG and air, to create a mixture compatible with NG. This LPG/air mixture is directly compatible with NG, it can replace directly NG and can therefore be used by any equipment that use NG such as burners, heaters, stoves, furnaces, water heaters, etc., without any modification to the equipment. Such systems can also be connected directly to NG pipelines. This makes operating the equipment easy, avoids lengthy and costly change-overs and guarantees uninterrupted energy supply.

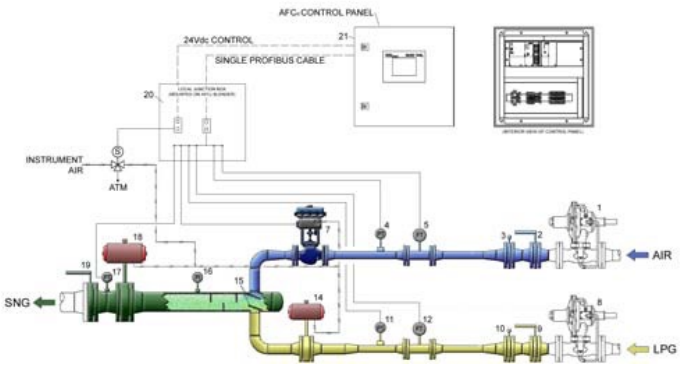
The alternative replacement of NG by LPG only, would certainly require changes in most of the burners and flow trains since those two gases belong to different gas families. For example, in a steel mill, there are hundreds of gas burners that would need to be replaced if a fuel change from LPG to NG or vice versa was necessary. The use of SNG seems to be a more suitable alternative for substituting NG in an existing installation for industrial customers.

The Figure below depicts a typical flow process of an SNG system. Liquid LPG is stored in tanks or cylinders under pressure. The amount of storage required depends on the output capacity of the proposed facility, the projected hourly usage, frequency of supply etc.

When the SNG system is in operation, LPG is transferred from the tank via a pump to an LPG vaporizer. As the LPG liquid passes through the vaporizer, it is heated to the vapour phase. The vaporizer also provides adequate super-heat to prevent re-condensation. To achieve this, the inflowing gas in the gas pipe is measured using a thermal flow measuring device. A process regulator calculates the necessary amount of air and controls a regulator valve in the air-inflow pipe. The actual air inflow is hereby determined using the thermal flow measuring device.



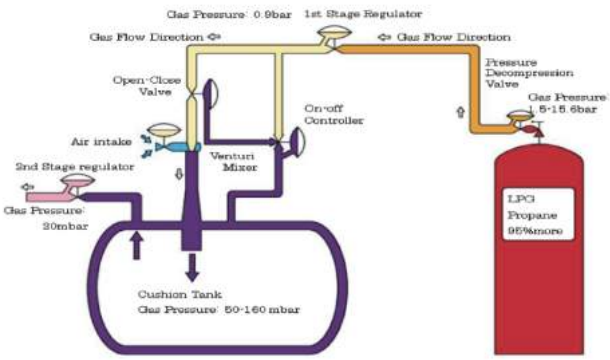

The super-heated LPG vapour is then blended with air supplied from an air compressor to a specific ratio creating the SNG. This mixing occurs in a proportional blending system as illustrated below. The system's flow control system then allows injection of the SNG into the gas distribution grid as required.




Smaller portable LPG/Air Mixer systems can use LPG from a cylinder, bank of cylinders or tank and mix with air via a venturi mixer. An open close valve ensures the correct amount of LPG enters the venturi. Within the venturi air is drawn in through the air intake at exactly the precise level. The venturi has a nozzle which is specifically calibrated for the matched gas mix. The mixed gas then flows into a cushion tank where an even flow rate for the outlet is ensured. The final pressure reduction is carried out at the second stage regulator which delivers the required supply pressure. The complete process is meticulously controlled by a number of components to provide safety and control to the system, an on-off controller which controls the open close valve assisting in obtaining the correct gas mix plus UPSO and OPSO safety devices with impulse lines to the various parts of the system.

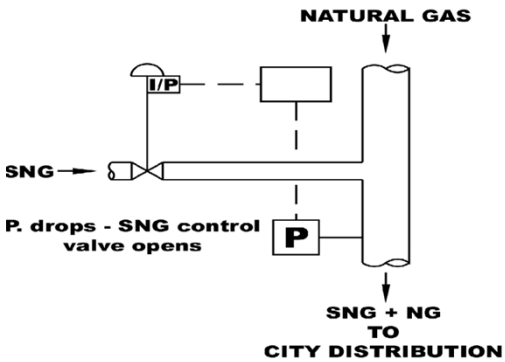
Illustrating the principle, a simple cylinder fed configuration is shown below. This configuration:

- Requires no external power source such as electricity.
- Generates SNG using LPG & Air pressure.
- Is small and light easily transportable.
- Can be used without changing nozzles or jets in appliances and equipment, as is the case with all SNG units.
- Provides stable calorific value without adjustment.
- Is equipped with safety devices ensuring total security.



**Mixing control principles**

**Pressure Control**: During operation, a pressure transmitter provides a flow control bias that adjusts the SNG flow rate based on the NG pressure in the pipeline. When this pressure approaches, a fixed pressure set point, SNG supply is reduced and vice versa. If the NG system pressure rises above that set value, the flow control valve closes and SNG injection will stop. When the line pressure drops, the flow process will begin again. This method is used often in peak shaving mode. When peak shaving in Pressure Control, the amount of SNG replacement of NG can vary from zero to 100%. The role of the SNG is simply to maintain line pressure and flow in the NG pipeline regardless of SNG/NG ratio.



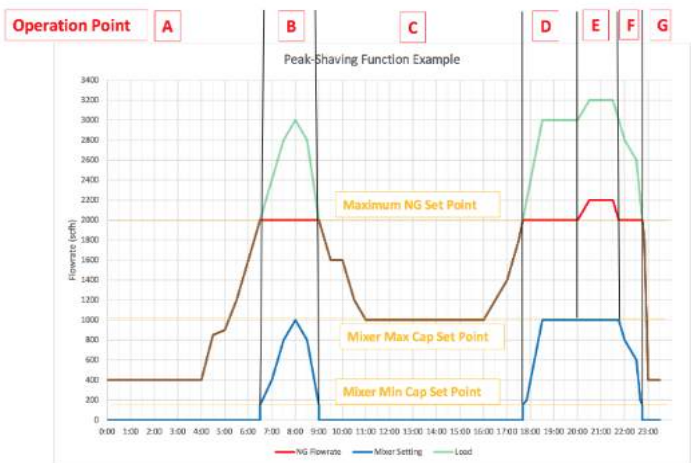

*Peak shaving using pressure control*

**Ratio Control**: In Ratio Control, a pressure and temperature corrected flow signal from a meter in the NG line upstream of the SNG tie-in is required. A similar flow signal is required from an SNG meter. These signals allow a Flow Control Valve installed after the blender to regulate a volumetric ratio up to ~40% of SNG to natural gas in the pipeline. This ratio ensures the overall specific gravity of the SNG/NG will remain below 1.00 (lighter than air). The control system also allows the SNG flow to vary as necessary, in a fixed ratio, as the NG demand varies.

Both systems have multiple safety elements that ensure safe operation.

**Example**

Example Settings:
Mixer Minimum Capacity Set Point (MMin)= 150 scfh
Mixer Maximum Capacity Set Point (MMax) = 1000 scfh
NG Peak Set Point (NGP) = 2000 scfh
Operation Point Description:




A. The mixer is in standby mode until the load reaches 95% of NGP. Once the load reaches 95% of NGP, the mixer turns on and provides SNG at MMin.
B. The mixer continues to provide more SNG as the load increases and controls output of the mixer to maintain NGP.
C. The mixer returns to standby mode as the load decreases below NGP. The mixer remains in standby until the load reaches 95% of NGP again.
D. The mixer continues to provide SNG to satisfy the load and maintain NGP.
E. If the load exceeds the NGP + MMax, the mixer is set to flow at MMax. NG flow meets the demand and NGP is exceeded.
F. As the load decreases, NG and SNG are able to meet the demand.
G. As the load decreases beyond NGP the mixer returns to standby mode.

### 3.1.3 Fuel interchangeability

Emulating NG with SNG is a conventional proposal, which can be used in base-load, backup, and peak-shaving systems. The use of SNG is not a new idea as mentioned above, it started over 50 years ago. Because its properties can imitate NG so well, SNG can be used interchangeably in systems designed for NG, grids, appliances, equipment. This offers significant benefits to companies or institutions that decide to implement SNG systems. They can avoid costly infrastructure or appliance conversions, unlike switching to a diesel, oil or LPG system.

Any replacement of NG by pure LPG certainly would require changes in most of the burners and flow trains since those two gases belong to different gas families, the interchangeability between NG and LPG is not straightforward.
The use of SNG systems however are a more suitable alternative for substituting NG and especially so for industrial customers.

The alternative of LNG or CNG is a complex task due to large investments required. Moreover, in contrast to LPG which can be kept liquefied indefinitely under lower pressure, CNG requires costly transportation and compressing processes. The LNG needs to be kept under cryogenic temperatures to avoid boil off, which limits its storage and transportation times. Even at cryogenic temperatures, LNG still boils off, with impact also to the environment, due to the radiant heat transfer. Therefore, LNG is a very poor solution as a back-up or peak shaving system.

SNG is more suitable for operating in short periods of time in backup or peak-shaving supply conditions and there are also interesting cases justifying the adoption of SNG even in base-load supply conditions.

There are various quantitative techniques to measure interchangeability. These techniques include Wobbe, Knoy, Weaver and others.

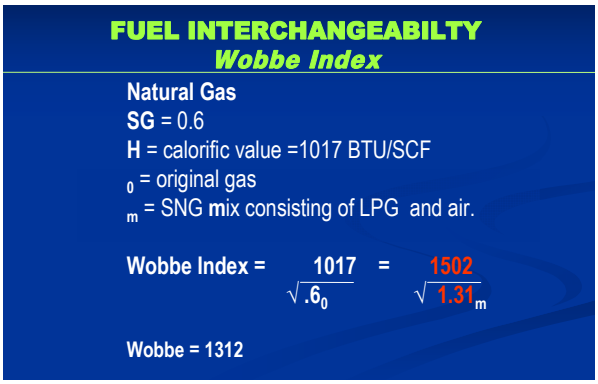
The most common method used to guarantee the exchangeability between two gases is based on **the Wobbe index.**
If NG and SNG have an identical or nearly identical Wobbe Index, they produce an equivalent amount of energy and require the same amount of combustion air. Burners operating on SNG will not require pressure adjustments and the measured and observed combustion characteristics show essentially complete acceptance.

The table illustrates the basic functional characteristics of SNG as compared to NG.

| FUEL TYPE | *CHARACTERISTICS* | | | | *INTERCHANGABILITY of NG and SNG* | | |
|---|---|---|---|---|---|---|---|
| | 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 on SNG to NG*

In industrial applications, this method used for NG and SNG can sometimes lead to problems such as incomplete combustion and flame instability. Eventually, changes in the combustion parameters are proposed taking into account how the gas-air ratio in the burner system is controlled.




Wobbe Index is considered one of the better indicators of the interchangeability. Wobbe Index can be generally defined as "energy flow". It is calculated as the ratio of the calorific value to the square root of the specific gravity relative to air (i.e. SG air = 1).

The ratio of LPG to diluent (air) will depend on the Wobbe Index of the fuel to be replaced (Natural Gas). Matching the Wobbe Index ensures the two different fuels behave exactly as same fuels and fuel swapping becomes seamless. Two different gases with identical Wobbe Index will produce equal amount of heat with the same amount of combustion air from the same burner. Matching Wobbe Index of two fuels ensures that they will behave exactly as same fuels and the changeover will be seamless with no change required in either pipelines or combustion equipment.

Wobbe index is used when "energy input" rather than "gas flow" is of priority. With an appliance for example, the gas input rate is controlled by the jet or burner. If the gas is supplied at a constant pressure, the flow is proportional to the reciprocal of the square root of the specific gravity. Hence, energy input is proportional to the Wobbe index. Such an index is necessary in cases where the feedstock LPG (i.e. blends of propane and butane) varies and can alter the calorific value. For example, assuming the LPG is propane, an SNG mixture to replace natural gas will have a specific gravity of about 1.29–1.31 and a kilocalorie value of 12460–113360 kilocalorie/cubic meter.

SNG can then be adopted as an alternative to NG when industrial consumers have to deal with eventual disruptions in the supply of NG from LDCs.

It can also be used when industrial customers have to be provided with an early gas supply, i.e., when NG has to be supplied even before the NG distribution grid is available.

As mentioned above, the most suitable alternative gas to replace the NG is indeed the SNG, keeping the same Wobbe Index. The replacement of the NG by the SNG is not supposed to cause any problem if their Wobbe Indexes do not differ in more than about 5%. To get such SNG with a Wobbe Index equivalent to the NG, the LPG-air ratio (in volume basis) must be 51.3% of LPG and 48.7% of air. Based on such LPG- air ratio, the NG and the SNG will present the main characteristics as shown in Table below.

| CHARACTERISTICS | UNIT | NG | SNG |
|---|---|---|---|
| Gross caloric value | kJ/m³ | 39,356 | 58,841 |
| | kcal/m³ | 9,400 | 14,000 |
| Net caloric value | kJ/m³ | 36,006 | 53,629 |
| | kcal/m³ | 8,600 | 12,809 |
| Wobbe index (gross) | kJ/m³ | 49,349 | 49,349 |
| | kcal/m³ | 11,787 | 11,787 |
| Wobbe index (net) | kJ/m³ | 45,149 | 45,149 |
| | kcal/m³ | 10,784 | 10,784 |
| Specific gravity | None | 0.636 | 1.411 |
| Density | kg/m³ | 0.763 | 1.696 |
| Stoichiometric air | m³ air / m³ gas | 10.3 | 13.9 (*) |

Remarks: m³ at 20°C and 101.3 kPa abs.
(*) the air content in SNG was taken into account.

Some aspects can be highlighted from table above:

(i) Comparing the heat values of both gases, 1 m3 of SNG is equivalent to 1.49 m3 of NG;

(ii) The NG is lighter than air while the SNG is heavier than air;
(iii) The stoichiometric combustion air to be delivered to the burning system is 13.9 m3/m3 of SNG (and considering the air content of 0.5 m3/m3 of SNG itself, the total stoichiometric combustion air equals to 14.4 m3/m3).

### NG and SNG's main characteristics

Mixing with air can create in general a flammable mix. However, mixing LPG/air to create SNG is not hazardous, since the LPG–air ratio is still far from the LPG flammability limits. The flammability limits for commercial propane and butane, the main components of the LPG, vary within the range from 1.8% to 10% of LPG (in volume basis) in the gas-air mixture. Consequently, **there is no risk** in mixing LPG/air to create SNG and feed it from the blenders to the burners by pipe.

Another important feature is that besides the specific gravity of the LPG (between 1.7 and 1.8) and air (equal to 1.0) being so different, the SNG is considered as a homogeneous mixture, as stated by the Graham's Law – the law of gas diffusion.

### The replacement of NG by SNG in practice

As referred above, most of the times, the main property to be kept unchanged in order to guarantee an adequate replacement of NG by SNG is the Wobbe Index. Yet, this statement is only accurate when the gas flow across the burners is controlled by a pressure differential. In the cases where the residential as well as the commercial NG consumption is dominant, focusing on the Wobbe Index method to guarantee the exchangeability between NG and the SNG usually leads to a satisfactory solution. Feeding SNG into the NG grid and just blending the two gases will provide suitable solutions for the customers.

However, in industrial burner systems, flow meters usually will control the gas-air ratio. In such a situation, holding the Wobbe Index unchanged may not guarantee the equal heat input rate across the burners. Therefore, the Wobbe Index method alone may not guarantee directly the perfect gas exchangeability. Performing additional changes in the combustion parameters as well as checking the flame conditions are required to avoid important technical difficulties for the customers.

The following five conditions must be considered during NG substitution in industrial users:

(i) Both gases must provide equal heat input rates;
(ii) The system as a whole, including the pipelines, valves, control equipment, burners, draft devices, and other equipment such as heat recovers, regenerators, and dust collectors, must be in grade to handle both gases;
(iii) The flame stability at the burners must be maintained;
(iv) The heat transfer from the flame to the equipment must keep the same pattern; and
(v) The flue gases inside the equipment must have the same function, so as to provide the same grade of oxidizing, neutral, or reducing atmosphere.

The Wobbe Index method to define the delivery conditions for the SNG represents an unsuitable method when the burning systems are controlled by PLCs, as it happens in many industrial processes nowadays. Introducing changes in the PLC software allows reaching the proper burning system configuration according to the features of both NG and SNG. The proposed procedures handle with different combustion air-gas ratios. They also seek to follow up and preserve flame stability, heat transfer pattern and flue gases composition, which proved to be an essential condition to guarantee the suitable operation of any gas replacement.

For example, one might suppose that a PLC sets up the maximum power of a burner at gas and air flow rates respectively equal to 100 m3 of NG/h and 1,080 m3 of air/h. By replacing NG by SNG without any additional change, the power

would significantly increase becoming out of the maximum range established for the burner by the PLC. The flow rate of 100 m3 of SNG/h is equivalent to 149.5 m3 of NG/h, which is almost 50% higher. Burning such flow of SNG with the same air flow rate of 1,080 m3 of air/h would result in incomplete combustion. Therefore, although NG and SNG have the same Wobbe Index, they cannot be replaced straightforwardly. It is necessary to change the gas- air ratio in the PLC software as well. Still, following the same example, the SNG flow rate equivalent to 100 m3 of NG/h would be 67.1 m3 of SNG/h (taking into account the net calorific value). As discussed above, the combustion gas-air ratios for the NG and the SNG are respectively 1:10.8 and 1:14.6, considering an excess of 5% in the combustion air. Therefore, the new flow rates to be set up by the PLC would be 67.1 m3 of SNG/h and 980 m3 of air/h.

In other words, the above gas replacement conditions (i) and (ii) can only be attained by producing a SNG based on a LPG-air ratio that guarantees a Wobbe Index equal to the NG, as well as by setting up new gas and air flow rates in the software of the PLC. Similarly, the attainment of the other gas replacement conditions listed above, (iii) to (v), cannot be assured just by assuming the unchanged Wobbe Index. They must be followed and checked during the commissioning of each burner with the SNG.

The flame stability at the burners depends upon several factors such as flame velocity, flammability limits, temperature at the burner, power range, and gas-air ratio (in premix burners). Two phenomena that can occur are flame lift and flashback. Since both gases, the SNG and the NG, present the same characteristic of low flame velocity within the same power range, flame instability may occur mainly in the premix burners. Particularly, the burners already presenting bad performance in terms of flame stability, when using NG, will most likely show similar problems when burning SNG. The stability of the SNG flame must always be checked within the burner over the whole power and temperature range (from ambient to maximum temperature). If several burners fire in the same combustion chamber, flame stability conditions must be verified in all on/off combination of burners.

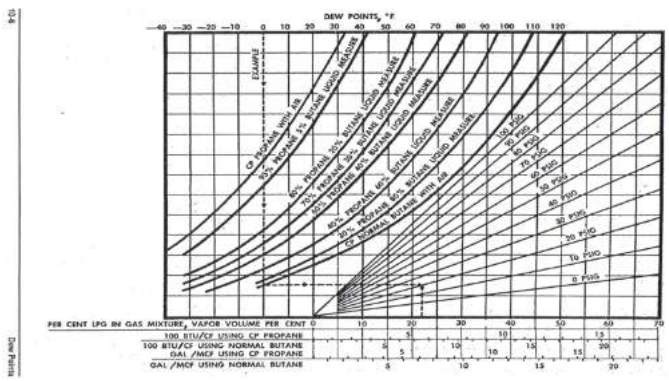
As far the pattern of heat transfer is concerned, the heat transfer from the flame to the equipment will slightly change during the gas replacement as the heat released from the SNG flame, which is somewhat a more radiant flame, differs from the heat obtained from the NG flame. Usually, such difference is small and, in most cases, the changes in heat released by convection are enough to compensate for the difference. The more the heat released by radiation is, the less the heat released by convection will be and vice versa). Yet, the influence of this parameter must be taken into account in terms of process productivity.

In terms of flue gases conformity within the equipment, the three “T” factors must be observed to maintain high quality combustion: Time, Turbulence, and Temperature. The combustion air- gas ratio for NG and SNG are very different. Therefore, changing the turbulence condition between the gas and the air may have significant impacts in the combustion, since the SNG will leave the burner nozzle at lower velocities than the NG. As a result, the atmosphere inside the equipment due to the flue gases may experience oxidation or reduction. Final adjustments are always necessary when using flue gas analysers to check out oxygen and carbon monoxide contents, unburned fractions, and NOx formation, and to set up proper new conditions for air combustion and turbulence.

### 3.1.4 Benefits of SNG

An SNG system has the following benefits:

- Enables utility companies to ensure supply to homes, hospitals, schools, etc. and avoid costly shutdowns
- Often needs no external power source – such as electricity
- In small capacities, an SNG system can be transportable and can be moved to different locations
- There is no need for jets change in appliances e.g. in cookers, heaters, making operating equipment easy, avoiding lengthy and costly change-over times.
- Control systems automatically stop the resource gas supply if any problems should occur.
- The fuel resource LPG is easy to obtain and readily available.
- Produces a stable calorific value output.
- When used for peak shaving, it offers a significantly lower capital investment, and lower maintenance costs than an LNG or CNG system.
- Users are allowed to monitor the cost of the two fuels. Due to gas market fluctuations, the cost-effectiveness of NG and LPG can interchange throughout the year. The systems may be utilized to produce some potentially large savings.
- In some places, NG companies often offer two basic rates, a firm and an interruptible one, the firm rate being the most expensive. An interruptible rate is the rate offered to the user with a standby system, being sometimes 20%-50% lower than the firm rate. SNG use allows taking advantage of the best rate.
- SNG allows LPG companies to market directly to the biggest energy users NG users.
- The SNG also has lower dew point than the neat LPG vapour and can therefore be distributed without any re-condensation occurring (temperature where SNG condenses from a vapour to a liquid). This means that SNG can operate at higher pressure and colder temperature than pure LPG. See the chart below
- The cost of SNG is cheaper than HSD (high sulphur diesel), LSFO (light sulphur fuel oil) comparable to RFO (Residual Fuel Oil) but is actually cheaper when capacity, availability, operational efficiency, leading to lower operating and maintenance costs, are taken into account.
- The carbon footprint of SNG is the same as NG, i.e. significantly smaller than other liquid hydrocarbons.



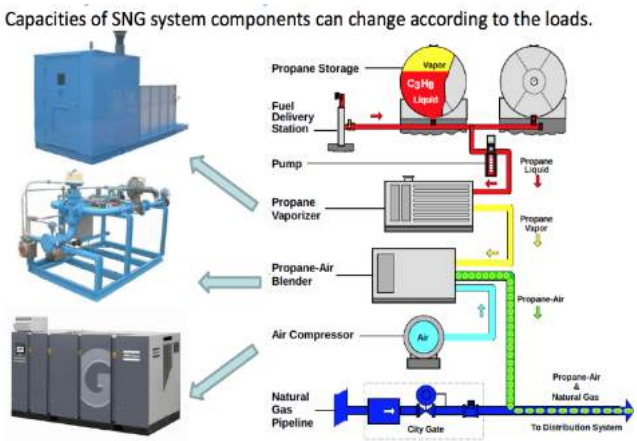
## 3.2 SNG Technologies and Components

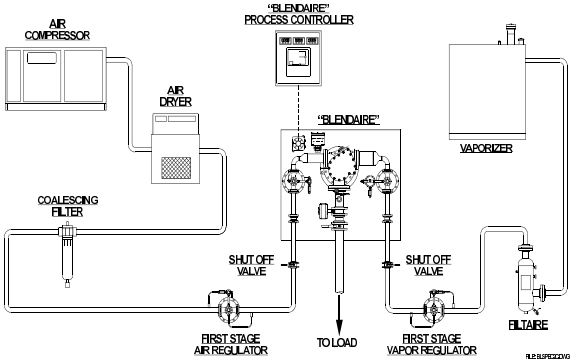
### 3.2.1 Components of an SNG system

Main components of a typical SNG system can include:

- LPG storage tank(s) or cylinder(s) (with loading facilities if needed)
- Vaporizer, if the natural vaporisation capacity of the tank or cylinder is not adequate
- Air compressor
- Interconnected piping
- LPG filter
- Pump(s) (feeding the vaporizer(s))
- Blender (mixes LPG and air) ranging in size and capacities
- Regulator stages
- Automated controls. The complete process is meticulously controlled by a number of components which give safety and control to the system — over pressure shut off, open-close valve controller ensuring a smooth, safe and consistent supply
- SNG properties controller (optional)

SNG can be used with equipment and appliances using NG without changing any burner tips, except for endothermic units with ceramic parts, thus making it the perfect alternate fuel.

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**SNG Plant in Pictures**

Amongst other things the pictures below show modularity and ease of construction:

### 3.2.2 Air Blending and Mixing systems

After the liquid LPG has been vaporised, it needs to be blended in correct proportion with air to duplicate the characteristics of NG at a rate equal to the appliance rate of consumption, and at a quality such that end-use equipment performs equally well under either gas. This is where mixers and blenders come in.

Gas mixing unit systems are required to meet a wide range of operating conditions.

There are several **methods to mix air and LPG vapour**. Probably the simplest method is to use a venturi tube and a nozzle. This method holds very accurate air-to-fuel ratios through a narrow range. This type mixer does not generally require compressed air for operation. However, the maximum achievable system pressure is somewhat limited. The mixture of air and vapour is fed into a surge tank, where it is maintained at a set pressure, and then drawn from the surge tank for use. This type system is usually recommended for intermittent periods of use and is very simple to operate.
Blenders and modulating proportioning mixers are usually more complex, but are usually also more accurate than venturi-type mixers. They are also capable of blending LPG vapour with air in much larger volumes at much higher pressure. These systems are recommended for continuous or long periods of usage, and are ideally suited for Peak Shaving and larger installations.
Regardless of the type vaporizer and blender, a standby system can be designed for the requirements of small users, or the requirements of large industrial and utility users. In times of uncertain oil prices and supplies, a standby system should be considered by all Natural Gas users.

The purpose of an SNG blender is to blend air with LPG vapour from a vaporizer in the correct ratio to create a gas interchangeable with NG. NG has a Kcal content of approximately 8900 Kcal/m3. Undiluted propane vapour has a Kcal content of about 22440 Kcal/m3. However, a mixture of about 45% air and 55% propane vapour results in SNG with a Kcal content of around 12645 Kcal/m3 and a specific gravity of 1.31. Therefore, SNG has a Kcal/m3 content of 12645 versus natural gas at 8900.

The reason that they are so different, involves the relative specific gravity (weight) of the gases. SNG is approximately twice as heavy as NG. SNG has a specific gravity (SG) of about 1.31 versus NG at about .65. The heavier SNG flows through a burner orifice more slowly. SNG is thicker or more viscous then the “lighter” NG. Since SNG flows more slowly, each cubic foot of gas must have a proportionately higher Kcal content in order to make up for the fact that less gas is flowing to the burner. Because of the specific gravity difference, there must be approximately 1.414 times as many Kcals in the heavier SNG than in the NG.

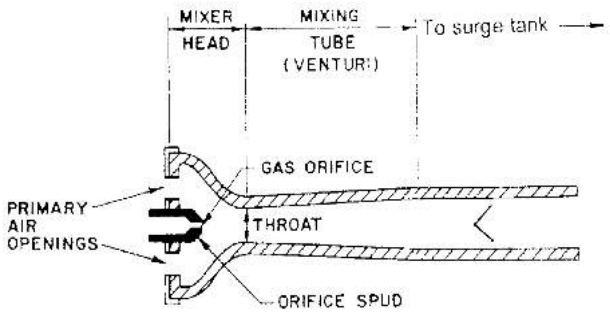
**Types of blenders:**
There are two basic SNG Blending processes.

- **Venturi Blenders:** No air compressor required; can provide 5-12 PSIG of propane/air pressure, also can be found as drawn air mixers, which use the energy of a gas (called "motive gas") to draw in the necessary amount of air by venturi effect.
- **Proportional Blending** (Air compressor required; can provide whatever SNG pressure is required) by the use the mixing Valves, which use the pressure of both gas and air to produce the final mixture.

Several methods exist to achieve LPG + Air blending. Standby has been instrumental in much of their development. Today two very different methods dominate mixer design, the venturi mixer and the parallel-pipe mixer.

#### 3.2.2.1 Venturi Blending

Venturi blenders use the kinetic energy in the LPG vapour stream to create the desired mixture. Venturi style mixing systems use high-pressure LPG vapour to entrain air directly from the atmosphere by venturi action.




With SNG venturi systems the velocity increases as LPG vapour passes through the throat of the venturi nozzle. During venturi operation, the LPG is gaining kinetic energy. The “pressure” (i.e., energy) is reduced and hence total energy again remains constant. The venturi creates “negative pressure” in the venturi chamber. Consequently, the atmospheric pressure is “greater” than the pressure in venturi housing. Air flows from the higher-pressure zone (atmosphere) to the lower pressure zone (into the venturi housing) to mix with the LPG. A “surge” (volume) tank is added at the discharge to prevent undesirable short cycling in operation.

From the previous example, it should also be apparent that the 1 spheric pressure can contribute is about (1) atmosphere or (14.7 PSIG). As the SNG pressure gets higher — the inlet pressure to venturi (the pressure from pump set) must also increase. There are limits on what LPG pressures are feasible based on vaporization and pumping.

Venturi mixers are batch style mixers, cycling on and off to maintain discharge pressure within a narrow operating band. They are the mixer of choice for blended gas pressures less than about 15 psig (1 barg) since they do not require a compressed air source. Also, they are considered to have infinite "turndown" due to their on-off nature of operation, and are therefore suitable for highly variable gas consumption profiles. In most cases, multiple mixing tubes are staged, to accommodate larger loads.
Many natural gas end-users utilizing LPG as a back-up fuel prefer venturi style mixers due to their simple operation and repeatable performance. They have also been used by utilities on low-pressure natural gas distribution systems. Furthering their reach is the addition of a compressed air package that allows operation at pressures greater than 15 psig (1 barg).

In summary, without using an air compressor or blower, venturi can provide.

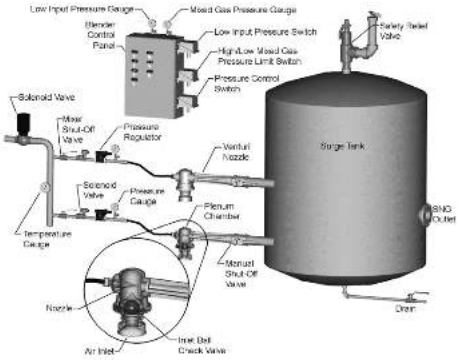
- 7 psig max of SNG pressure if the LPG is ~ 50% butane and 50% propane (* this can vary slightly).
- 12 psig max of SNG pressure if the LPG is 100% propane.
- 6 psig max of SNG pressure if the LPG is 100% butane.

Or alternatively stated

- To generate 5 psig of SNG, the liquid LPG pressure must be 40 psig.
- To generate 8 psig of SNG, the liquid LPG pressure must be 90 psig.
- To generate 12 psig of SNG, the liquid propane pressure must be 140 psig.
- To generate 15 psig of SNG, the liquid propane pressure must be 185 psig.

If increase of SNG pressure above these pressures with a venture is required, the available air pressure above atmospheric pressure must be increased. This requires use of an air compressor or blower.

**Typical Venturi Blending System**

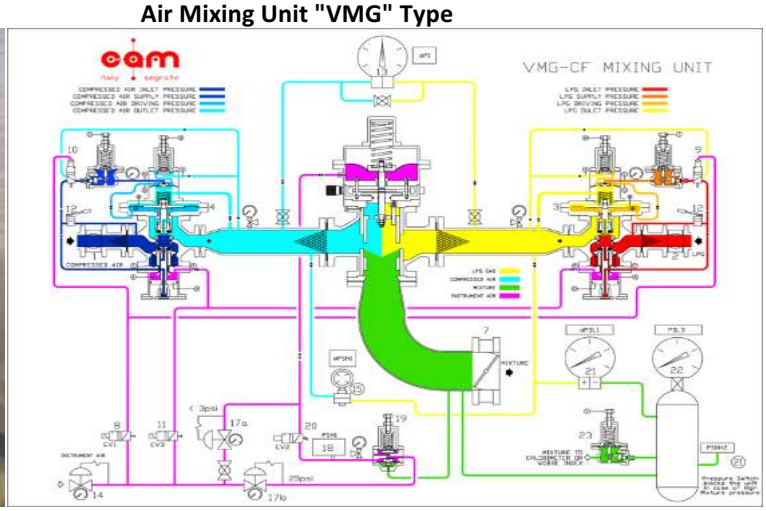



- A venturi solenoid valve is energized by a pressure control switch which senses pressure of the SNG in the SNG Surge Tank.
- The pressure regulator controls the undiluted LPG vapour pressure to the venturi nozzle.
- As SNG from the surge tank is consumed by the downstream gas consuming equipment, the SNG pressure in the surge tank drops. The pressure control switch senses the pressure of the SNG surge tank dropping and energizes the solenoid valve allowing LPG vapour at a regulated pressure to be fed through the Venturi nozzle and then through the Venturi chamber.
- The LPG vapour passes through the plenum chamber between the nozzle and the venturi throat at a high velocity. A negative pressure is created and this inspires the required volume of air throughout the venturi throat into the expansion section (diffuser) of the venturi where the velocity of the mixed gases is converted to static pressure.
- Air entering the plenum chamber passes through the inlet back check valve.
- SNG leaving the venturi passes through the manual shut off valve and into the SNG surge tank.
- When pressure in SNG surge tank rises to its set point, the pressure control switch opens, thus de energizing the solenoid valve which then closes.
- The inlet ball check valve in the venturi housing prevents escape of SNG back to the atmosphere.
- Safety limits include a high/low SNG pressure limit switch, low input pressure limit switch and the low water temperature limit switch on the vaporizer. Any of these devices will de-energize the solenoid valve on the vapour discharge side of the vaporizer and shut down the SNG system.

**Gas mixing unit examples**

**LPG - Compressed**

**Air Mixing Unit "VMG" Type**




The main features of the VMG Mixing Unit are:

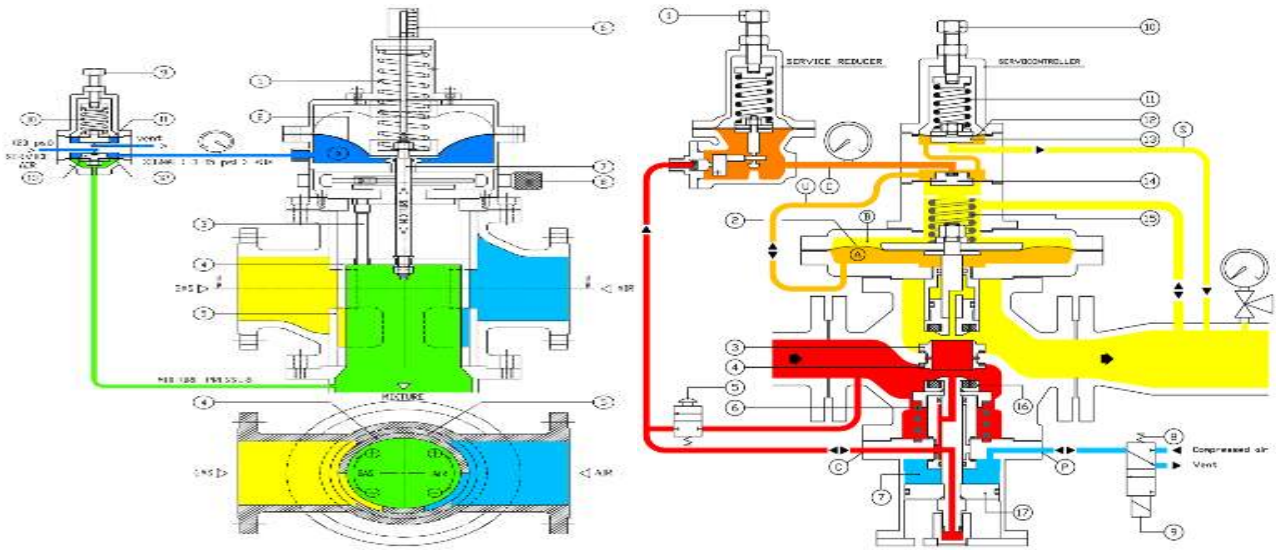
- variable flow rate from 5% to 100% of nominal capacity
- mixture outlet pressure: from 1 to 5 bar
- high control accuracy of outlet pressure
- fast and prompt response to the change in consumption
- gas / air ratio easily adjustable

- fail-safe design

These units are commonly used as **stand-by system for both industrial and utilities** users of NG, against a supply curtailment or interruption, offering them an alternate source of energy fully interchangeable. These units can also be used as "**peak shaving**" system to supplement the NG supply when the consumption rises above the contracted amount.

The mixing unit provides a variable flow-rate of LPG/Air mixture, **according to the request** (from 5% to 100% of its nominal capacity), with a steady output pressure. At the same time this unit is capable of maintaining a constant LPG/Air ratio on a value manually adjusted by the VMG valve. The automatic functioning of the unit is managed by a PLC installed in the Control Board. The mixing unit automatically starts and begins to deliver mixture, as soon as the downstream pressure drops due to the gas consumption of the users. When the pressure drops below the set point, the pneumatic servo control (pos. 19) raises its output signal, until it reached the set value of the pressure switch PSH1 (pos. 18), whose contact will be detected by the PLC. The Control Board activates the solenoid valve EV1 (pos. 8) and opens at the same time the two Pressure Regulators (gas and air - pos. 3 - 4). Following this, the pressure downstream the Regulators increases up to the set point value (about 0.3 bar above the set point of the VMG) and the differential pressure between LPG and Mixture raises until the opening of the contact of the pressure gauge dPSL1 (pos.21). A few seconds after the contact of dPSL1 has opened, the Control Board activates the solenoid valve EV2 (pos. 20), which was holding the VMG at minimum flowrate position. At this point the Valve starts to regulate the delivery of the mixture, in order to keep the pressure steady in the network. When the consumption drops below the minimum capacity of the VMG (about 5% of the flow-rate), the downstream pressure tends to rise while the differential pressure between LPG and Mixture decreases. As soon as it reaches the low limit and closes the contact of the pressure gauge dPSL1 (pos. 21), the Control Board stops the unit, by closing the solenoid valves (EV1 - EV2 pos. 8 – 20). The minimum of the Mixing Valve is set during manufacture by means a mechanical lock mounted inside and can be only increased by adjusting the signal through the Pressure Regulator (pos. 17a). Otherwise the line of this Regulator must be kept closed. When the consumption is lower than the minimum flow rate of the VMG, the differential pressure between LPG and Mixture does not reach the threshold of the dPSL1 pressure gauge and so the unit continues to operate ON / OFF at the minimum flow rate (with EV2 pos.18 always de-energized).

**VMG Valve** **LPG Pressure Regulator**

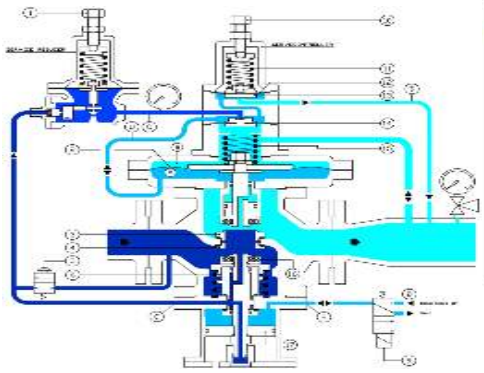



**The mixer valve, "VMG-CF" series**, is designed to deliver an Air/Gas mixture with **a fixed ratio** all over the range of flow rate (from 5% to 100%), keeping the downstream pressure steady. The gas/air mixing ratio can be adjusted through the hand-operated twist grip (8) in a range between 25% and 75% of gas in the mixture: the set value is shown by a sliding index placed on the valve body. The gas and air pressures at the valve inlet must be the same and 300 mbar higher than

the required pressure of the mixture. The valve regulates the mixture flow rate by opening and closing the two ports where gas and air pass through. This is achieved by sliding the piston (4) inside the cylinder (5) where the ports are obtained. The piston is connected to the diaphragm (2) by means of the rod (7) and it is normally kept in closed position from the preload of the spring (1). It is driven by the service air pressure, into the chamber (A), which shall be about 15 psi for the complete opening of the ports. The pressure in the chamber (A) is continuously adjusted by a pneumatic servo control, according to the pressure of the mixture. So, for instance, when the pressure of the mixture tends to drop because of the consumption, the servo control increases the air pressure in the chamber in order to raise the flow rate and restore the set pressure. The pressure value of the mixture can be set by means of the adjusting screw (9), by turning it clockwise to increase or counter clockwise to decrease.

The pressure regulator seat (3) is normally kept closed by the spring preload (15). The seat (3) opening is due to the feeding of the service gas into the chamber (A). The service gas pressure for a complete opening of the seat must be at least 300 mbar higher than the pressure reducer setting value. Service gas pressure is controlled by the servo controller provided with an inlet (C) and outlet (S) port. The ports opening is regulated by the shift of the servo controller mobile equipment (13) connected to the membranes (12-14). The inlet port (C) is normally open because of the spring thrust (11) while the outlet port (S) remains closed. On the lower membrane (14) there is an uplift pressure created by the downstream pressure in chamber (B), this uplift is opposed to the spring thrust (11). Until the pressure on the lower membrane (14) is less than the spring thrust (11), the service gas, which feeds the chamber (A), opens the seat (3) and therefore causes the increase of the downstream pressure. When this pressure reaches the value to balance the spring thrust (11), (setting value), the mobile equipment of the servo controller shifts in order to keep the pressure arisen in the chamber (A) at a constant level. If the regulated pressure (downstream the reducer) tends to overcome the setting value, the servo controller mobile equipment (13) shifts upwards in order to reduce the pressure in chamber (A), blowing off the service gas through the outlet port (S), so reducing the openings section of the seat (3) until pressure downstream reaches the setting pressure. The setting pressure value can be changed by using the adjusting screw (10), turning the screw clockwise to increase it and counter clockwise to reduce it. The safety stop valve, incorporated in the reducer, works with gas or compressed air operated feeding. The stopper (16) keeps the bottom of the seat (4) normally closed, because of the spring preload (6). The opening of the seat (4) is done by the air pressure into the port (P). When the pressure downstream reaches the setting of the electrical switch, the EV valve change its position by the spring (8), and vents the air. The stopper is no more kept, so that the uplift of the spring (6), makes it move up and close the seat (4).

**Air Pressure Regulator**



| VMG UNITS - TECH DATA | | | Pressure Drop (inlet - outlet pressure, bar) 2 - 1 | 3 - 2 | 4 - 3 | 5 - 4 | 6 - 5 |
|---|---|---|---|---|---|---|---|
| VMG TYPE | VMG FEATURES DNin - DNout (1) | RS / DN (2) | VMG UNIT MAX CAPACITY (3) Nmc/h | Nmc/h | Nmc/h | Nmc/h | Nmc/h |
| VMG-100-50 | DN 50 - DN 80 | DN 50 | 400 | 600 | 750 | 1000 | 1150 |
| VMG-150-50 | DN 50 - DN 100 | DN 50 | 800 | 1200 | 1550 | 2000 | 2300 |
| VMG-200-65 | DN 65 - DN 125 | DN 65 | 1600 | 2400 | 3200 | 3950 | 4600 |
| VMG-250-80 | DN 80 - DN 150 | DN 80 | 2800 | 4200 | 5600 | 6400 | 7300 |
| VMG-250-100 | DN 100 - DN 200 | DN 100 | *2800* | *4200* | *5600* | 7000 | 8200 |
| VMG-300-100 | DN 100 - DN 200 | DN 100 | 4700 | 7100 | 8500 | 10000 | 11500 |
| VMG-300-125 | DN 125 - DN 250 | DN 125 | *4700* | *7100* | 9400 | 12000 | 13200 |

(1) VMG unit - Inlet / Outlet nominal size
(2) Pressure Regulator nominal size
(3) Capacities calculated based on: LPG composition = 90% c3 - 10% c4 ; Mixture composition = 56% LPG 44% air; HCV = 13800 kcal / Nmc ; specific gravity = 1,33

**VENTURI mixers "compact" Type**

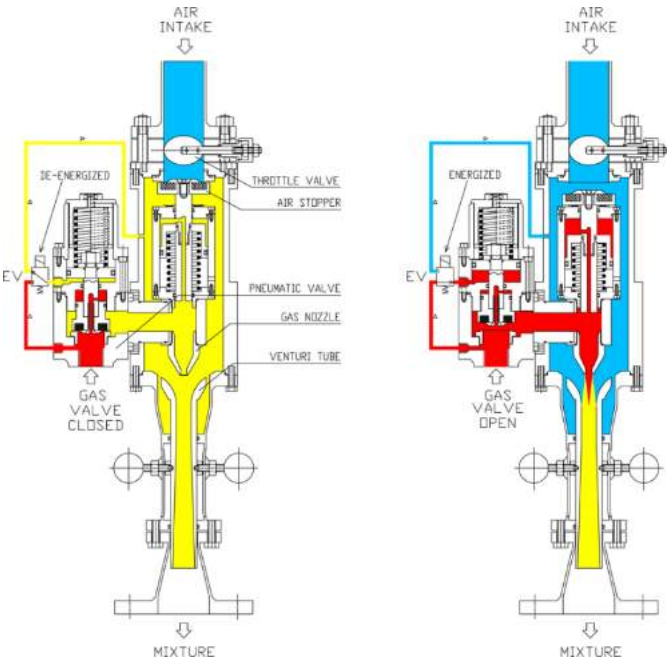
The main features of this type are:

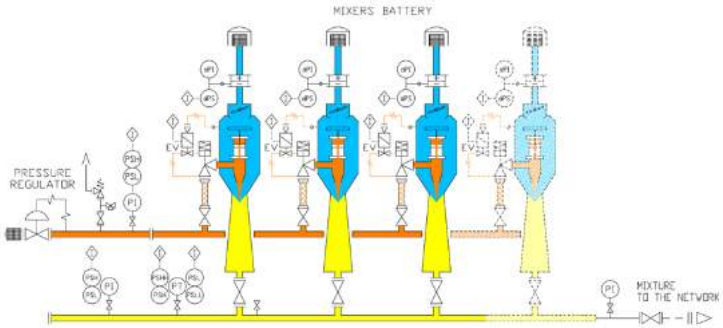
- fixed flow rate
- mixture outlet pressure up to 500 mbar
- mixing ratio highly stable
- gas / air ratio easily adjustable
- fail-safe design

When mounted and combined in a battery these mixers can reach a very high turn-down ratio and an almost unlimited capacity (flow rate). This type of mixers is particularly suitable for civil distribution systems with big network volume and low working pressure.

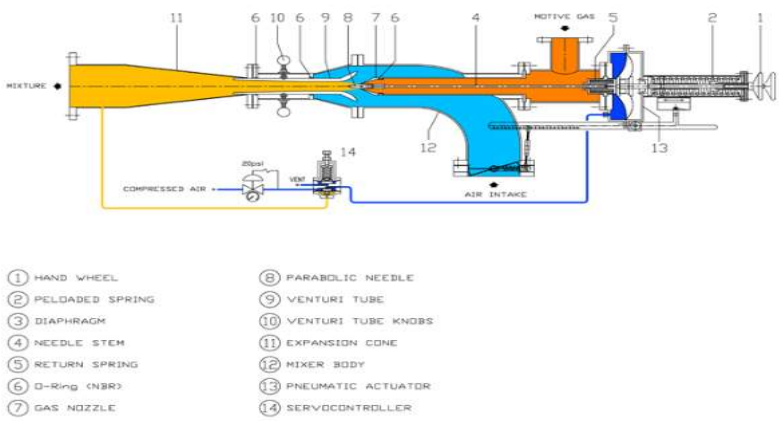
When the solenoid valve EV is de-energized, the motive gas (red zone) doesn't flow to the actuator and therefore both pneumatic gas valve and air stopper are kept closed by means of springs. After the solenoid valve EV has been energized (right picture), the motive gas pressure (red zone) opens the pneumatic gas valve by means of its actuator and the gas starts flowing through the valve to the gas nozzle. In the same time the gas enters the chamber of the pneumatic air actuator, pulling the air stopper down so as to open the airport (orifice). Due to suction created by the gas flowing through the nozzle and the tube section ("venturi effect"), the ambient air is drawn into the mixer and blended with the gas inside the tube. The mixture produced is sent to the mixer outlet cone (section) thanks to the motive gas (energy) pressure. While the gas flow rate is always steady (due to steady gas inlet pressure and to fixed orifice of the nozzle), the amount of air in the mixture can be adjusted by a throttle valve and checked by a differential pressure gauge, both placed on the air suction pipe. In this way is possible, at any time, to set the right calorific value of the mixture.

When the mixers are mounted in a battery, the automatic functioning of the unit is managed by a PLC inside the Control Panel, as below described. The mixture outlet pressure is continuously checked from the PLC, through the Pressure Transmitter PT (pos. 7), and compared with four thresholds (PSLL, PSL, PSH, PSHH) inside the PLC memory. The thresholds are set around the pressure value required from the system. When, due to change in consumption, the pressure drops or rises till to reach the inner thresholds (PSL-PSH), the PLC activates the mixers, according to a sequence which increases or decreases the mixture flow rate of a same quantity for each step, so as to keep the outlet pressure within the set range. On reaching the inner thresholds (PSH - PSL), the sequence moves of only one step, while if the pressure reaches even the outer ones (PSLL – PSHH), this means that flow rate variation of the previous step has not been enough and therefore the sequence speeds up, by carrying out more steps so as to restore fast the mixture pressure. In case of failure of the Pressure Transmitter, the contacts of the Pressure Gauge (pos. 8) will take over the unit control, by managing the Mixers like with the outer thresholds of the Transmitter (PSLL-PSHH).




**Variable Venturi Mixers**

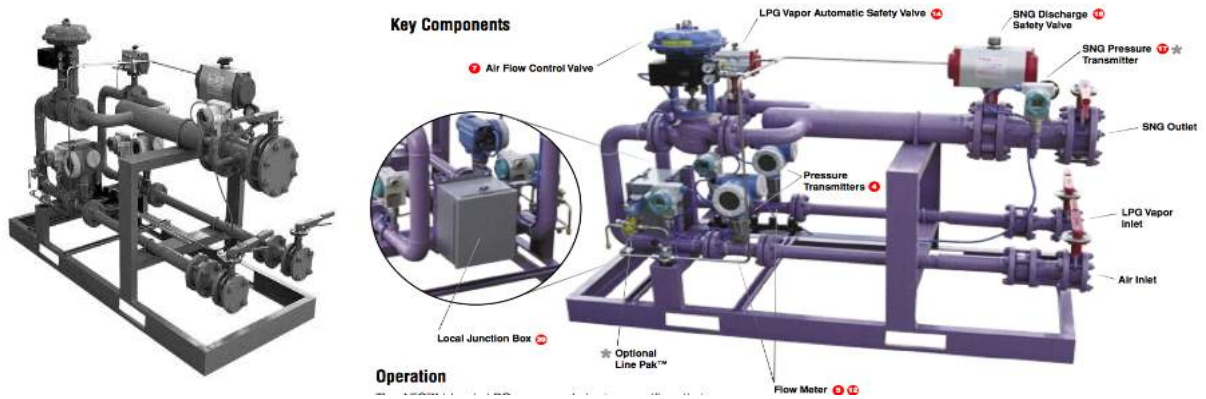


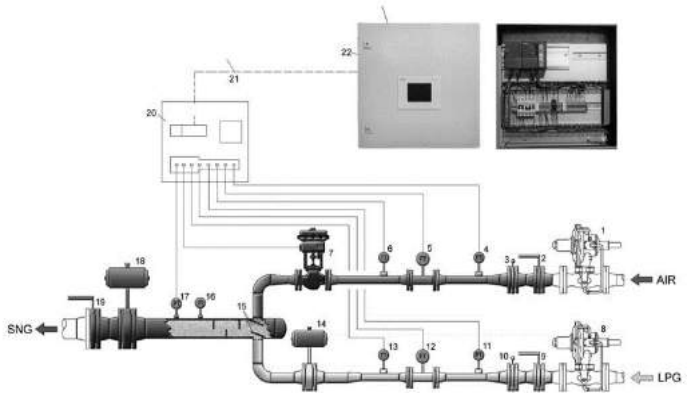
### 3.2.2.2 Proportional Blending

Proportional blending is usually designed to accommodate small to very large capacities to handle a multitude of industrial and peak shaving activities. It blends LPG vapour and air at a specific ratio to perfectly simulate the combustion characteristics of natural gas. Pressure and temperature compensated flow meters, as shown in the schematic, measure the regulated flow of LPG and air. The volumetric flow of both gas streams is converted to their true molar values with a sophisticated gas flow algorithm that takes into account the system 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 natural gas being simulated.

Adjustments to the ratio are made only on the air side of the system. Adjustments are automatic and are performed by the Air Flow Control Valve. As the flow of SNG either increases or decreases, the Air Flow Control Valve modulates and maintains an exact and constant mixing ratio between the LPG and air streams. The result is a Wobbe value that typically varies < +/- 1%.

Pressure regulators installed upstream maintain constant pressure to both the vapour and air inlets. When providing SNG in a piped network, as the gas distribution pressure decreases, the SNG flow rate will increase to maintain pressure. Likewise, when the gas distribution pressure rises, the SNG flow decreases. The LPG vapour regulator establishes the discharge pressure. The proportional mixer provides SNG mixtures at pressures from 13 psig to over 150 psig in a capacity range from 10 million Kcal/HR to 500 million Kcal/HR.




1, 8 Pressure Regulators (Not provided)
2, 9 Butterfly-type Isolation Valve
3, 10 Wafer-type Back Flow Check Valve
4, 11 Pressure Transmitters (Pressure correction of the flow data)
5, 12 Flow Meters
6, 13 Temperature Sensor [RTD] (Temperature correction of the flow data)
7 Air Flow Control Valve (Controls air flow based on flow and control parameters)

14 LPG Vapor Automatic Safety Valve (Pneumatically opens – spring close; Valve closes where there is a safety violation)
15 Turbulators (Internal to header)
16 Pressure Indicator (Displays mixed gas discharge pressure)

17 Pressure Transmitter (Provides mixed gas discharge pressure signal to the control system)
18 SNG Discharge Safety Valve (Pneumatically opens – spring close; Valve closes when there is a safety violation)
19 Butterfly-type Isolation Valve
20 Local Explosion-proof Junction Box (Mounted on the AFC Blender)
21 Profibus Cable (Single cable link from the AFC Junction Box to the Control Panel)
22 Control Panel (With "Touch Screen;" Operator-friendly and compact)

**Algas-SDI BLENDAIRE**

*Blendaire Three Port Proportional LPG/Air Mixer*

This proportional mixer accurately mix 2 gas streams at pressures up to 150 PSIG for standard units and up to 250 PSIG for high pressure units. Standard packages are set up for LPG-air mixing to replace or augment the supply of natural gas for industrial back-up or for city gas SNG production as a lead in to natural gas or for augmenting the supply of natural gas such as peak shaving. It provides accurate LPG/Air mixtures within desired adjustable ratios and delivery pressures of up to 150 PSIG.

**Parallel Pipe Mixers**

Parallel pipe mixers, such as Standby's MFC mass flow mixer, blend the two gases at the same rate at which gas is being consumed. Automated valves control the flow of each gas to achieve the goals of maintaining pressure (alternatively energy flow rate), and maintaining gas quality. Generally used by gas utilities in peak shaving operations and by large end-users, parallel pipe mixers offer certain advantages over other mixer types.

Parallel pipe mixer is a sophisticated mixer incorporating multiple blending modes. It is used to maintain system pressure or energy flow rate, while maintaining a constant final mixture Wobbe Index. Normally the energy flow of LPG is measured, the mass flow of air required is computed based on design criteria, and airflow is adjusted so as to meet this requirement. When used in peak shaving to supplement natural gas energy flows, the amount of natural gas flowing is also evaluated as this impacts gas quality and final mixture specific gravity.

This style mixers require a compressed air source and are generally used in pressure applications greater than 15 psig (1 barg) with high flow capacity requirements and the need for greater control capabilities than can be obtained with other styles of mixers.

**Prolimix system**

*Prolimix*

The main part of this system is the nozzle head in which four to six nozzles are mounted.
The propane is distributed to an aerosol and is evaporated by the intake of warmth from the bio-methane. At this point, there is already a good enough mixing of both gases taking place. In the outlet side-connected static mixer, the gas mixture is mixed by an appropriate redirecting and swirling process.

**Advantages of the system:**

- No evaporator is required because the conditioning process takes place with injection in the liquid phase.
- For any eventual, necessary pre-warming of bio-methane to 35°C, the heat generated from other biogas production or compression processes can be used.
- When using compressors, the system can provide cost-free cooling. With a mixture of around 3% propane, the temperature of the mix gas sinks to around 12 Kelvin.
- Pressure regulation, trace heating and insulation of the gas phase are not necessary.
- Measuring and controlling components are smaller in size according to their application in the liquid phase.
- Through the multiple-nozzle technique, an adaptation of the propane mixture to modified bio-methane flows can take place with the same nominal dimension of the mixer.

Pump system for high pressure dosing systems:

- Submersible dosage diaphragm pump inside the tank.
- Motor and hydraulic system on top of the tank.
- Flow rate controlled according to the request of propane.
- No heating of liquid inside the tank.
- High pressure up to 40 bar and more is possible.

## 3.3 Applications

Emulating NG with SNG is a conventional proposal capable of being employed in one of four common ways in a typical NG market, which can be used in standby or backup, base-load, peak-shaving and commingling systems.

SNG is a tactical tool. The applications of SNG can be summarised in four major areas of such system usage:

- **Backing up** NG delivery interruptions drawn from accidents, interruptible contracts, or any sort of maintenance needed in the transportation or distribution NG systems from utility companies.
- Overcoming the lack of NG in **base-load** supply for few years, **as a primary fuel source**, in areas where Natural Gas is not available or will be available in the future due to NG supply constraints.
- Dealing with NG supply restrictions in peak hours, due to upper limits in the contracted demand, or high pressure drops in old and under dimensioned gas pipelines **(peak-shaving)**.
- **Co-mingling** and co-habiting without any technical problems local NG distribution systems.

In an emerging NG market the gas provision for the 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 the glass works, steel mills, ceramic industries, or foundries cannot run out of gas without the risk of permanent damages. The installation of SNG backup systems proved to be a suitable solution.

### 3.3.1 SNG Standby or Back up Fuel Systems (Industrial Applications)

The need for **energy backup** is related directly to the risk of interruption in the existing main energy supply system. Concerning the use of NG, usually the main causes for supply interruptions are the unexpected accidents or the necessary stops for maintenance in transportation and distribution systems. In both cases, the pressure in the NG grid tends to fall.

*Photo by TransTech Energy*

*SNG system installed at a Pilkington glass factory in the USA-picture courtesy of Algas-SDI*

The amount of time over which the gas pressure will still allow the consumers to be supplied of the product depends upon several factors such as the grid volume, the initial pressure, and the gas demand downstream the interruption point. When a NG supply break occurs close to the end of a single pipeline, the pressure can drop down in just few minutes in case of a high gas demand. Such perspective turns the provision of SNG backup systems almost mandatory in order to avoid business interruption and/or further losses for the customers.

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 important fuel cost reductions, particularly under major gas price fluctuations. Still, the consumer will have to count upon the SNG to substitute the NG whenever the NG supply is interrupted by the LDCs.

Furthermore, in many industries, a 'standby' or backup fuel system is an imperative for maintaining steady operation both as a means to supplement an inconsistent fuel supply or in cases where there is risk of fuel supply interruption. For those using natural gas fuel, SNG is an ideal backup fuel solution.

The SNG system 'ties in' downstream of the LDC's custody transfer / pressure reducing station. The SNG system enables the factory to continue normal operation and production even during curtailment periods. When natural gas becomes available again, the SNG plant deactivates and returns to its "standby" role.

Most NG utilities offer larger users highly discounted rates for so-called "interruptible service". This discount rate is available to the user year-round. When demand exceeds allotted pipeline-capacity (i.e., when domestic demand flares up during extremely cold winter days), the utility company curtails their "interruptible" customers, who then switch to their standby system. Curtailments usually occur only a few days throughout the year and happen only with 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 system within 6 to 18 months. Thereafter, all savings on energy costs are direct improvement for the "bottom line".

Critical installations, such as hospitals, military installations, livestock farms, etc. often require backup systems for electricity and natural gas. AES Propane / Air Systems produce gas that is readily available and directly compatible with natural gas.

**Benefits**

- Standby fuel systems provide the opportunity for large gas users to reduce NG costs by as much as 30-40% or more, by utilizing 'interruptible service' gas savings rates. This holds true especially for companies using natural gas that have loads greater than 2 million Btu/Hour.
- In some cases, as it is in the Glass Industry, fuel interruptions are devastating. Fuel shortage not only results in production losses, there are also hundreds of thousands of dollars lost in capital investments. Covering this risk with a back-up fuel system is a requirement.
- Many industrial processes operate continuously. Fuel interruption halts mass production and as a result major economic losses are incurred. The goal for companies in all industries is to be in a competitive position. Seeking a reliable and environmentally friendly energy source that will also offer the lowest possible manufacturing costs can put them ahead of the game. Propane-air back-up systems allow companies to benefit from interruptible Natural Gas rates while relying on environmentally clean fuel sources.
- Simply stated, during times of high demand or low supply, customers with interruptible rate contracts will allow their supply to be curtailed by their utility, during which time they will simply switch over to their LPG-fed standby system.
- In exchange, NG utilities provide significant rate discounts to these customers – throughout the term of their contract. Discounted rates are generally provided whether or not service is interrupted, so the savings delivered by a standby system continues to 'pay back' regardless of how often it is put into use.

**Case study**

Argonne National Laboratory conducted a preliminary study assessment in 2012 of an LPG backup system to supplement natural gas 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 LPG-air system. The analysis looked at the amount of LPG-air that could be provided to the area's approximately 350,000 residents served by local natural gas utility.

The report assumed that 50% of natural gas deliveries would be switched to SNG, estimating 15,700 gallons of LPG per day would be required, given that 11 gallons of LPG equals to 1 MBTU and assuming that the typical caloric value of NG is roughly 1,000 BTU/cf and that the average –day demand of 173 million cf/day is equal to 173 billion BTU per day.

### 3.3.2 SNG Base-Load Systems

Base-load systems provide SNG fuel to energy users to overcome reliability restrictions on NG supply. This situation most often arises from one or combination of events:

- Supplying a local distribution network in anticipation of the imminent arrival of a secure and permanent NG supply.
- To replace a NG supply that has been lost and constrained beyond the limits of existing infrastructure.
- To replace NG supply lost due to old infrastructure.

SNG base-load systems are also commonly deployed in developing NG market prior to the arrival of NG where SNG is used as a 'bridge fuel' in preparation for natural gas availability also referred as town gas.

Base-load systems using the SNG are the best way to overcome base-load restrictions on NG supply, lasting over just a few years. The foremost alternatives are to feed the SNG into the NG grid and blend the two gases; or to dedicate a gas grid to operate exclusively with SNG. In either way, the internal gas pipelines, the control systems, and the burners will be ready to receive the NG whenever it becomes available.

A SNG base-load system can help to anticipate the gas supply for NG grids built in regions with no immediate access to the NG. Such solution was pursued in Uruguay, with a LDC called Conecta, which operated with SNG before the Country started importing NG from Argentina. Less frequently, the SNG base-load system is conceived to operate in longer terms serving consumers located where the NG grid is not expected to reach.

*Photo by TransTech Energy*

Another strategy was proposed in Brazil to reduce the overall NG supply risk from the LDCs. There, a few large industrial customers already connected to the NG grid, and holding a significant share of the total NG consumption, were chosen to be eventually converted to operate with the SNG. Such strategy sought to alleviate any long-term major supply restrictions for the rest of the NG grid.

The following conditions must be considered during a gas substitution in industrial users:

- Both gasses must provide equal heat input rates.
- The system as a whole, including the pipelines, valves, control equipment, burners, draft devices and other equipment such as heat recovery, regenerators, and dust collectors must be able to handle both gases.
- The flame stability at the burners must be maintained.
- The heat transfer from the flame to the equipment must kept the same pattern.
- The flue gases inside the equipment must have the same function, so as to provide the same grade of oxidizing, neutralizing or reducing atmosphere degradation.

**Benefits**

- Because LPG which can be easily pressurised and transported as a liquid (LPG) via truck or rail, and therefore does not call for the significant infrastructure requirements associated with NG, its use can be implemented much more readily.
- For remote regions, SNG base-load systems allow for the use of low-cost, environmentally friendly LPG, regardless of location.
- Developing NG markets, currently dependent on diesel or crude oil, switching to SNG support plants convert oil powered turbines to gas power before NG infrastructure is complete and could begin benefitting from lower cost, cleaner burning gas power sooner and to be ready for natural gas once it can be delivered

**Case studies**

Superior Energy Systems customer Logan Aluminium Kentucky started using LPG-air mix when NG could not meet their demand. They started using LPG-air for peak shaving. The facility has four 90,000 underground tanks and one 90,000 aboveground tank. With LPG – air mix as supplement, Logan Aluminium can meet their production needs.

National Gas offers energy solution to Salalah factories.
The factories facing fuel shortage in Salalah due to local production most tied to export commitment and priority usage with power sector. Industries may not have to struggle hard to get another source of energy to run their establishments smoothly with the availability of SNG.

**Case study**

**Liuzhou City- Base Load in China**

In Liuzhou City, China, there are three SNG stations. Each station is designed to fuel 50,000 households, LPG –air mix is used as the baseload, the primary energy to fuel the city. They have 1 million gallon spherical tanks and a rail unloading station. They use 6,100 tons of LPG a month, per station.

Main features:
3 Stations, 1100 MM BTU/Hr each
Each station designed for 50,000 households
30 psig
2 x 1,000,000 gallon spherical tanks, rail unloading station, 3 x positive displacement pumps
3 x hot water vaporizers, 3 x proportional LPG/air mixers, 3 x air compressors, 3 x dryers, 3 x air filters, 3 x LPG filters, calorimeter and flare stack.

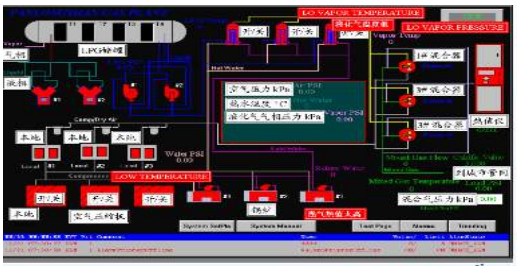
Purpose
Base load to feed city⇒LPG Consumption: 6100 tons/month for each station

City Tanks

Pumps

Unloading compressor

Mixer and Vaporizer



Controls

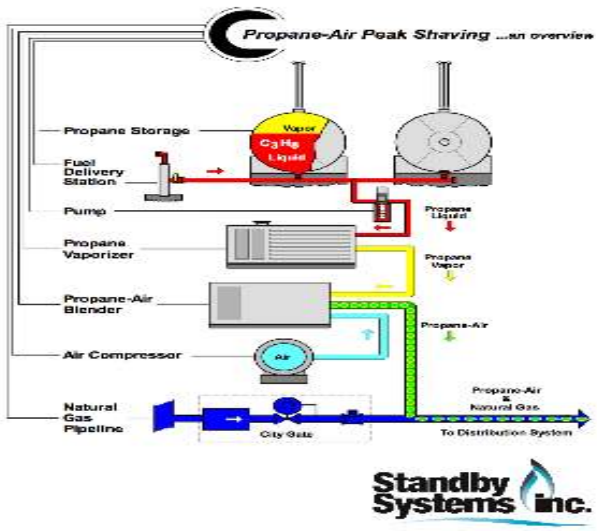
### 3.3.3 SNG Gas Peak Shaving Systems (Industrial and Utility Applications)

Peak shaving systems are primarily used either for economic reasons (pricing envelopes of NG contracts) or to complement NG quantities when supply is not sufficient to cover the needs.

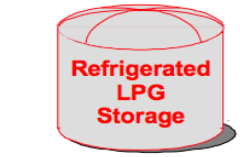
Utility Companies and large industrial users typically have supply agreements for a certain amount of natural gas over a certain period of time (day, week, month), with set pricing for this amount. As they exceed their contract amount (i.e. on extremely cold days), prices typically increase dramatically. LPG/Air systems can be installed that carry a percentage of the total load, keeping the consumption from the main supplier within acceptable limits, avoiding the payment of penalties.

The use of SNG for peak shaving must be understood under two perspectives, the **daily** and the **seasonal** peak shaving. The first is required daily, over just few hours in weekdays, when the flow rate in the NG grid reaches its maximum value. The pressure drops at the end of the distribution system creating bottlenecks, which make it difficult to match the expected demand in the grid. The restrictions become more critical when the gas grid operates with old and/or under dimensioned pipelines, which reduce even more the capacity for the LDCs to supply the market. The use of SNG peak-shaving stations at the end of the NG grid allows LDCs to aggregate new costumers into the gas grid with minor investment. Instead of investing heavily to expand and/or modernize the whole NG grid, which may not be possible or profitable, the SNG will help to cope with the punctual bottlenecks. Similarly, SNG peak-shaving facilities might be suitable to balance the NG supply system and match the total gas demand in the high season. Usually the high season may take place during the winter in the cold countries and throughout the summer in the hot countries. The restrictions in the NG supply are registered over the entire peak season and not only for few hours a day. The shorter is the average high season, the more competitive is the SNG for seasonal peak shaving, as compared to other solutions such as LNG or underground NG storage.

*Photo by TransTech Energy*




*Peak shaving facility in the Midwestern USA. Photo courtesy of Algas-SDI*

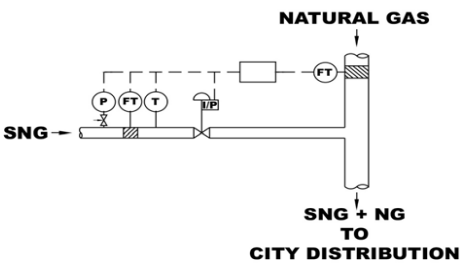




LPG-air peak shaving systems operate as follows:
LPG is delivered to a peaking site via pipeline, truck or railcar and stored in LPG tanks. Very large storage capacities may involve refrigerated tanks or underground caverns.
Liquid propane is withdrawn from storage and the pressure raised via motor-driven pump. Optionally, NG may be used to 'pressure pad' storage tanks. Liquid LPG is heated in a vaporizer and converted to super-heated vapour.

LPG vapour is mixed or "blended" with air, producing a "LPG-air" mix. The mix is injected into the natural-gas distribution system. The volume of LPG-air is normally limited to less than about 50% of the combined natural gas / LPG-air stream, keeping the specific gravity of the combined stream at less than 1.00 (Air = 1.00).

**SNG for peak shaving** is typically injected into the natural- gas grid to replace up to about 25 to 40% of the total gas flow. The "right" mixture quality (BTU/Ft$^3$) for a peak shaving site involves several factors, including the composition of the natural-gas and LPG streams and the interchangeability criteria to be met.




*Peak shaving using ratio control*

When peak shaving, there are two common control methods:

- Ratio Control or
- Pressure Control.

**Benefits**

- Peak shaving systems have lower capital investment, ease of fuel storage, lower maintenance costs and running savings dealing with NG supply restrictions in peak hours, due to upper limits in the contracted demand, mainly due to better pricing envelopes of NG contracts.
- Peak shaving systems support natural gas utilities minimize the impact of unpredictable consumption as well as other unexpected supply constraints by augmenting natural gas fuel with SNG, during times of high demand, or high pressure drops in old and under dimensioned gas pipelines.
- When called for, peak shaving facilities blend SNG and then inject it directly into the natural gas distribution system to augment natural gas volumes received from LDC suppliers. Peak shaving facilities are activated as needed to mitigate times of peak demand and avoid overrun penalty fees.
- Peak shaving plant equipment requirements are virtually identical to stand-by plant equipment, but with the addition of a controller which is used to restrict natural gas consumption to a pre-set maximum amount. Once the maximum (or peak) is reached, the system will automatically begin feeding SNG into the natural gas stream to augment NG volume and temper demand peaks.

**Design and Construction**

The design and construction activities associated with an **SNG peak shaving 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 vaporizer)
  - Liquid LPG vaporization 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 Natural Gas Grid completed
- Site security and landscaping
- Commissioning/Training/Handover to Client

**Construction Times/Costs**

The amount of time required to design and construct a **peak shaving facility** depends on the complexity and size of the system. Four to eight months are reasonable construction estimates. These estimates include the design, manufacturing, field erection and commissioning activities.

The cost of an SNG System also vary dramatically largely depending on system capacity and sophistication. As LPG storage requirements increase — costs increase significantly. Estimates from $400,000 to $7+ million USD are reasonable. Storage capacities, soil conditions and amount of field piping have the most direct impact on costs.

Small systems, with capacities of 10 million BTU per hour (approximately 10,000 cft per hour) start at under $ 10,000 (plus tanks and installation). Larger systems can cost in excess of $ 250,000, when combined with large tank capacities, or when site conditions require complex installations.

Savings largely depend on the rate-differential between "firm" rates and "interruptible" rates. Typically, the difference is 30% or more. If average monthly energy bill for natural gas is $ 6,000, then $ 6,000 x 30% savings x 12 months = $ 21,600 per year is expected. Based on these assumptions, a system for this size load would amortize in well under one year. Thereafter, savings would be approximately $ 1,800 per month. The running cost of SNG depends on the cost of LPG, which fluctuates throughout the year. Most customers compensate for this through buying their LPG during the summer months, when prices are usually lower than in winter. Even after compensating for the fact that the heat content of 1 gallon of liquid propane is approximately 10% less than the heat content in 1 therm of NG, "production" cost of SNG gas is very close to, or sometimes even below, the cost of NG. This means that even extended periods of curtailment do not pose a problem.

Modular “plug and play” pre-packaged, wired and piped systems constructed inside ISO containers are common. These modules reduce construction and commissioning time and costs.

**LPG Storage System**

Sizing of the liquid LPG storage facility depends upon the demands on the process and the availability of LPG supply. An analysis of the projected use can define the minimum appropriate storage required.

**LPG Pumps**

LPG is delivered to the SNG mixing system at a pressure elevated above equilibrium pressure. Vapor pressure in the tank is dependent upon the “percent full” and ambient temperature of the LPG. As the LPG temperature drops and/or the storage tank level drops as with use, the vapour pressure in the tank will also drop. Hence, liquid pumps ensure sufficient LPG flow and pressure are available at the SNG mixing systems. LPG pumps are rotary pumps, generally either positive displacement or turbine type.

**Vaporisers**

Vaporisers convert liquid LPG to vapour by adding heat. For a utility application, the vaporizer is typically a gas-fired water-bath.


*Typical Large Waterbath Vaporizer (Photo of Aprogas, Peru)*

The vaporizers (see photo) use either an atmospheric or forced draft power burner system to heat a solution of ethylene-glycol and water. The ratio of water to ethylene-glycol for freeze protection is established based on local temperatures. The water bath indirectly heats the LPG via the LPG heat exchanger. Water bath capacities are available up to 15,000 gallon/h in one unit.

Ambient temperature vaporizers are now commonly available, using only the warmth of air movement and no fossil fuels such as electricity they are now seen as the eco-friendly way forward in vaporization.

**LPG-Air Blending**

The typical SNG blender provides discharge pressures from 15 – 70 psig but 100 to 250 PSIG are available. Modern blenders operate on molar (volumetric) relationships. The percentage of gaseous LPG and compressed air are then blended to maintain a specific SNG mixture. An optional Wobbe Index meter monitors the SNG gas quality and determines its interchangeability with the natural gas. The blender will use the Wobbe Index signal to adjust the mixing ratio to the desired gross WI value. Typical correlation is +/- 1.5% of set point. The Wobbe Index meter also alarms any High or Low Wobbe value that might be measured.

Modern SNG blenders monitor the following conditions. If one of these process characteristics is out of normal range, the blender will alarm and shutdown as necessary.

- Low LPG Supply Pressure
- Low LPG Supply Temperature
- Low Air Supply Pressure
- Flow Control System (Faults if the flow ratio of two gas streams is incorrect)
- Air Flow Control Valve — (Faults if the actual Air Control valve position differs by more than 2% of the required
- theoretical position)
- Low Wobbe Index
- High Wobbe Index

The SNG Blender has the capability of operating in two different modes of operation for peak shaving. It can operate in Ratio Mode, wherein a fixed ratio of the natural gas flow is displaced by SNG. Alternatively, the blender can operate in so called Pressure Mode, wherein all natural gas is displaced by SNG.

*Wobbe Index Meter for monitoring of SNG quality*

When in **Pressure Mode**, the Blender typically operates at 1" to 3" of water column pressure higher than the regulated natural gas. This configuration requires a check valve be installed in the Natural Gas piping up stream of the SNG injection point. When SNG is being injected at the slightly higher pressure, it will automatically close this check valve shutting off the Natural Gas supply. SNG now supplies all the gas into the pipeline. If the blender were to shutdown, the gas distribution system pressure will fall allowing the natural gas check valve to re-open and Natural Gas to flow back into the facility.

When in **Ratio Mode**, a Flow Control Valve is required on the discharge of the Blender. The blender will operate similar to the Pressure Mode as described above with the SNG discharge pressure 1" to 3" of water column higher than the regulated Natural Gas pressure at the point of injection. The SNG Flow Control Valve will control the SNG injection rate using a dedicated PID Process Controller that monitors the ratio of the corrected Natural Gas and SNG volumetric flows. The natural gas flow signal will be provided from a meter installed upstream of the SNG tie-in. The blender creates a corrected flow signal for controlling the SNG through normal programming. The Flow Control Valve controller will only allow a volumetric ratio up to 40% SNG to Natural Gas. This ensures that the overall specific gravity will remain below 1.00 (lighter than air), The control system also allows for the SNG volume to adjust as necessary, in a fixed ratio, as the Natural Gas Flow demand changes.

**Peak Shaver Controls**

Advances in controls technology allows peak shaving operations to be extremely flexible, user friendly and safe at affordable prices. Generally, a centralized control station is either a traditional relay based system or more commonly handled via a PLC utilizing either an Ethernet or Data Highway design. Either way, today's controls allow integration of the entire process — from the bulk storage tanks thru to the gas/air mixing and gas quality measurement and control functions. System design should focus on achieving a coherent operating strategy that ensures a safe, simple and reliable process.

**Case study**

**High Tech SNG replacing a huge consumption of NG in an integrated steel mill**

The challenge was to replace natural gas in a huge integrated steel mill. When Ultragaz got the first contact the whole equipment and facilities was already designed and built to natural gas as usual. It was necessary to design and build two different SNG facilities: one for temporary delivery just to the start-up of the coking plant and other for permanent delivery to the steel mill for at least 10 year. Both sites must operate producing different SNGs without any interruption even in case of major force. The overall investment reached 10 million US dollars and more than 30,000 tons of LPG were sold at the first year. Outstanding controls to assure the gas quality and fine tuning cascade operation as PLCs and calorimeters as well as automatic standby systems were developed tailor made for this enterprise. The invoicing of LPG has been done by Coriolis meters in real time.

**Benefits**

- High turndown ratio of SNG requiring automatic fine tuning cascade of LPG vaporizers, air compressors and dryers and several blenders.
- Guarantee of non-interruption of supply even in case of major force.
- Outstanding configuration for the blenders in order to run 24/7 without any interruption.

*Metering station for invoicing*

*Waterbath LPG vaporizers*

*Dry compressed air station, surge tank and flowtrain.*

*LPG-air blenders*

*PLCs and calorimeters*

### 3.3.4 SNG Commingling Systems

In operation, SNG injected into NG distribution system replaces an adjustable percentage of NG on a “full time” basis or ‘as required’. The process consists of injecting SNG in pipeline in order to mix with NG. Flow meter and chromatograph 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.

During periods of high NG demand the use of NG for industries is restricted due to demand outstrips supply. The Thermal Power Plants are also affected by the restrictions on NG supply and consequently must use liquids fuels. An alternative to this is the use of SNG injection as peaking in Gas Transport System. This is a more economical alternative to liquid fuels. The LPG for injection will be produced and stored during low demand and high supply period (summer). This has an advantage over traditional peak-shaving plants, since it is easier to store liquid propane (-43.6°F) than Liquid Natural Gas (-256°F).

This system provided a great opportunity for collaboration between NG and LPG in market development.

### 3.3.5 Specific Applications

#### 3.3.5.1 Power Generation

The systems shown below are two typical SNG/Propane -Air Systems.

The system on the **left** has the water bath vaporizer and the surge tank mounted on a common steel skid. The venturi mixers can be seen mounted between the surge tank and the vapour outlet header of the vaporizer.

The system on the **right** is a typical combination of a direct fired vaporizer with 2 venturi mixers, for a nominal capacity of 20 million BTU per hour. A system of this size would most likely be sufficient to supply a medium size factory with SNG as a direct replacement for natural gas. Both systems are skid-mounted, allowing for easy installation and maintenance.

The small footprint of the units allows installation almost anywhere. The venturi mixers can be equipped with air-intake silencers, so that even installations in residential areas are no problem. In fact, several hotels are using this type of standby system with great success and without any complaints from guests or neighbours. The LPG storage tanks can be installed at a remote location. Some customers prefer underground tanks for residential areas. However, all storage tank installations are currently exempt from Risk Management Plan requirements, if the stored LPG is used as “fuel”.

**SNG systems are implemented for power generation**






### 3.3.5.2 Other Applications

**Emergency and recovery backup activities**

LPG is an extremely efficiently distributed source of energy. As a reliable, portable energy, unlike grid-based energy services, LPG plays an important role in disaster relief efforts. When a tsunami or an earthquake happens, infrastructure could be damaged. Sometimes electricity supply is cut off and city life is suspended.
SNG systems could prove to be as a reliable and easily distributed recovery energy source.

- City NG companies can supply the SNG manufactured by a LPG and air mixture to customers who lost access to city gas by pipeline. They could maintain the portable gas manufacturing facilities using LPG as the disaster prevention equipment.
- Mobile LPG-Air systems can replace damaged natural gas networks in vital buildings such as hospitals and schools.
- Temporary Evacuee housing units could be secured by governments in areas that are mostly affected by natural disasters.

**Examples - SNG in practice**

**Nara Prefecture, March 20th 2016**

A newly built citizen centre purchased two LPG- Air systems. When the city office requested bids for construction, an architectural design firm won with a novel plan based on a concept of “disaster-resilience” ahead of everyone.

A PA-30 was included in the original plan to supply back-up gas to a small city gas cogenerating unit for power & heat as this facility will play a role as an evacuation centre at the time of disaster. Finally, 2 units of PA-30s adopted; one for 6 units of GHP, and another for cooking and hot water system.

**Shizuoka Prefecture 2016**

A fire station purchased a PA-8 during renovation. When a disaster occurs, they will establish a rescue headquarters and work in cooperation with the city government. At that time, their LPG -air will be operated to provide firefighters themselves with hot water, hot meal, and hot shower after their hard rescue work.

Following the Great East Japan Quake and Tsunami in 2011 it took 2 months for 90% of the city gas supply to be recovered. After only 17 days following the disaster ITO had been responsible for 7,000 households in Kamaishi city.

## 3.4 Main Players

The companies listed in the table below are global players and the most active 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, temporarily replace, or limit their primary natural gas consumption. These companies carry out projects for Government, Utility and Manufacturing or Industrial applications (Appendix 2).

| | |
|---|---|
| Algas-SDI | **Algas-SDI** designs and manufactures a wide variety of LPG Vaporizers, LPG-Air mixers for replacing or increasing the supply of Natural Gas 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. |
| SCHARRTEC bringt Energie ins Leben | **Scharr Tec**: Gas technology: LPG plants, gas-air-blending plants, technical gases<br>PROLIMIX: the new generation of bio-methane mixer<br>LPG plants: From the initial permit through to inspection and final authorisation, all from one hand. From small tanks and contain. |
| 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. |
| ELGAS New Zealand | Elgas provides LPG and solutions for home, business and cars |
| Ely Energy Origins 1898 | **Ely Energy,** Inc. designs, manufactures, and markets equipment for air pollution abatement, supplementation, and replacement of natural gas in the United States and internationally. The company provides SNG systems for natural gas industrial back-up and curtailment applications. |
| KGE | **KGE** is growing into a global company, with strong endeavor 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. |
| MACS | **MACS** is a leading Organization in the business of Factory Automation, Industrial/Commercial LPG/SNG Systems, LPG Auto GAS Stations, LNG Gasification Systems, Heat Exchangers, Process Filtration equipment, Control cables & Explosion Proof LED Lighting Systems and enclosures. |
| TRANSTECH ENERGY | **TransTech Energy** is a leader in NGL & LPG storage and handling across all stages of oil and gas production, processing and distribution. |
| aetherdbs | Ae**ther DBS** delivers the best value to its clients by providing practical, engineered modular systems for energy, gas, and environmental infrastructure projects. |
| CAM | Since 1955, **CAM** has been designing, manufacturing, and installing gas mixing plants for industrial facilities and for gas distribution companies. |

## 3.5 Regulatory Framework

**Applicable Regulations and Standards**

For SNG systems, LPG regulations cover storage tanks and pipework whereas the work premises are covered by other regulations - mainly commercial premises such as offices, shops, hotels, schools, hospitals and similar places. LPG regulations also apply to gas fittings used for the purposes of SNG processes but, if part of the premises is used for domestic or residential purposes then they do follow regulations applicable to these parts.

In USA, construction, maintenance, and emergency planning involving LPG peak shaving systems are affected by the requirements of Federal, State, and local governmental agencies. The U.S. Federal regulations in 49 CFR 192 (Transportation of Natural Gas 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. The National Fire Protection Association publication NFPA 59 (Utility LP-Gas Plant Code) is commonly applied as a minimum standard for utility-owned plants. This standard addresses the materials of construction and installation and operation, with reference to other standards (NFPA 2012).

Insurers such as Factory Mutual and Industrial Risk Insurers also have specific requirements. Local code officials and fire departments need to be consulted prior to construction and trained in the safety features of any system. Some minimum distances required by the National Fire Protection Association are described in publication NFPA 58 (Liquefied Petroleum Gas Code).

In Germany, the German "DVGW-Regelwerk" contains a special code for gas-mixing-units: G 213, version 2013-10. The code includes the following elements: Scope of application, Code reference, Definitions, Componentry of gas mixing units, LPG plants, Test procedures, Operation and maintenance. The code is available in German language only.

## 3.6 Training

Training of personnel in new technologies, new equipment and particularly in areas where safety is of prime concern is key. This is the case when LPG is introduced as a SNG fuel in any equipment and operations. Adequate training is a prerequisite before any such equipment is put into service.

## 3.7 Safety

The development of any new technology and especially so if the new technology involves equipment, that use LPG as a fuel, requires uppermost attention and consideration of safety implications.


SNG can be entirely safe as long as the equipment is designed correctly with all safety aspects taken into account and the operation is equally carried out in the same manner. SNG systems require thorough assessment of all potential safety risks. LPG tanks, vaporisers, fuel lines, and other components must meet strict specifications.

When designing the system, the utmost importance is given to the construction and diversity of the safety fittings. System operators must understand the basic properties and associated hazards of LPG. It is important that the differences between NG and SNG, the properties of which are also linked to LPG properties, are well understood.

## 3.8 Quality of fuel

Modern equipment and advanced technologies come most often with increased requirements as far as the quality of the fuel is concerned. The same holds also for SNG and in particular even more so when this is used in industrial uses that need to provide continuous and reliable service.

Currently the quality of LPG can vary significantly from country to country. For example, in Germany (as also in other countries) propane and butane are sold separately, the quality is fixed in DIN 51622. LPG (mixed propane-butane) is sold only for special requirements.

As a consequence, to qualify and maintain LPG as a SNG fuel for today and for the future for residential and for industrial applications, it is becoming increasingly important to ensure a constant composition and quality of the fuel, together with improved controls in the distribution chain to maintain it free of impurities and contaminants.

The reasons for such a mandatory need are related to a few but important aspects:

- **Mixing quality:** The quality of the mixed gas is influenced by several factors. To ensure an exact mix the mixed gas is burned in a calorimeter and the energy delivered is calculated. This signal, as a regulated volume, is sent to the proportional regulator. Through this repeated messaging, any distortions in volume are thus eliminated. Deviations in LPG compositions and also deviations in temperature in air pressure and in the LPG, are thus balanced.
- **Wobbe index:** The further development of the market of SNG systems depends on accuracy of achievable Wobbe index, and this in turn depends on the availability of reliable, good quality fuel in the market.

## 3.9 Main stakeholders

The role of the various stakeholders is instrumental in driving growth of SNG in the market, helping products commercialise and raising customer and policymaker awareness.

Key stakeholders include:

- LPG distribution companies
- Utility companies
- Governments
- SNG systems manufacturers
- Independent SNG system integration service companies
- National and international LPG Associations
- Policy makers, regulators

## 3.10 Market Status

The successful role of SNG in coping with gas shortages, both in the USA and in the rest of the world is further validated by the large capacities of SNG systems existing today, some dating from the 1960's.

SNG has been used as a means of improving the calorific value of very lean LNG delivered into Japan and Korea. Utilization of this has happened over the last three decades.

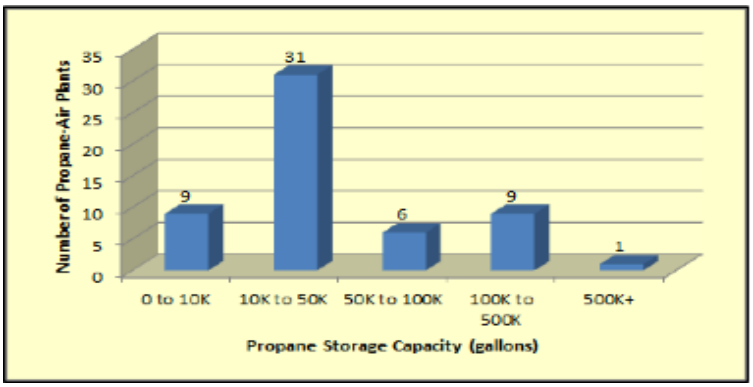
A few notable systems include:

| | |
|---|---|
| Center Pointe Energy/USA | (204 MMCFD) |
| Laclede Gas/USA | (132 MMCFD) |
| AGL Resources/USA | (40, 29 and 18 MMCFD) |
| Metrogas/Chile | (93 MMCFD) |
| BGE/USA | (91 MMCFD) |
| YPF/Argentina | (60 MMCFD) |
| Springfield Utilities/USA | (41 MMCFD) |

A total of 56 propane-air facilities in operation in the United States (Appendix 1). The majority of the propane-air facilities are located along the East Coast because of the relatively long distance from the Gulf Coast NG supply and relatively cold winters.

Figure below the breakdown of propane storage capacity for existing propane-air plants. The figure shows that the majority of U.S. propane-air plants have a maximum propane storage volume of 10,000 to 50,000 gallons.

**Breakdown of Total Propane Storage Capacity at Existing Propane-Air Plant**




- LPG will have an important role to play within the global Energy sector in the next 10 to 30 years.
- Global gas demand will grow by about 45 percent from 2015 to 2040, in all major sectors led by electricity generation.
- In some countries does not exist an established network of NG pipelines and the infrastructure is often reserved for areas of high population density, high industrial and business activity leaving some other areas with little or no access to NG. In such cases, there is a clear opportunity for LPG to provide a solution for SNG.
- In some countries, governments are increasingly considering the potential for using LPG as a 'bridging' fuel. In these cases, power plants using LPG are built with a longer-term plan to convert to NG once the pipeline infrastructure will be in place.

### 3.10.1 SNG in Different Regions

**Several SNG systems are already installed in Argentina, Brazil, Chile, Germany, Hungary, Indonesia, Italy, Japan, Pakistan, South Korea and USA and in countries of the world.**

The market for SNG is highly variable depending on the SNG technology and the region. SNG systems are mature and well-established in Argentina, Brazil, Chile, Japan, Mexico, Pakistan (Quetta and Gwadar), South Korea, USA and emerging very slowly in Europe. Furthermore, it is slated to be implemented in Mina City, Abu Dhabi and Oman.

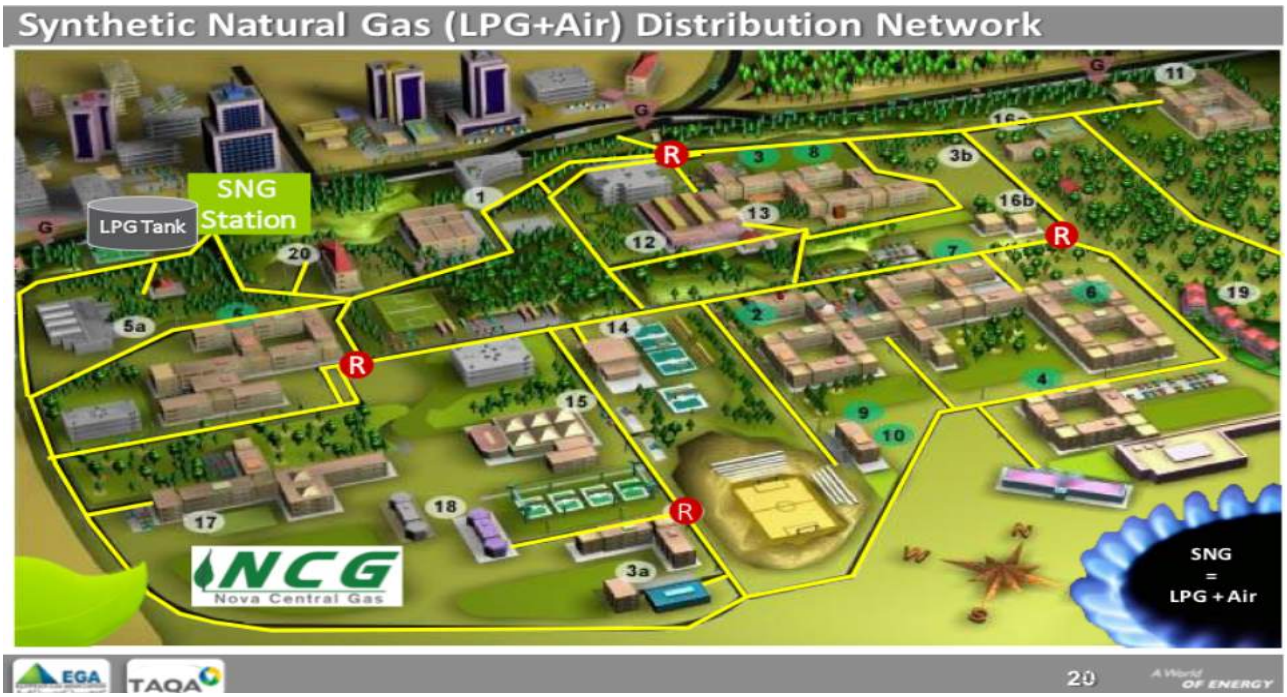
#### SNG systems Success stories

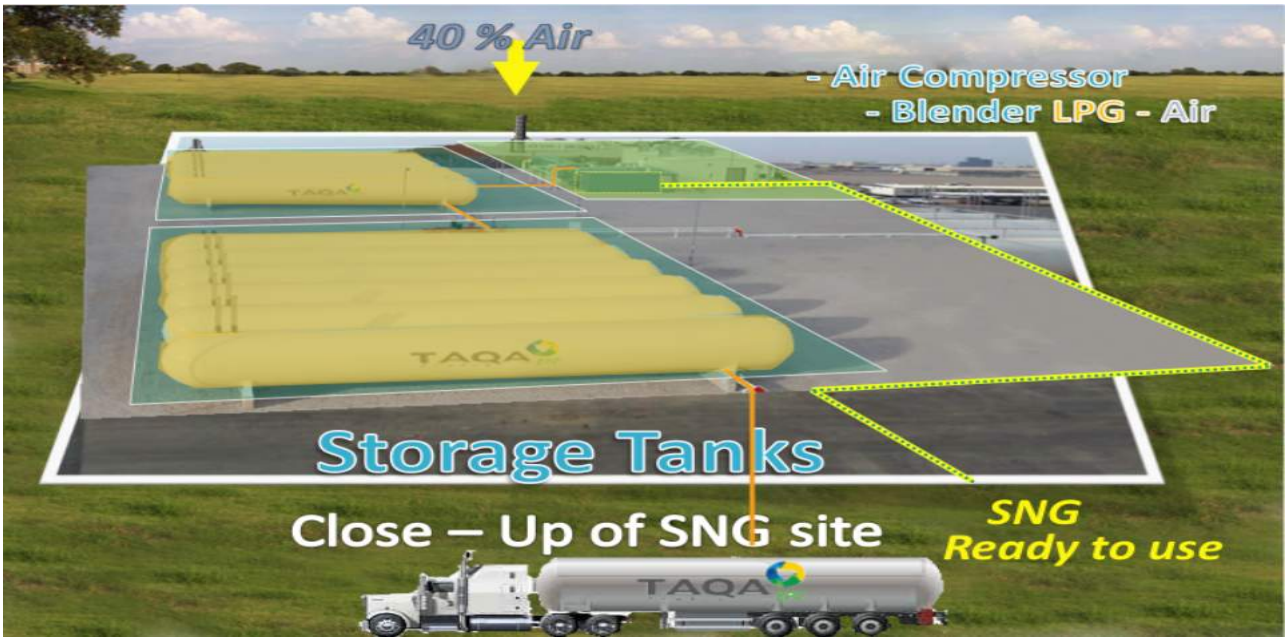
Field applications utilising SNG systems in different countries are described below.

#### 3.10.1.1 Africa

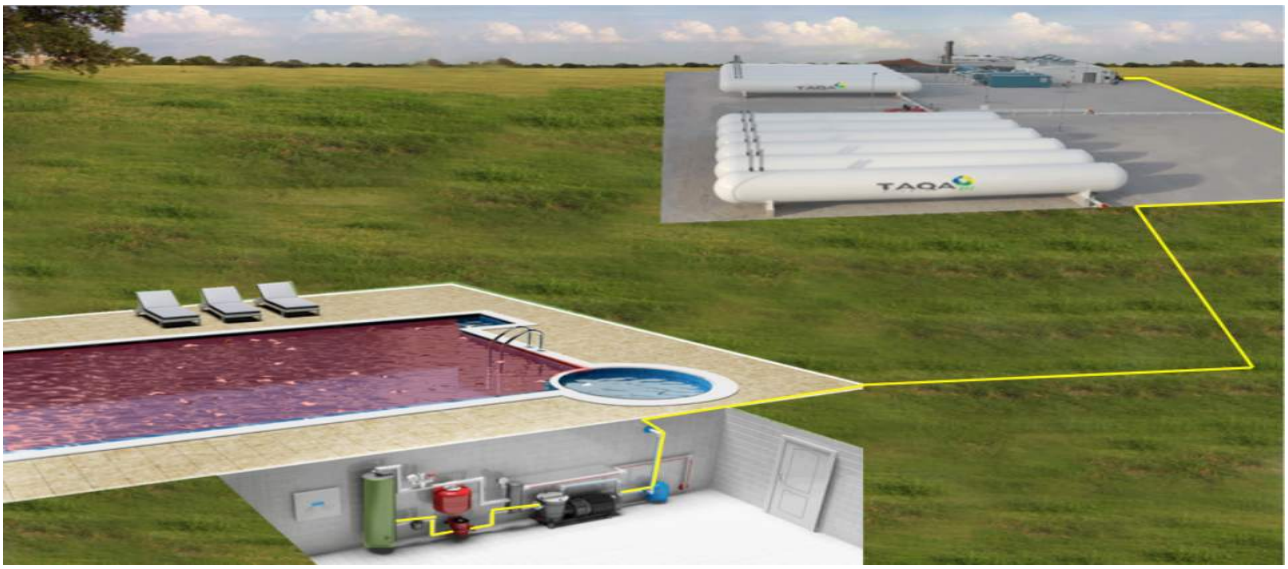
#### Egypt

TAQA Arabia is using SNG as a bridge fuel to precede NG.




40 % Air
- Air Compressor
- Blender LPG - Air
Storage Tanks
Close – Up of SNG site
SNG
Ready to use
TAQA


TAQA


TAQA

### 3.10.1.2 Asia

#### Indonesia

| | |
|---|---|
| **PT. Universal Indofood (Indonesia)** | • **Equipments for SNG 36mmbtu/hr supply system**<br>- LPG + Air Mixer(SNG Blender)<br>- Electric and water bath type LPG 500 & 200kg/hr Vaporizer<br>- Peak Shaving system<br>- Control panel having PLC and touch monitor<br>- Supervision and commission in Indonesia |

#### Japan

**SNG backup system for 5.000 houses**


**SNG system in Japan for a population of 8.700 people**

**SNG for a hospital in Japan**

#### Mongolia

| | |
|---|---|
| **Mongolia Company (Mongolia)** | • **LPG 2.0ton Package Tanks 2sets**<br>- LPG 2.0ton Tank<br>- Electric and water bath type LPG 50kg/hr Vaporizers 2sets<br>- Pressure regulator & Gas detector<br>- Valves, Piping, Local control panel |

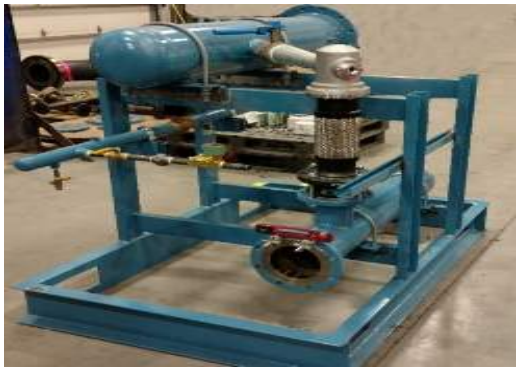
#### Pakistan

SNG technology has been successfully utilized worldwide for the past four decades. Pakistan has been a pioneer in this technology – through the provision of LPG Air Mix plants in Quetta, Larkana and more recently in Gwadar, Nushki, Mirpur Khas and Dalbandin.

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.

**MOD-AIRE™ SNG Blending Skid – Karachi, Pakistan**

Aether DBS provided a MOD-AIRE™ SNG Blending Skid for a project located in Karachi, Pakistan.



Project scope included Air Assist Mod-Jet™, SNG Surge Tank Trim, Air Surge Tank Trim.

**SNG system for a plant in Pakistan**

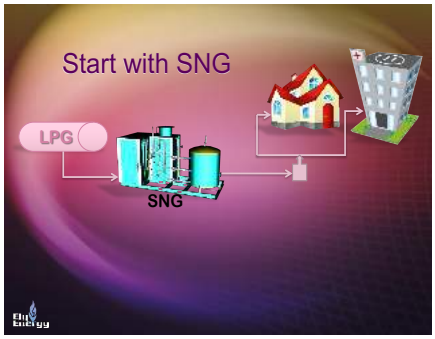
| | |
|---|---|
| ATLAS METALS (PRIVATE) LIMITED (Pakistan) | • **Equipments for SNG 36mmbtu/hr supply system**<br>- LPG + Air Mixer(SNG Blender)<br>- Gas burner and water bath type LPG 900kg/hr Vaporizer<br>- LPG Feed pump skid<br>- Auto Actuation system<br>- Control panel having PLC and touch monitor<br>- Supervision and commission in Pakistan |
| ATLAS BATTERY LIMITED (Pakistan) | • **Equipments for SNG 36mmbtu/hr supply system**<br>- LPG + Air Mixer(SNG Blender)<br>- Electric and water bath type LPG 900kg/hr Vaporizer<br>- LPG Feed pump skid<br>- Auto Actuation system<br>- Control panel having PLC and touch monitor<br>- Supervision and commission in Pakistan |

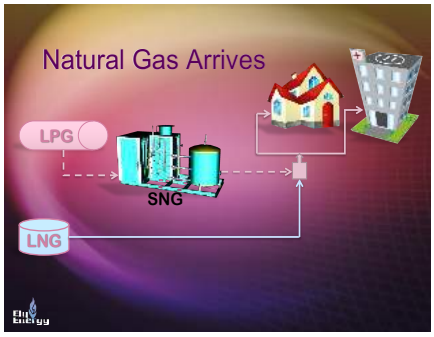
**Gwadar SNG Facility**

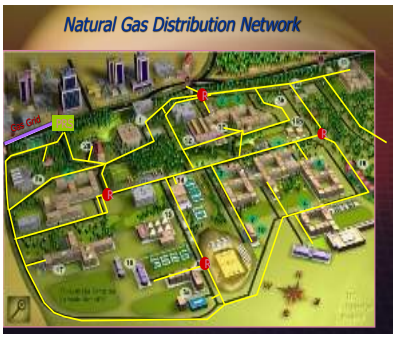
### South Korea

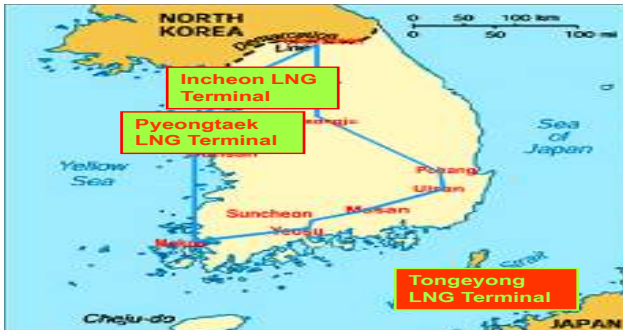
**CityGas Development – Development of NG pipeline using off-grid SNG - Pre- 1980's**

LPG Cylinder market with naptha gas in Seoul and Pusan





Korea changed from almost no piped gas to highly developed gas system in about 15 years.

### 3.10.1.3 Australia

Elgas manufactured an SNG plant, reticulating SNG through a pipeline network to customers in the town of Armidale. New South Wales has also a large onsite SNG plant for the University of New England in Armidale.

### 3.10.1.4 Europe

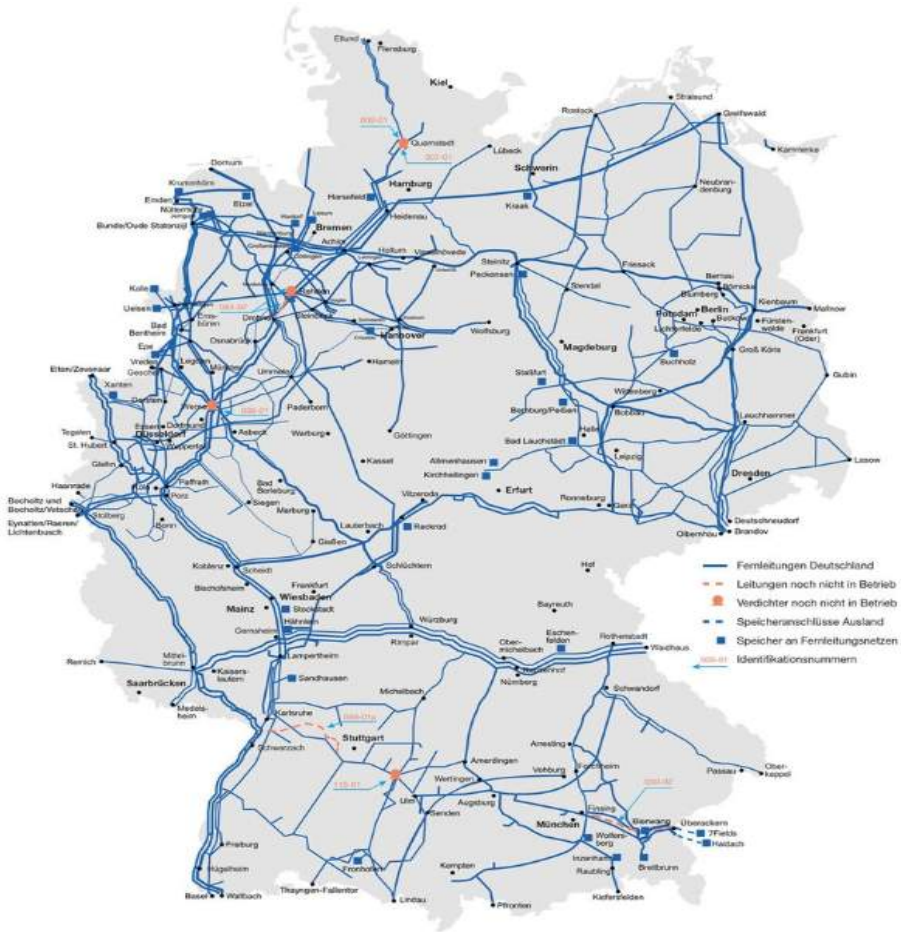
### Germany

SNG use is no longer that common in Germany. Since the German gas supply has been strictly separated (unbundling) into "network services" and "gas sales" the operation of SNG plants has no longer any benefit for the clients.

The NG grid is covering the most important cities and industrial areas. Therefore, NG is a very important energy source in Germany. The NG gas grid has a total length of 511.000 km.

Chart below is showing the main grid with high pressure distribution network.

Before the unbundling most public services and the bigger industrial gas users had an advantage when operating a SNG plant. During winter time the NG price increased and normally LPG was cheaper than NG. Also, peak shaving plants were rewarded with lower NG prices.




Because of the unbundling the public services can't bear the costs for the SNG plants any longer. The SNG plant is part of the network, but it is not required to run the NG network. The purpose of the SNG plant is only to reduce the gas price in times of high demand. Therefore, it's no longer allowed to add the operation costs of a SNG plant on the operation costs of the network.

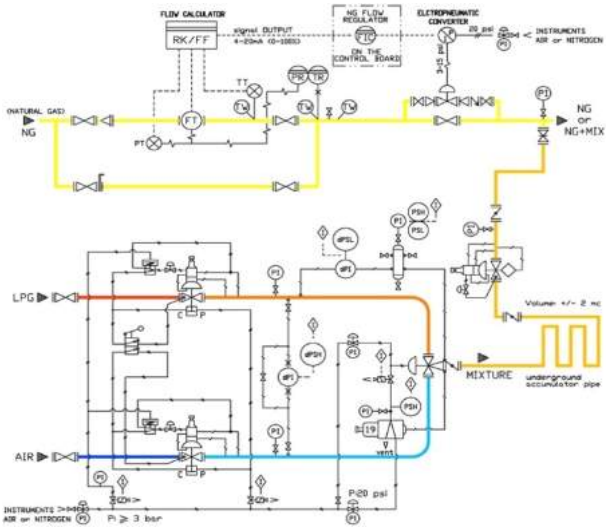
Most of the SNG plants are out of order for the last 10 years. The NG offer is nearly unlimited in Germany at the moment. The price is cheap and LPG has no advantage. Operating a peak shaving plant has no benefit for industrial clients at the moment.

## Hungary

### Peak Shaving NG Demand with LPG-Air for Suzuki


In its Hungarian factory, the car company Suzuki had to limit NG consumption in winter time, due to the constraints of their NG supply contract. Indeed, they had to meet their energy needs with an alternate source. Given the availability of LPG, they asked for the supply of a stand-by system capable to automatically curtail NG consumption (with a pre-set maximum value) and to face peak demand with a supplement of a LPG / air mixture interchangeable to NG.

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 Nm³/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/Nm³
- Mixture HHV: 14150 kcal/Nm³
- NG Max Capacity: 4500 Nm³/h
- NG Limited Capacity: 2500 Nm³/h
- NG Regulated Pressure: 1.6 bar
- NG HHV: 9080 kcal/Nm³
- NG Wobbe Index: 11995 kcal/Nm³

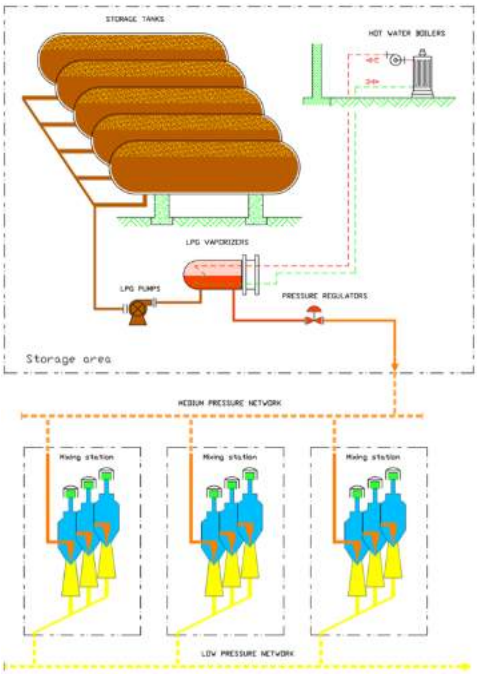
## Italy

**Civil Gas Distribution: Mixture of LPG and Air for the City of Cagliari**


Compact venture mixers (constant flow rate type) were used.
Simple functioning of the mixers (on-off) and high (overall) range ability made this system a proven solution for this distribution network creating the following characteristics (low pressure, big volume, highly variable gas consumption). Thanks to the gas interchangeability factor, the LPG-air plant produced a steady calorific value mixture that feeds directly into NG appliances.

Since 2000, Cagliari, Sardinia (Italy), distributes gas with an LPG / air mixing plant. In this case, CAM supplied all the components to produce an LPG-Air mixture interchangeable to NG, starting from liquid LPG upload to the mixture delivered to the network; namely, storage, vaporizing, pumping, pressure regulators, and mixing units. Due to the considerable amount of gas to be processed and the large extension of the city, the plant has been divided into several functional units.

A great storage area (nine 200 m³ tanks) with unloading compressors, pumps, hot water vaporizers and main pressure regulators, is located in a remote area and produces the LPG-Vapour that feeds the mixing stations.
Three mixing stations, complete with super heaters, second-stage regulators, and mixers, are placed inside the urban area and produce the LPG / air mixture for the end users. All the units have boilers which provide the hot water either for vaporizers or for super heaters. A medium pressure LPG-Vapour line, coming from the storage area, also feed the three mixing stations. The mixing stations are connected to each other by the low-pressure mixture network.
Storage area

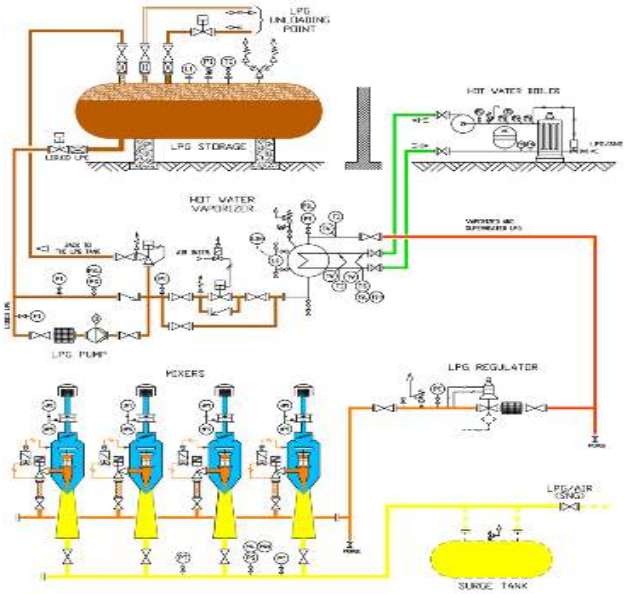



| | |
|---|---|
| LPG storage: | 9 tanks, 200 m³ each |
| LPG unloading compressors: | 2 units, 100 m³/h each |
| LPG pump: | 3 units, horizontal, multi-stage, centrifugal type |
| LPG pumps flow rate: | 24 m³/h each |
| LPG pumps head: | 4.0 bar |
| LPG vaporizers: | 3 units, horizontal shell BKU Type, hot water powered, 6000kg/h each |
| LPG pressure regulating line: | 2 units, max capacity 9000 Sm³/h each, outlet pressure 4 bar |
| Boilers: | 3 units, 800000 kcal/h each |
| Mixing stations | |
| LPG-Vapour super heater: | 1 unit, 3000 Sm³/h |
| Mixers: | 5 "Compact" Venturi |
| Mixture capacity range: | 0-6000 Sm³/h |
| Mixture Outlet Pressure: | 300 mbar |
| Mixture Average Composition: | 53% Air + 47% LPG |
| Mixture HHV: | 12000 kcal/Sm³ |

**Gas Distribution in Cold Alpine Winters: Mixture of LPG and Air for the Town of Bagolino**

More than one thousand end users in the small town of Bagolino were served. Despite the severe weather conditions of their winter, they never experienced lack of service.
As a matter of fact, it is always convenient to have gas with a steady calorific value that can be directly used with NG appliances. Furthermore, the low dew point (much lower than pure LPG) makes the mixture particularly suitable for distribution, especially in cold climates.
In this case, CAM supplied all the equipment to produce an LPG-Air mixture interchangeable to NG, starting from liquid LPG upload to the mixture delivered to the network; namely, storage, vaporizing, pumping, pressure regulators, and mixing units.


| | |
|---|---|
| Mixture Capacity Range: | 0-1000 $Nm^3/h$ |
| Mixture Outlet Pressure: | 40 mbar |
| Mixture Average Composition: | 53% LPG + 47% Air |
| Mixture HHV: | 12000 kcal/$Nm^3$ |
| Mixing Unit: | 4 "Compact" Venturi Mixers |
| 2 Pressure Regulators: | set point 2.5 bar: 550 $Nm^3/h$ |
| LPG Vaporizer, horizontal shell BKU Type, hot water powered: 1000 kg/h | |
| 2 LPG Pumping stations, horizontal, multi-stage, centrifugal type | |
| Pumps flow-rate: | 2100 litres/h each |
| Pumps head: | 2.5 bar |
| 2 LPG Storage Vessels: | 50 $m^3$ each |
| LPG Average Composition: | 50% Propane + 50% Butane |




## Portugal

**Use of the SNG (LPG-Air mixture) in Hotel in Oporto.**

Early in October of 2017, the Hotel Vila Galé Porto Ribeira, located in Oporto, Portugal was set to be inaugurated. However, the fact that the hotel was built in an historical part of the city led to a delay in the connection to the NG main due to some bureaucracy and archaeological procedures that needed to be performed. That delay could have compromised the inauguration of the hotel and tens of customer reservations would have been cancelled, causing loss in revenue and upsetting customers.

The ITO PA4 is a SNG Generator which mixes propane and air to produce a matched gas, matched to the local NG supply, using no electricity whatsoever. Totally portable, totally self-contained in a range of capacities from 4 m3/hr to 90 m3/hr.

The tests to the gas installation, water heating system and the first days of soft opening were possible due to the use of the system that was producing SNG from a 45kg cylinder of LPG. The PA4 worked for 17 hours and 30 minutes providing the Hotel it the “NG” needed to properly rehearse its installation and be ready to be inaugurated in time.

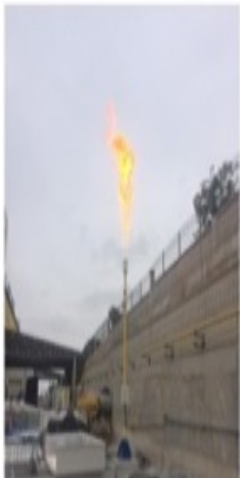


ΦITO

## Turkey

**SNG back up system for glass factory in Turkey**

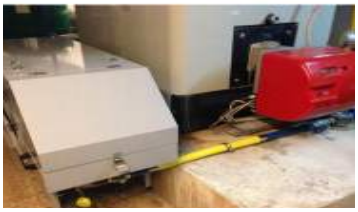
**SNG backup system for Ulker biscuit factories in Turkey**



From factories in Turkey to neighbourhoods abroad, LPG –air mix is used as a solution to NG challenges.

**SNG Application in Aygaz Headquarters**

- Heating system of Aygaz Headquarter building is equipped with 2 NG boilers
- SNG system from ITO, Japan is installed and connected to one of the boilers
- LPG is supplied by 4 x 45kg propane cylinders



### 3.10.1.5 Middle East

**Dubai Palm Jumeirah- Base load system to supply SNG until NG arrives**

*Photos by Lootah BCGas*

The project consists of designing, installing, owning and operating LPG gas pipeline distribution networks that were initially fed by central LPG tank farms. This included installation of SNG facilities to facilitate more efficient conversion to NG upon availability. Scope of work includes all installation from the inlet of the tank farm to the customer appliance (commercial & residential). The pipeline network is constructed of PE piping and includes all valves, regulators, and metering necessary for operating a safe system.

Also, included in scope are safe and reliable operations and maintenance services for a Concession period of 30 years. This project will consist of an estimated 55,000 meters of gas mains and gas service for over 2,500 residential & 9,000 flats, more than 47 Hotels and many other commercial customers.
LPG Consumption: 1400 tons/month

**Discovery Garden Group - Dubai**
The project consisted of designing, installing, owning and operating LPG gas pipeline distribution networks that were initially fed by central LPG tank farms. This included installation of SNG facilities to facilitate more efficient conversion to NG upon availability.

*Jebel Ali Village by Lootah BCGas*

Scope of work includes all installation from the inlet of the tank farm to the customer appliance (commercial & residential). The pipeline network was constructed of PE piping and includes all valves, regulators, and metering necessary for operating a safe system. Also, included in scope are safe and reliable operations and maintenance services for a Concession period of 30 years. This project consisted of an estimated 120,000 meters of gas mains, six 50 ton below ground LPG Tanks and SNG System convertible to NG, including two SNG Tank Farms, which serve over 75,000 customers.

**Jumeirah Village South- Dubai**

In Dubai, Palm Jumeirah is using a base load system to supply SNG until NG arrives. LPG consumption is 1,400 tons a month. The project consisted of designing, installing, owning and operating LPG gas pipeline distribution networks that were initially fed by central LPG tank farms. This included installation of Synthetic NG (SNG) facilities to facilitate more efficient conversion to NG upon availability. Scope of work includes all installation from the inlet of the tank farm to the customer appliance (commercial & residential). The pipeline network was constructed of PE piping and includes all valves, regulators, and metering necessary for operating a safe system. Also, included in scope are safe and reliable operations and maintenance services for a Concession period of 30 years. This project consisted of an estimated 56,000 meters of gas mains, 9 to 18 - 75 ton below ground LPG Tanks and SNG System convertible to NG, which serve over 99,000 residential units, 6,700 hotel rooms, 780 Retail and commercial outlets.

**International City – Dubai**

The project consisted of designing, installing, owning and operating LPG gas pipeline distribution networks that are initially fed by central LPG tank farms. This included installation of SNG facilities to facilitate more efficient conversion to NG upon availability. Scope of work included all installation from the inlet of the tank farm to the customer appliance (commercial & residential). The pipeline network was constructed of PE piping and includes all valves, regulators, and metering necessary for operating a safe system. Also, included in scope are safe and reliable operations and maintenance services for a Concession period of 30 years. This project consisted of an estimated 56,000 meters of gas mains, 9 to 12 - 50 ton below ground LPG Tanks and SNG System convertible to NG, which serve over 95,000 residential units and various commercial customers.

*Photo by Lootah BCGas*

### 3.10.1.6 North America

**USA**

Pinnacle Propane is applying an interchangeability of LPG air and NG to two cases in Mississippi in which customers are losing their NG service due to a 90-year old steel gas line being decommissioned. A new line was put in a different location, leaving various customers unable to be connected to the new line.

One customer was a state prison, Wilkinson County Correctional Facility.

The NG company was responsible for the switch and was required to pay the costs to get users back up and address their thermal needs. Pinnacle provided an LPG-air mix system, including the LPG storage (30,000 gallon tank), vaporizer, air mixer.

**SNG system for a town in USA**

**SNG system for an industrial plant in USA**

**SNG system for a research centre**

**SNG system for NG back-up in residential areas**

**SNG back up system for ceramic factory**

**SNG for a glass factory in USA**

**Gas Utility Peak Shaving System, Missouri**

In 2007, a utility company in Springfield, Missouri wanted to add a peak shaving system.


*Photo by Ely Energy*

Aether DBS designed, manufactured, installed, and commission a system to deliver 1,700 MMBTU/H of SNG at 150 PSIG.

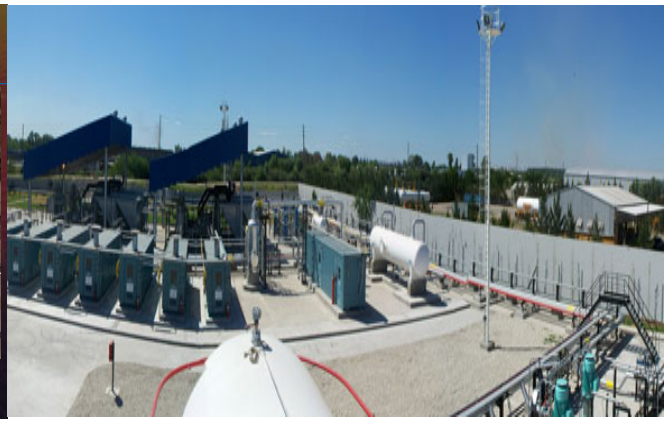
| | |
|---|---|
| Capacity: | 1,700 MMBTU/H |
| Injection Pressure: | 150 PSIG (10 Bar) |
| User Base: | 75,000 Residential, 8,000 Industrial |
| Vaporizers: | 2 X WB13,750H |
| Blenders: | 1 X AFC A7 |
| Storage: | 12 X 60K Gallon |
| Application: | Peak Shaving |

### 3.10.1.7 South America

#### Argentina

**Municipal SNG Solution**

While NG is relatively expensive, artificial price controls set by local governments can often cause unintended consequences. To keep prices affordable for the domestic market, governments often set price caps on NG for domestic consumption. As a result, investments in new gas field exploration taper off just as demand is rising.

In Argentina, which historically had been a large exporter of NG, the increasing consumer demand coupled with a decrease of gas field exploration led to a shortfall of NG. To meet the demands of the users, an SNG Utili-Pak system was designed and commissioned by Aether DBS in 2008. Implemented in Buenos Aires, the system has 1.9 million combined residential and industrial users.

| | |
|---|---|
| Capacity : | 2,500 MMBTU/H |
| Injection Pressure: | 330 PSIG (22 Bar) |
| User Base: | 1.9 Million Combined Residential and Industrial Users |
| Vaporizers; | 9 X WB 3000H |
| Blenders; | 1 Utili-PAK with 1X AFC A8 |
| Storage ; | 1 X 30K Gallon tank with LPG pipeline |
| Application; | Peak Shaving |

**Peak shaving facility owned by Camuzzigas, located near Bariloche**

*SNG Peak Shaving System, Bariloche, Argentina (Photo courtesy of Camuzzigas, Argentina)*

**AFC Gas Blenders for SA Steel Mill – South America**

*Photo by Aether DBS*

A key SA Steel Mill was having gas supply challenges. Aether DBS designed, engineered, manufactured, and shipped five (5) fully-assembled and tested AFC Gas Blenders for fuel gas blending at a confidential South American Steel Mill. Systems included gas blenders, Wobbe index meters, PLC controls, and full integration of gas blenders into existing installation and fuel gas piping.

### Brazil

Since 1995, the use of NG has been increasing significantly in the Brazilian energy mix. The acceptance of the NG by the consumers has been expanding due to its large availability, which reduces the 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 gas-fired power plants in the total power capacity increased from 4% to 7%. The gas demand for power generation grew substantially faster than the demand for other uses (Brazil's Energy and Mines Ministry, 2008). However, NG-fired power stations production fluctuates depending on the annual rains and the water availability in the hydropower system. As a consequence, the gas availability for other uses also swings from long moments of excess supply to short periods of scarcity. Moreover, the government imposes that power and residential sectors have priority in receiving NG in case of any temporary shortage. This contributes to the perception of risk of lack of continuity in attending the demand for gas by industrial users. Such situation amalgamates industrial gas consumers as well as the entire gas industry to find alternative solutions for a more reliable gas supply. As a consequence, temporary solutions to cope with eventual NG shortages and/or interruptions have been addressed and carried out by some LDCs and industrial consumers. Proposed strategies target low investments and small changes in consumers' burner systems to be easily reversible in the future.

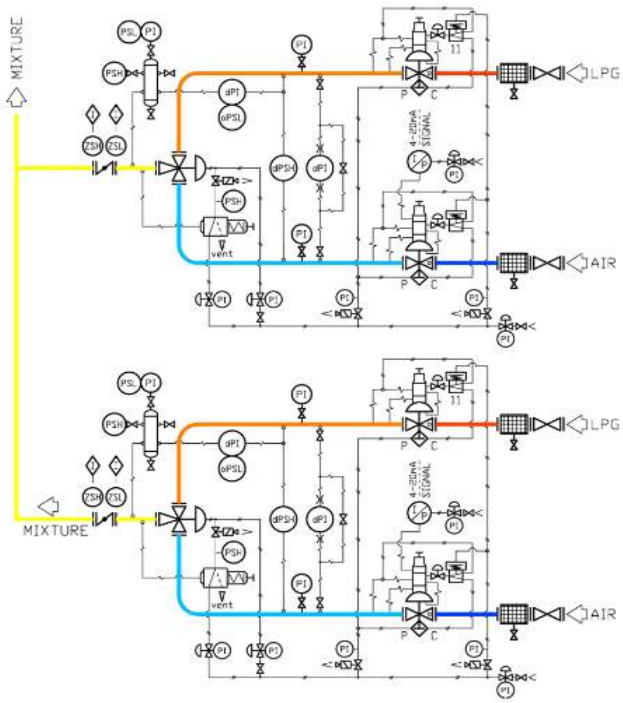
**The use of SNG to replace NG has been suggested as the most suitable solution.** The replacement of NG by SNG through the use of adequate technical procedures was adopted in Brazil and proved to be a flexible solution to industrial applications overall. Reducing the number of industrial users to be converted to SNG was also considered to be the best strategy to avoid the technical difficulties. Applications have been used as SNG backup systems, which are installed primarily in industrial sites with high temperature processes such as glass works, steel mills, foundries, and ceramic industry. For those customers, the perception of NG supply insecurity was already high enough to justify the introduction of SNG. The practical experiences pursued in Brazil offer applicable concepts for many other countries, particularly in emerging gas markets dealing with similar risks of NG supply instabilities. This experience revealed the weaknesses of just taking the Wobbe Index method as the only criterion to guarantee the exchangeability between NG and SNG. The adequate replacement of NG by SNG (and vice versa) depends upon the introduction of additional technical procedures, including changes in the combustion control systems.

**A Redundant Solution: Mixture of LPG and Air for Alumar's Industrial Plant**

In 2011, Liquigas Distribuidora S.A., manufactured an LPG-Air mixing system for ALCOA Company. Due to energy savings and environmental impact, LPG-air mixture had to replace diesel oil, the fuel used in the anodes baking furnaces in Alumar's facility, the largest refinery of alumina in Brazil. The LPG-air plant has been designed as a "fully redundant system," since, at present, the mixture is the only fuel available.


For this installation Alumar received an award for environmental management in 2012. This fully redundant installation has been achieved firstly by using two "VMG" mixing units in parallel, each one sized for the maximum consumption. This way, one unit is always available as full backup. Secondly, in regards to the control system, a redundant PLC configuration (certified back-up system) manages the automatic swap of the units in case of fault. Besides, a dual AC / DC Power Supply, with backup battery, prevents the halt of the units in case of power fault or loss of energy. Furthermore, so as to meet the furnace requirements, 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.

| | |
|---|---|
| Mixture Capacity Range: | 0 - 3200 $Nm^3/h$ each unit |
| Mixture Outlet Pressure: | 4.0 bar |
| Mixture Average Composition: | 57% LPG + 43% Air |
| Mixture Wobbe Index: | 11800 $kcal/Nm^3$ |
| Mixture HHV: | 13300 $kcal/Nm^3$ |




**High technology SNG replacing a huge consumption of NG in an integrated steel mill.**

SNG replaced NG in a huge integrated steel mill. When Ultragaz got the first contact the whole equipment and facilities was already designed and built to NG as usual. Due to the NG shortage, the unique solution was to delivery SNG). Until

now the use of SNG in Brazil was just as backup systems in the case of NG shortage or failure which rarely occurs. But in this case the SNG facilities must guarantee the gas delivery continuously to the steel mill without any interruption even in case of major force.

It was necessary to design and build two different SNG facilities:
One for temporary delivery just to the start-up of the coking plant and other for permanent delivery to the steel mill, which will operate continuously for at least ten years.
It was necessary to design and build two different SNG facilities: one for temporary delivery just to the start up of the coking plant and other for the permanent delivery to the steel mill.

Both sites must operate producing different SNGs without any interruption even in case of major force. Outstanding controls to assure the gas quality and fine tuning cascade operation as PLCs and calorimeters as well as automatic standby systems were developed tailor made for this enterprise. The invoicing of LPG has been done by Coriolis meters in real time. The challenge was to replace NG in this huge integrated steel named Cia. Siderúrgica do Pecém (CSP), a joint venture of the Koreans Dongkuk Steel and Posco with the Brazilian Vale, which will produce 3,000,000 metric tons of steel per year. When Ultragaz got the first contact the whole equipment and facilities was already designed and built to use NG as usual. During this period, all maintenance must be done without any interruption of the gas flow. While the gas delivered to the steel mill must comply with NG characteristics, it means the same Wobbe Index (WI), the coking plant needed a SNG more compatible with coke-oven gas due to the regenerative burning phase (WI lower than NG).
Another challenge was the invoicing of the LPG as in order to be in accordance with the NG. Instead of charging the customer by the weight when unloading the stationary tanks, the option was to invoice just the liquid LPG flowing to

the consumption by Coriolis gas meters in real time. Once again, the wide turn-down ratio has required meters to handle different flows with automatic change over, besides backup systems. In order to guarantee the absence of gas bubbles at the meters, a pumping system was installed between the storage tank and metering station. After metering, the LPG pressure is then reduced to feed the water bath vaporizers (one group for operation and another group for backup).
The high turn-down ratio of both gas sites made also necessary the installation of LPG-air blenders of different capacities in each site besides outstanding controls to assure the gas quality and fine tuning cascade operation as PLCs and calorimeters as well as tailor made automatic standby systems. The same way, it was necessary to install a reliable system for the dry compressed air to feed the blenders. As the original design of the steel mill took into account the use of NG, no fire- fighting system was available, requiring the construction of 2 big water reservoirs, pumping system and accessories for each site.

Temporary site for the coking plant - main features:

- LPG maximum flow rate: 9,005 kg LPG/hr.
- Dry compressed air maximum flow rate: 7,900 Nm3/hr.
- LPG storage: 4 gas trailers performing as stationery tanks, totalizing 100 tons of LPG
- SNG lower Wobbe index: 32,6 MJ/Nm
- Water reservoir: 500 m3
- Permanent site for the steel mill – main features:
- LPG maximum flow rate: 8,645 kg LPG/hr
- Dry compressed air maximum flow rate: 3,230 Nm3/hr
- LPG storage: 6 stationery tanks, totalizing 324 ton of LPG
- SNG lower Wobbe index: 49,4 MJ/Nm3
- Water reservoir: 1,000 m3

The overall investment reached 10 million US dollars and more than 30,000 tons of LPG were sold at the first year. It's an outstanding LPG application, considering technical complexity, innovation and LPG sales in a single customer.

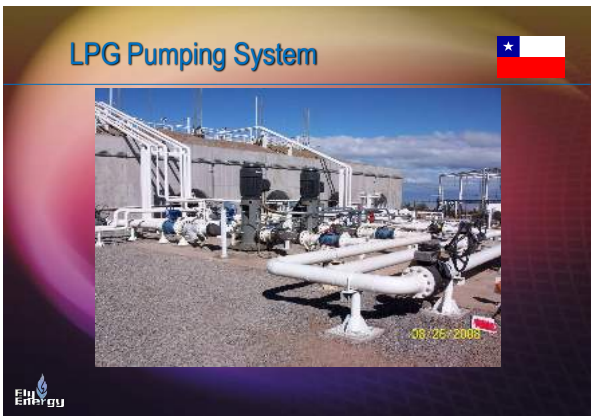
## Chile

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. Aether DBS designed and supplied two large-scale facilities 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, the Aether DBS systems in Santiago provide 3,900 million BTU/h of NG equivalent.

**Example**






## Uruguay

SNG base-load system solutions was pursued in Uruguay, with a LDC called Conecta, which operated with SNG before the Country started importing NG from Argentina. Less frequently, the SNG base-load system is conceived to operate in longer terms serving consumers located where the NG grid is not expected to reach.

## Chapter Four

# Roadmap

### 4.1 Market Outlook on Technology

The market outlook looks forward up to a maximum of five years.
LPG will have an important role to play in the Energy Mix in the next 10 to 30 years. As the trend towards clean fuels continues throughout many parts of the world the role of gaseous fuels as a lower carbon has never been more important.

The International Energy Agency (IEA) anticipates a 50% growth in the demand for NG in the period 2016 to 2040 – with much of this growth associated with electricity generation.

If pipeline network exists in close proximity to the demand, NG is the gaseous fuel of choice mainly for industrial uses. However, many countries do not have an established network of NG pipelines. In such cases, there is a clear opportunity for SNG systems with LPG could provide 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 and governments cannot afford NG to fuel new-build power plants. Therefore, 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 built with a plan to convert to NG when infrastructure will be in place.

Air mixing systems are essentially a mature technology, with general consensus regarding design concepts amongst manufacturers. Therefore, there are unlikely to be significant conceptual developments.

Incremental Improvements for components and systems are likely to happen, including new types of valves which will lead to some efficiency improvements. Cost reductions should come as competition heats up.

## 4.2 Market Trends: Inherent Characteristics of Strong Market of SNG with LPG

The 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. If a region has all of these characteristics, the potential is strong for SNG systems with LPG. Each global region is assessed based on these inherent characteristics listed in the table below.

| Market Characteristic | Ingredients for success |
|---|---|
| **Limited NG penetration or non-existent of NG infrastructure** | Countries with limited access or no access to NG supply grids which have plans to develop NG infrastructure in the future are of high interest. |
| **Local Production of LPG and infrastructure** | Countries with abundant of LPG supply or domestic production are potential opportunities. These countries can control the cost of LPG and are not exposed to risks such as price fluctuations, transportation costs or shortages of supply etc. Also, these have better infrastructure in place such as distribution network and this make LPG competitive to be used even in smaller quantities. make Price variability and seasonal volatility demand the ability to strategically manage shortages of supply as well as pricing issues. |
| **Expected growth in industrial activity which creates energy demand** | Significant use of NG by both residential and commercial sector create growth of SNG systems. Economic growth strongly influences world energy consumption. As countries develop industry and business activity increase, energy demand tends to grow rapidly. Power plants operating with NG are often the preferred choice, but where the pipelines are not yet in place, LPG is well placed to act as a 'bridging' solution until the necessary infrastructure is in place. Also, countries that have rapidly growing energy demands and require solution to avoid black-outs. |
| **Fuel prices** | In off-gas grid areas, diesel is often the primary fuel for power generation. With LPG, often significantly cheaper than diesel, there is a strong opportunity for using LPG as an alternative fuel source in these areas. LPG can be used to mitigate the risks associated with fluctuating oil prices. SNG systems are a good alternative where the electricity grid is unreliable, and therefore grid-independence is a strong consumer driver. Further, even if the grid is reliable, SNG systems can still be an attractive way to avoid the costs and the hassle associated with grid connection. |
| **Policy/ regulatory framework** | There is growing political and public pressure to reduce global carbon emissions from the energy sector. In addition to greenhouse gas (GHG) emissions, targets are gradually being considered for criteria pollutants such as NOx, SOx, particulate matter, etc. LPG has lower emissions profiles when compared with NG, LNG, and diesel. Countries which are seeking to lower their carbon emissions may consider LPG as an alternative fuel, especially when used as bridging fuel until NG grids are in place. |
| **National Energy Goals** | Some countries have introduced an emissions trading scheme, which is designed to encourage coal-to-gas switching over the long term as the price of carbon increases. Some governments may reduce subsidies for diesel to encourage switching to gas, including LPG. |

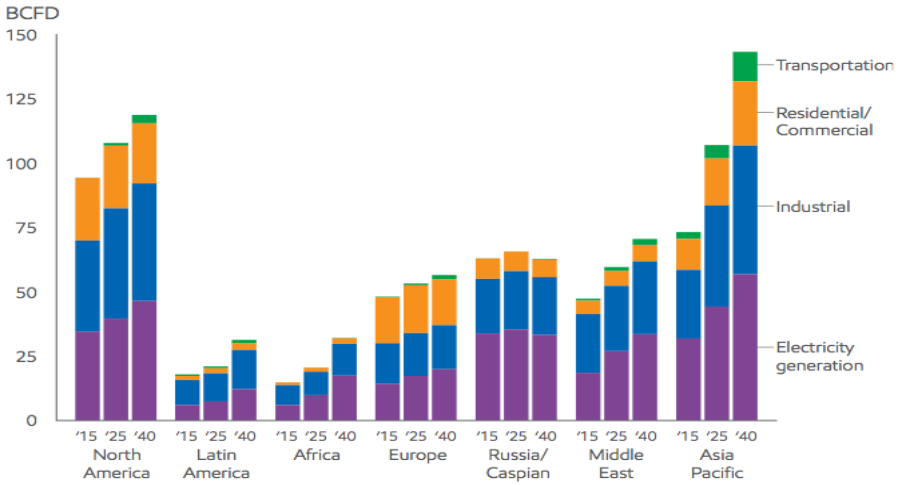
## 4.3 Market Potential: Target Regions for SNG

### 4.3.1 Target Regions

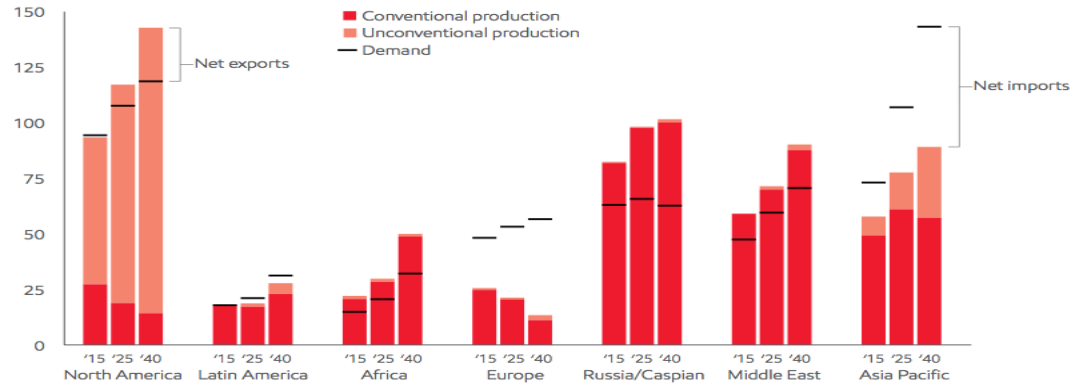
Areas looking for abundant availability of low-cost, more environmentally friendly NG, an interim strategy gaining favour is the use of SNG, until NG infrastructure can be built.

**NG** – projections
Regional gas demand highlights growth & end-use versatility
Global gas demand grows by about 45 percent from 2015 to 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 percent of global growth.




**NG** – projections
Gas supply highlights regional diversity.




According to P&GJ's 2017 Worldwide Pipeline Construction survey figures indicate 83,802 miles of pipelines are planned and under construction worldwide. Of these, 38,390 include projects in the engineering and design phase and 45,412 in various stages of construction.
Planned Pipeline Miles: North America 16,535; South/Central America and Caribbean 2,859; Africa 2,268; Asia Pacific 9,753; Former Soviet Union and Eastern Europe 2,006; Middle East 4,794; and Western Europe and European Union 175.

Mileage Under Construction: North America 15,279; South/Central America and Caribbean 1,821; Africa 1,716; Asia Pacific 10,085; Former Soviet Union and Eastern Europe 10,700; Middle East 4,423; and Western Europe and European Union 1,388.

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

**Africa**

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

Sub-Saharan Africa is in dire need of greater power generation capacity to provide energy to the 600 MM people on the continent who have no access to electricity. The region's proven NG reserves of more than 496 Tcf could be a major driver for countries in the region to achieve energy security.

Across sub-Saharan Africa, increasing demand for sustainable sources of energy is driven mainly by a growing middle class population, urbanization, increased household consumption and other infrastructure projects that are directly linked to power generation, transmission and distribution.

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 $6 billion natural gas pipeline in Mozambique. The $12 billion Trans Saharan Gas Pipeline is a 4,401 kilometres NG project to be constructed from Nigeria, starting from Warri, Delta State, to Algeria via Niger Republic, and from Algeria to Spain. The outlook for SNG systems is of great potentiality.

**Asia**

World energy consumption is expected to increase by 48% over the next three decades, led by strong increases in the developing world – especially in Asia, according to the International Energy Outlook 2016 released by the U.S. Energy Information Administration (EIA). Developing Asia accounts for over half of the projected increase in global energy use through 2040.

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. Work is targeted for completion by late 2018. 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 and NG projects by 2025, according to Global Data. The UK is expected to account for 25 while nine will be located in Norway and two in Denmark.

**North America**

North America accounts for 31,814 miles of new and planned pipelines but several major projects have been delayed causing problems in the industrial sector. One bright spot for potential market growth in North America may be Mexico.

Experts predict a 75% increase in demand for NG over the next 15 years as Mexico's economy continues growing and the country switches to natural gas-fired power generation. Major pipeline construction project delays are also being seen in Canada. These include TransCanada's Energy East project and Enbridge Energy's $7.9 billion Northern Gateway project. The prospects for SNG are positive.

**Middle East**

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

**South America**

In 2014, only four countries – 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 the beginning of 2014, Argentina has drilled over 275 shale gas and tight oil wells and led shale resource development outside North America in the first half of 2015 with the potential to significantly increase production. Colombia and Mexico are also beginning to explore and produce hydrocarbons from shale and other tight resources, but are short of reaching commercial production. For the moment, there is a limited NG pipeline construction therefore 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.

**This figure provides analysis of market potential for SNG using LPG in each region based on inherent market characteristics.**

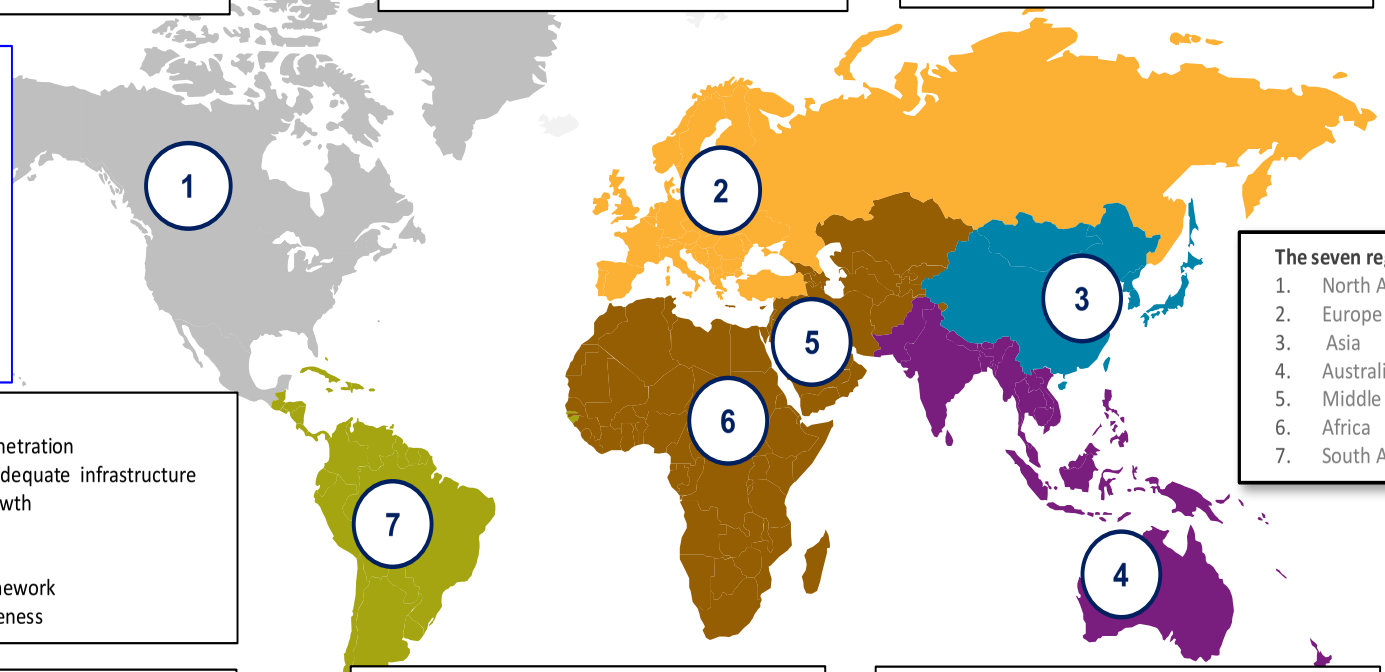
**1. North America**
- Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
+ National Energy goals
+ Energy Prices
- Policy/ regulatory framework
+ Alternative fuels awareness

**2. Europe**
- Limited natural gas penetration
- Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
- Energy Prices
+ Policy/ regulatory framework
+ Alternative fuels awareness

**3. Asia**
+ Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
- Energy Prices
+ Policy/ regulatory framework
+ Alternative fuels awareness

**Attractiveness based on these factors: High to Low**

Africa
Asia
South America
North America
Middle East
Europe
Australia




**The seven regions:**
1. North America
2. Europe
3. Asia
4. Australia
5. Middle East
6. Africa
7. South America

**7. South America**
+ Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
- Energy Prices
+ Policy/ regulatory framework
- Alternative fuels awareness

**6. Africa**
+ Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
+ Energy Prices
+ Policy/ regulatory framework
- Alternative fuels awareness

**5. Middle East**
+ Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
- Energy Prices
- Policy/ regulatory framework
- Alternative fuels awareness

**4. Australia**
- Limited natural gas penetration
+ Availability of LPG & Adequate infrastructure
+ Business/Industry Growth
- National Energy goals
- Energy Prices
- Policy/ regulatory framework
- Alternative fuels awareness

### 4.3.2 Market Potential for SNG systems by 2020

There is no size limitation for these systems but generally speaking it is not economically feasible for loads less than 1-2 million Btu/hr.

This table 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. The African Renaissance Gas Pipeline (ARGP) is the biggest planned gas project on the continent and is set to link Mozambique's 180 of reserves with consumers at home and in South Africa. |
| **Asia Pacific** | Asia is expected to become the largest energy-consuming region in the world. Countries that have limited NG infrastructure and having as strategy to replace high emitting fuel such as coal are of high priority.<br>As such are China, Japan, Vietnam, Thailand and Myanmar and Indonesia.<br><br>China uses SNG as precursor fuel for new built cities and still has vast areas with no access to NG.<br>In Japan SNG systems can be used on a concept of "disaster-resilience".<br><br>India is of high priority as the share of NG in the energy mix of India is expected to increase to 20% in 2025 as compared to 11% in 2010. However, given that all the plans for expansion in NG supply in the country with the help of additional RLNG terminals, nationwide transmission pipeline network and transnational pipelines are expected to materialize by 2025, it is envisaged that the share of NG in the primary energy mix would reach 20% till 2030 if not more. |
| **Europe** | Not many systems in place. It is expected very slow growth. |
| **Middle East** | Huge residential and commercial complexes could SNG until NG arrives. Dubai and Qatar are good examples. |
| **North America** | Remains strong market. There is a swift to cleaner fuels. A lot of systems manufacturers could create demand. |
| **South America** | Remains steady market.<br>Argentina is facing constrained NG supplies during times of peak demand and there could be an opportunity. |

## 4.4 Barriers to Growth

Inherent market characteristics have been mentioned above which will make some regions more attractive to SNG systems with LPG. Beyond these inherent market characteristics (which are difficult to influence), there are several specific barriers/challenges which vary significantly by region, and which will determine the size of the market opportunity. Key issues below are highlighted below, and in the following Recommendations chapter, it will be analysed how the barriers can be overcome:

### 4.3.1. Awareness/Perception: SNG systems Need to be Considered by Policy-Makers, Customers, Installers, Utilities and the Industry

Raising awareness of the existence of SNG, their possible applications and their market potential, is the first major challenge for SNG. The use of SNG in Japan, Middle East is relatively well-known, but is not on the radar elsewhere, so there is a role for LPG companies to promote this concept.

### 4.3.2. Customer Economics: Upfront Cost the Greatest Challenge

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

### 4.3.3. Policy/Regulatory Framework

Support for LPG technologies in policy is general 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 industry unless now tackled effectively. The support of LPG in the regulatory framework is critical for all types of systems where economics is considered important. Receiving subsidy and tariff support as renewables will support the uptake of implementation in different applications.

### 4.3.4. Technology Development: Slow Rate Will Limit Growth

As LPG – Air is still a niche market today, there is a perceived lack of opportunity associated with designing, manufacturing and marketing products fuelled by LPG. The emergence of a wide range of applications is ultimately the key to a larger market share. A significant part of the market potential for SNG is currently based on the expected technology developments which will widen their applicability. If this does not happen as expected (i.e. if there is not sufficient investment in R&D, the market potential will be more limited.

### 4.3.5. Commercialisation and Getting Products to Market: Trained Installers, Servicing/Maintenance Networks and Sales Channels are Required

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 network is a critical issue for all types of all applications entering new regional markets. The strongest markets are USA, Asia.

Chapter Five

# Recommendations

## 5.1 Key Actors with a Role to play

In the Roadmap section above, there are have been identified five critical barriers to market uptake for SNG systems with LPG. Recommendations are presented on how each of these barriers can be overcome, and which type of market actors have a role to play.

**All relevant players need to work together in a coordinated way to maximise the market opportunities for SNG.**

The summary table below indicates the varying roles of each type of player in overcoming the barriers to market growth. Each barrier is explained in detail in the text after the table. It is differentiated between "Lead Role" (the actor is critical in overcoming the barrier), and "Support Role" (the actor can support but is not the critical element in overcoming the barrier).
Key: xx = Lead Role; X = Support Role.

| Barrier | Market Actor | | | |
|---|---|---|---|---|
| | Industry Associations | Utilities/LPG Companies | Manufacturers | Government |
| Awareness/perception | xx | x | x | xx |
| 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 |

## 5.2 Engagement of stakeholders

The engagement of utilities, manufacturers, industry associations and other players, can be instrumental in driving growth in the market, helping products commercialise and raising consumer and policy-maker awareness. It is worth to be noted that the engagement of the utilities sector and governments is of particular importance in large SNG applications.

The SNG market has tended to develop more quickly where utilities have shown a strong interest for such systems.

When increasing consumer demand coupled with a decrease of gas field exploration led to a shortfall of NG. To meet the demands of the users, SNG system could be implemented. As such, in Buenos Aires an SNG system has been developed for 1.9 million combined residential and industrial users.

Coordinated engagement of the stakeholders is important to work towards the key objectives:

- Working on new innovative applications.
- LPG companies must work with specific market segment, local communities to identify and develop equipment, practices, and infrastructure needed to use LPG fuel safely, economically, and reliably.
- Systems manufacturers must have a cost advantage and be timely in development. A general challenge for the LPG industry is meeting cost and time requirements of users as they continuously seek to drive costs down and improve productivity. By meeting this challenge, the LPG industry can create a robust, growing market in the SNG systems sector.
- Cultivate retailer, end-user, and government awareness of LPG as an exceptional energy source. The LPG industry must work vigorously to create and maintain a high level of awareness regarding LPG's unique benefits among propane retailers, consumers, and lawmakers.
- SNG systems developers should view NG market as attractive source of revenue and should educate them to see LPG as an exceptional fuel that they can use cleanly and cost effectively in nearly every application.
- Lawmakers must understand LPG's advantages, particularly its superior environmental performance, to ensure proper consideration in environmental regulations.

## 5.3 Awareness/Perception: SNG Need to be Considered by 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. The goal could be to reach a specified market penetration for SNG - interim measures could be to identify the national markets and market sectors with most potential, identify the technology adaptations or developments which will support application in these markets, and identify the policy interventions required to facilitate this. ROLE FOR ASSOCIATIONS to communicate this vision to other players.
- **Marketing/awareness-raising activities** involving for example 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 MARKET ACTORS - ASSOCIATIONS could 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 which SNG are making to carbon saving targets etc., to be targeted at governments. ROLE FOR ASSOCIATIONS

## 5.4 Customer Economics: Upfront Cost the Greatest Challenge

- **Offering financing packages** via energy services companies, utilities or other players, which could shift the upfront investment & risk away from the end-user - this approach could create significant market growth. ROLE FOR UTILITIES
- **Providing incentives** will bring down either the upfront cost or running costs (depending on the structure of the incentive - a grant or a tariff. ROLE FOR GOVERNMENT
- **Considering** mechanisms to reduce the risk of future LPG price volatility, and thus improving the confidence of end-consumers of the fuel. ROLE FOR GOVERNMENT
- **Lobbying to ensure that SNG systems receive a fair incentive rate** to be on a level playing field with other competing technologies will ensure that SNG systems are considered as an option. ROLE FOR INDUSTRY ASSOCIATIONS
- **Technology development** will create cost-reduction potential, and improve the system efficiencies, with running cost benefits. ROLE FOR MANUFACTURERS

## 5.5 Policy/Regulatory Framework: SNG Needs to be on a Level Playing Field with Competing Technologies

- **Lobbying** to ensure that SNG systems are included in regulatory framework and incentive schemes. Primary ROLE FOR ASSOCIATIONS and potentially a role for other actors such as UTILITIES to make policy-makers aware of the potential for SNG, and ensure the treatment of the technology is fair.

## 5.6 Technology Development: Slow Rate Will Limit Growth

- **Investment** to support and accelerate the development of SNG technology and maximise its potential market applications. This could include, for example, (i) investment in testing new system combinations to widen the operating parameters; or (ii) investment in development and testing of new SNG versions at larger or smaller scales. These sorts of developments are necessary to grow the potential market applications for SNG, but all require investment and a long-term vision of what the market requires. Primary ROLE FOR MANUFACTURERS but also potential role for other supporting actors such as LPG UTILITIES (e.g. to ensure LPG versions of the technology are made available). There could be a ROLE FOR POLICY-MAKERS in, for example, making R&D funding available for R&D to 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. ROLE FOR MANUFACTURERS (to lead development) AND ASSOCIATIONS (to gather market information).

## 5.7 Commercialisation & Getting Products to Market: Trained Installers, Servicing, Maintenance Networks and Sales Channels are Required

- **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, identify required competencies for LPG installation), MANUFACTURERS (developing product-specific training), ASSOCIATIONS (potentially developing/running training schemes)
- **Support with developing partnerships in new regions** for distribution and sales of LPG SNG systems. ROLE FOR REGIONAL 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 LPG SNG to their product portfolios. ROLE FOR MANUFACTURERS AND 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 & the sales technique to be adapted to best engage the target market sectors. ROLE FOR ASSOCIATIONS and MANUFACTURERS to educate distributors, installers and other customer-facing actors.

# Appendices

## Appendix 1

**LPG- Air Facilities in USA by State**

| Plant State | No. Facilities |
|---|---|
| Alabama | 1 |
| Connecticut | 4 |
| Illinois | 3 |
| Indiana | 2 |
| Iowa | 2 |
| Kentucky | 1 |
| Maryland | 3 |
| Massachusetts | 9 |
| Minnesota | 4 |
| Missouri | 1 |
| Nebraska | 1 |
| New Hampshire | 1 |
| New Jersey | 4 |
| New York | 2 |
| North Dakota | 1 |
| Ohio | 3 |
| Pennsylvania | 4 |
| Rhode Island | 1 |
| South Carolina | 2 |
| Virginia | 7 |
| **TOTAL** | **56** |

## Appendix 2

**Cases by CAM S.r.l. around the world**

| END USER | CLIENT | LOCATION | MIXING UNIT | MAX CAPACITY [NM³/H] | GROSS HEATING VALUE [KCAL/NM³] | REGULATED PRESSURE [MBAR] |
|---|---|---|---|---|---|---|
| Alumar - ALCOA | Liquigas | Brazil | VMG Unit - LPG/Air | 3200 | 12000 | 4000 |
| Volkswagen | Fas | Russia | Venturi Unit - LPG/Air | 640 | 13000 | 200 |
| Trakya Glass | ACS | Bulgaria | VMG Unit - LPG/Air | 9800 | 12000 | 1000 |
| LOI Poland | JP | Poland | Venturi Unit -/LPG Air | 7500 | 5000 | 50 |
| Radisson Hotels | Saitech | Croatia | Venturi Unit - LPG/Air | 1500 | 12000 | 500 |
| Kroman Celik | Danieli | Turkey | VMG Unit - LPG/Air | 4500 | 13000 | 1000 |
| Marinha Grande | Agner Service | Portugal | VMG Unit - LPG/Air | 2700 | 13500 | 1200 |
| By-Gas | JP | Denmark | Venturi Unit - LPG/Air | 105 | 13000 | 100 |
| City of Nuoro | CPL | Italy | Venturi Unit - LPG/Air | 5000 | 12000 | 350 |
| Powerchip | EGB | Taiwan | VMG Unit - LPG/Air | 800 | 14000 | 3000 |
| City of Sassari | Hera | Italy | Venturi Unit - LPG/Air | 3000 | 12000 | 300 |
| Honda | Acs | Turkey | Venturi Unit - LPG/Air | 240 | 13000 | 260 |
| Pearl Inv. | Pearl Inv. | Egypt | VMG Unit - LPG/Air | 1100 | 12000 | 1800 |
| Lorestan Glass | Lorestan Glass | Iran | VMG Unit - LPG/Air | 2100 | 14000 | 1000 |
| Lucchini | Lucchini | Italy | Venturi Unit - NGGas/Air | 4500 | 6125 | 550 |
| City of Oristano | Cpl | Italy | Venturi Unit - LPG/Air | 3500 | 12000 | 400 |
| Hyundai | Acs | Turkey | VMG Unit - LPG/Air | 5300 | 14000 | 1000 |
| City of Cagliari | Cpl | Italy | Venturi Unit - LPG/Air | 6000 | 12000 | 300 |
| City of Bagolino | Eni | Italy | Venturi Unit - LPG/Air | 1000 | 12000 | 40 |
| Renault | Acs | Turkey | VMG Unit - LPG/Air | 2400 | 14000 | 1000 |
| Citroen | Gas Iberica | Spain | VMG Unit - LPG/Air | 2000 | 13500 | 2500 |
| Flexipack | JP | Germany | Venturi Unit - LPG/Air | 600 | 12600 | 100 |

## 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 |

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