Figure 2. Two Cryobox® trailers at a remote well site in the Mendoza province coupled to a third trailer on which gas pre-treating equipment is installed to prepare the gas for liquefaction (courtesy of Galileo technologies).

HAS BOUTIQUE LNG GONE MAINSTREAM?

John Sheffield and Kindra Snow-McGregor, Petroskills|John M Campbell, present a worldwide overview of the small scale LNG industry.

More than 70 years ago, at the birth of the LNG industry, everything was small scale. However, once it became possible to export gas, liquefied at -160°C, in specially modified ships, the LNG business as a means of transporting gas was born, and the scale of the plant facilities dramatically increased as operators strived to drive-down costs. In 2017, the international trade in LNG amounts to more than 290 million tpy, which represents some 36% of all internationally 'traded' gas, clearly a significant proportion. More than 28 countries now import LNG, and a fleet of more than 450 ships ensure the reliability and security of this means of delivering gas at a price competitive with alternative fuels for power generation and many other applications.

However, in addition to this commodity market, there is a growing small scale LNG business which has some clearly different characteristics. This business could be termed the 'boutique LNG business' a very apt description, since the Oxford English dictionary defines 'boutique' as 'a business or establishment that is small and sophisticated or fashionable'. This is precisely what has been quietly developing over the past 20 years. From small beginnings, typically peak-shaving facilities, built to balance supply and demand on pipeline networks, small scale local distribution by trucks from and to remote facilities, and growing demand as a transportation fuel, this sector of the gas market now amounts to more than 50 million tpy and growing apace.

This is a specialised business, that is beginning to utilise a wide range of innovative technologies to grow and provide much needed clean energy to communities which have been deprived of access to clean, low cost power sources, and to provide fuel for sea and land transport which eliminates the emissions of particulate contamination.

There are several sectors in the small scale LNG business, including:

- Monetising stranded gas.
- Virtual pipelines.
- Distributed small scale power generation.
- Fuel for marine transport.

- Fuel for road and rail transport.
- Fuel for heavy machinery.

This two-part article will outline the key characteristics of the development of the small scale LNG business and the many new business opportunities that can be developed.

Virtual pipelines

Stranded gas implies a source of gas which is remote from potential users. The gas may be flared gas, a by-product of oil production, or a small reserve but in either case, too small to justify the installation of a pipeline to bring the gas to a consumer. In such a case, liquefying the gas at source and transporting it to consumers by road tankers is a developed and economic option. The first commercial 'export' plant in Australia at Alice Springs was commissioned in April 1989, and produced 30 tpd, some of which was transported 450 km to the 15MW Yulara power station, built in the shadow of Ayres Rock, by road tankers.

Transporting LNG by triple road tankers (Figure 1) has become a well-established practice in Australia. The EDL plant at Karratha produces 200 tpd and supplies LNG to five power stations in the Kimberly region with transport distances of up to 1500 km. The tanker barrels were designed and supplied by CEM International Pty Ltd in Australia, have a capacity of about 55 m^3 and are vacuum insulated, such that LNG can be stored in these tanks for several weeks, even in the heat of the northern part of Western Australia (WA). It was the Plant Manager of this facility who coined the term, the 'boutique LNG business', to distinguish it from the multi-million ton North West Shelf project some 20 km away.

At the southern end of the Dampier-Bunbury pipeline, KleenHeat developed a small scale LNG business to supply fuel for heavy truck and remote power stations. Unlike the power generation business, providing fuel for heavy trucks is more of a chicken and egg situation, since the engines need to be modified, so the population of users grows slowly. To develop the market, KleenHeat started to produce LNG by direct contact with liquid nitrogen, an inefficient process, but one which enabled a viable market to be established in a couple of years, prior to the commissioning of a liquefaction plant at Kwinana which now produces 175 tpd of LNG used by local transportation fleets in Perth and also transported by road into the eastern mining areas of WA for power generation and fuel for the heavy machinery.

Figure 1. Triple LNG road tanker train (courtesy of EDL Ltd).

The LNG plant operated by KleenHeat in WA used single mixed refrigerant (SMR) technology developed by Linde, which was also the technology used for the Shanshan LNG plant, Xinjiang province in the far north west of China. This plant was commissioned in 2004 and the LNG produced from this 400 000 tpy plant was trucked up to 4000 km across China to remote satellite LNG stations for fuelling trucks and power generation. In addition to the Shanshan facility more than 10 other remote LNG liquefaction plants based on Black & Veatch, Linde and Chinese technology were built. These plants and associated truck fleets and satellite stations represent a virtual pipeline network for distributing gas across China.

The Chinese have now developed 10 LNG import facilities around the coast allowing them to import LNG in bulk from Australia and other sources, and now import as much as 25.4 million tpy of LNG. Nearly 50% of this LNG is subsequently distributed using road tankers to inland satellite LNG stations for power generation and the refuelling of heavy trucks. It is estimated that there are more than 20 000 LNG fuelled road tankers in China.

Another example of the virtual pipeline concept has been developed by Galileo in Argentina, on a much smaller scale, with a 10 000 usg/day (about 17 tpd or 5700 tpy) liquefaction unit, Cryobox®, which is mounted onto a flatbed trailer and can be moved directly to the source of gas. Figure 2 shows two Cryobox® trailers at a remote well site in the Mendoza province coupled to a third trailer on which gas pre-treating equipment is installed to prepare the gas for liquefaction.

The LNG is then transported by road tanker to Anchoris City where a 40MW thermal power station using gas engines supplied by Wartsilla has been built to supply power to the local community. Several units are located at different well sites to ensure a continuous supply of fuel to the power station. Once the well is depleted the units can be moved to another location.

These concepts can be scaled to meet the local power demand:

- LNG production scaled from 10 – 100 tpd, single or multiple sites. Liquefaction technology could be SMR, nitrogen or expansion cycle. At the smaller scale the N2 and expansion cycle units could be unmanned as has been demonstrated at Snurrevarden in Norway.
- LNG transport by road tanker or road trains allows transport over long distances and transportation capacity is both scalable and flexible.
- Power stations based on gas engine technology are more efficient than open cycle gas turbines and the modular approach facilitates load matching. Above about 60 MW capacity and with suitable load patterns, CCGT power generation can be considered.

Fuel for marine operations

The Galileo Cryobox® technology also formed the basis of providing fuel for the Buquebus ferry *Francisco* which carries 1000 people across the river Plate at speeds up to 58 knots. LNG fuel is produced by liquefying natural gas from a pipeline using several Cryobox® units each producing about 7 tpd of LNG which is taken by truck to the dock-side to refuel the ship each day.

Figure 3. *Engie Zeebrugge* refuelling a car transporter (courtesy Port of Zeebrugge).

The use of LNG as a fuel for marine transportation has been pioneered in Norway where local ferries and offshore rig supply vessels have been converted or built to use LNG as a fuel. There are now five small scale LNG facilities in Norway, mostly on the coast and LNG is loaded either directly to the ships fuel tanks (Risavika), into trucks, or into small LNG carriers including the Pioneer Knutsen, a 1500 m^3 LNG carrier, for distribution to local communities.

Around the world many project developers are looking at the use of small LNG carriers to distribute LNG to power hungry communities with small ports and minimal infrastructure. IM Skagen, a small gas carrier operator, is working to develop several projects in Africa, and particularly West Africa, where there is a great need for gas. Offshore Cameroon a small scale FLNG vessel is being tested and should produce about 1.2 million tpy, a concept which could be deployed in other locations if successful.

The demand growth of LNG as a marine fuel has been driven by the establishment of marine Emission Control Areas (ECA), where the level of particulate emissions and SO_x is strictly controlled. In the Baltic and northern European waters, and the US east and west coasts, ECAs are already established, and very soon the Mediterranean Sea will be controlled. Shipping companies are evaluating their options and there are now about 120 ships operating using LNG as fuel with more than 100 on order.

The types of ships which are considered candidates for using LNG as a fuel include:

- Tugs and supply boats which operate from a base and can be easily refuelled each day from tanker trucks.
- Container and cruise ships which call at ports within ECAs. These ships require more fuel, as much as 500 – 1000 t of LNG, making refuelling from tanker trucks virtually impossible resulting in the development of LNG bunker ships.

Recently, Galp Energia now supplies LNG from their Sines terminal on mainland Portugal, in 40 ft containers, to Funchal on the island of Madeira, where some of the LNG is now used to refuel the cruise ship *Aidaprima*, and some for a new gas fired power station.

There are now three LNG new-build bunker ships operating and several on order. These ships are essentially small LNG carriers built to be very manoeuvrable and equipped with an LNG transfer system using flexible cryogenic hoses and rigid articulated arms.

- The *Engie Zeebrugge* (5100 m^3) (Figure 3) operates out of the Port of Zeebrugge.
- The *Cardissa* (6500 m^3) was developed by Shell and now operates out of Rotterdam.
- The *Coralius* (5800 m^3) is operated by Skangas in the Baltic area.

There are other ships under construction and the ability to quickly refuel large ships is becoming well established in the key European ports. These small LNG bunker ships can also operate as small LNG carriers.

All of this activity in the exploitation of the use of LNG as a fuel is bringing many new players into the market and there are clearly concerns about the level of safety that needs to be maintained. In the marine fuels sector, several established and new organisations (SIGTTO, SGMF, and SEA/LNG) will strive to ensure the adoption of safe and consistent practices.

The future will bring new opportunities

The business is well supplied with competent equipment and systems builders who can ensure that there is proven technology available for:

- Small scale liquefaction processes.
- LNG storage in vacuum insulated tanks from 10 – 1000 m^3.
- LNG transport in road tankers, containers, and small LNG carriers.
- LNG transfer systems using flexible hoses and hard arms with safe couplings.
- Engine technology for ships, heavy trucks, exploration, and construction.
- Modular power generation units.
- Vehicle refuelling technology.

There are three business segments in the small scale LNG business which some expect to grow to around 100 million tpy by 2030:

- LNG for small scale power units (25 – 35% of the total demand).
- Marine fuel (30 – 40%).
- Road transport fuel (30 – 40%).

These segments are connected by virtual pipelines of small ships, road tankers, and containers giving a very flexible capability to supply energy where it is needed in an economically viable and safe manner. The potential for growth is great, and it is remarkable to see so many system innovations whereby, established, reliable technologies and equipment can be harnessed to create a new business opportunity and bring much needed clean energy to new and disparate markets.

The final word goes to Pascal De Buck, Fluxys managing director and CEO who stated recently that small scale LNG "ticks all the boxes to curb the carbon and health impact of heavy duty road transport, shipping, and remote industry." LNG

To be continued in part 2, in the June issue of LNG Industry, reviewing US developments.