The LNG industry and market place have rapidly evolved in the last 10 years and continue to do so. In the last couple of years, US energy forecasters have totally reversed their initial projections. In 2005, the US was short of gas supply to fulfill the winter season demand. Major energy companies, utilities and traders were scrambling to meet this demand. Engineering companies were busy designing and permitting new LNG import terminals in the US, Europe and Asia, as well as LNG export terminals in gas producing countries. By 2006, natural gas had completely decoupled from petroleum fuel prices in the US. North America was planning to add 39 new import terminals to the existing five.

Today, while many LNG import terminals are being constructed around the world, most of the proposed US import terminals have been cancelled. Only six terminals were ever completed, and all but the Boston Everett and Elba Island terminals sit idle with declining utilisation.

Improved seismic exploration, horizontal drilling, and fracturing technologies unlocked the massive gas and oil resources left behind by traditional vertical drillers. With these new technologies, vast reservoirs of shale and tight gas can be quickly drilled and produced.
Now, both new and existing LNG import terminals are diligently working to protect their investments. Most have requested export permits. With LNG tanks and marine facilities already in place, they plan to add liquefaction trains to reverse the flow of LNG, exporting the massive excess of US natural gas.

The glut of low cost natural gas is making this fuel more attractive to large traditional LNG importers and new users with less demanding requirements. Furthermore, the implementation of more stringent emission guidelines by the US Environmental Protection Agency (EPA) has also created a new market of small LNG users. Today, LNG is being provided as fuel for automobiles, drayage trucks, over-the-road trucks, drill rigs, mine haul trucks, and industrial users. LCNG stations, which are capable of dispensing LNG or CNG from an LNG source, are being built at major intersections along the US Interstate Highway System. Small industrial users are converting from diesel and fuel oil to CNG and LNG.

IMO/MARPOL has adopted strict air pollution requirements limiting SO\(_x\) and NO\(_x\) emissions of ships operating in the designated Emission Control Areas (ECA) in coastal waters of the adopting countries. These rules have been adopted by the US, Canada, the US Caribbean Territories and most of the Baltic and North Sea countries. Shipping companies are beginning to take advantage of the inherent emission reduction and cost effectiveness of LNG. New container ships, automobile carriers, crude carriers, bulk carriers, tugs and LNG bunker vessels are on the drawing board or under construction to be equipped with LNG tanks and high efficiency dual fuel/gas injected engines to meet the ECA requirements.

Locomotive manufacturers such as EMD and GE Transportation have already designed and tested LNG-fuelled locomotives. North American rail operators are working diligently with the US Federal Railroad Administration and Transport Canada to develop and adopt LNG standards and regulations for LNG storage, transfer, and tender cars to meet the stringent environmental and safety requirements for rail operations.

In the last decade, the global LNG industry has exponentially grown from larger liquefaction trains to larger LNG carriers. The global appetite for LNG continues to grow, attracting more players and serving more markets. Much of this new global demand comes in the form of small scale LNG projects. The question then is: how will the US serve this growing small scale LNG market?

**LNG peakshavers**

Since 1965, over 50 small scale liquefiers ranging from 1 to 25 million ft\(^3\)/d have been built and operated by utilities in the US. These facilities have offered fuel hedging security for times of winter peak demand and high cost periods. LNG peakshavers liquefy and store low cost natural gas during off-peak periods and regasify the LNG during times of high demand. This ability reduces cost to the rate payers and provides supply security during times of insufficient pipeline capacity. Some of these facilities supply remote gas utility customers by trucking LNG from the storage tanks at the liquefaction facility to nearby satellite storage and regasification facilities accessible to the customers. Most of the utility LNG peakshavers are owned and operated by local gas distribution companies (LDCs), which are capitalised by bonds with ongoing operations funded by utility tariffs charged to the users. Usage of the assets of these facilities are highly regulated by Public Utility Commissions (PUC). Merchant sales of LNG to the public or private enterprises was typically prohibited in the past. However, some utilities have started to work with their PUCs to allow limited sales of LNG to the public when it is in the ratepayer’s interest. Due to the size of their market and the need to fulfill a small LNG demand in the industry, some LDCs are even considering converting the larger peakshaving facilities into LNG merchant and bunkering facilities. LNG merchant facilities and LNG bunkering are discussed later in this article.

**LNG import terminals**

For 20 years (1985 – 2005), three of the four US LNG import terminals experienced limited LNG imports and intermittent operation. The GDF SUEZ import terminal at Everett, Massachusetts, is the oldest LNG import terminal in the country and the only terminal to continuously operate since it was commissioned in 1971. LNG is received by ship, stored in two large storage tanks, vapourised and sent to power plants and several interstate and utility pipelines. Many New England utilities with LNG peakshavers have found it less expensive to receive LNG by truck from the Everett LNG facility than to operate and maintain their own liquefaction facilities. Currently, the facility supplies over 10 000 truckloads of LNG annually to the regional market. Everett is not a regulated LDC and offers merchant LNG to local utilities and other consumers.

**LNG export terminals**

Several US LNG export terminals are in various stages of permitting, engineering or construction. Cheniere Energy was the first company to build an import terminal during the 2005 – 2007 rush. The massive 2.6 billion ft\(^3\)/d facility near the mouth of the Sabine River includes two ship berths and 800 000 m\(^3\) of storage. Cheniere was also the first company to receive permits to convert its existing facility to export LNG. Several other import terminals are adopting the same strategy including Freeport LNG, Cove Point, Elba Island, Lake Charles, and Cameron LNG.

Figure 1. The largest US peakshaving facility (image courtesy of Philadelphia Gas Works).
What role will these big LNG projects play in fulfilling the demand of small LNG markets? LNG America is proposing and has agreements in place to receive LNG from Cheniere’s Sabine Pass facility in small shuttle barge loads. The LNG will be transported, stored and distributed to major ports along the US Gulf Coast. This approach can provide fuel for ship bunkering, rail, container handling, and drayage trucks. Similar contracting and supply ventures are likely to evolve in the near future.

Small scale, merchant liquefaction facilities
Companies such as Applied LNG, Clean Energy Fuels, Stabilis, Plum Energy and others have built or are planning to build new small merchant liquefaction facilities across the US to support small scale transportation and industrial LNG users (i.e. trucks, drilling, mining operations, industrial heating, etc.) Others are being proposed for marine bunkering and LNG ISO container operations in Florida, Louisiana, California, Pennsylvania and Washington.

Regasification barges
Large floating storage and regasification units (FSRU) have efficiently served the large scale LNG market for the last nine years. They have been developed as an alternative to onshore LNG import terminals to take advantage of a variety of benefits such as lower CAPEX, OPEX, and faster delivery of the first gas. The existing FSRUs serve large LNG demands of up to 4.8 million tpy.

Many power plant operators in different regions (Asia, Central and South America, Africa, and the Middle East) are currently using or considering using FSRUs to satisfy their fuel requirements. The majority of these massive power plants have large natural gas demands that perfectly accommodate and justify the use of an import terminal or FSRU. However, in many countries in Latin America, the Caribbean and even Africa, fuel switching is being considered for environmental and economic reasons. The need for limited supplies of natural gas is increasing every day. So the question is, who is targeting the needs of clients with reduced but equally important natural gas demands? In the world of small scale LNG, what will be the next generation of FSRUs look like?

The next generation of FSRUs will specifically target the small scale market and will most likely come in the form of a regasification barge. Although project specific logistics (i.e. selected site, LNG carrier size and availability, etc.) will determine if a regasification barge is a good fit for each specific project, in general regasification barges could target many areas in Latin America, the Caribbean, West Africa, the Middle East and even the US (Hawaii). A regasification barge could serve areas such as:
- Combined cycle power plants between 10 – 500 MW (depending on the storage requirements).
- Thermal power plants between 10 – 250 MW (depending on the storage requirements).
- Power barges that are somewhere between 20 – 220 MW.
- Shallow water ports or sites where dredging is not feasible.
- Caribbean island resorts requiring natural gas for in-house power generation.
- Small industrial clients requiring natural gas or LNG transported via ISO-containers.
- Remote construction projects.
- Initial plant commissioning and startup operations.

Several companies are already designing and building regasification barges to accommodate smaller markets (e.g. Exmar-Pacific Rubiales, Exmar/VGS, and others.)
**LNG carriers**

As FSRUs shrink in size to accommodate reduced demands, the next generation of LNG carriers are also following this trend. Most LNG carriers are massive, ranging from 125 000 to over 250 000 m$^3$ to efficiently transport large quantities of the LNG to large utility and industrial clients. However, it is not well known that small scale liquid gas carriers ranging from 1100 to 36 000 m$^3$ are currently serving LNG, ethane, ethylene, and LPG markets with additional ships on order. Many of these small ships are designed to be able to carry multiple cargoes. Ship-to-ship (STS) cargo transfer, proven in large scale LNG carrier operations by SPT and Excelerate Energy, have now been proven at smaller scales, allowing direct transfer of LNG from larger carriers to smaller lightering and bunkering vessels. The 1100 m$^3$ Pioneer Knutsen has received cargoes from the 87 000 m$^3$ Höegh Galeon and the 7500 m$^3$ Coral Methane. Japex’s 3500 m$^3$ Akebono Maru received multiple LNG cargoes from Mitsui O.S.K. Lines’ (MOL) 125 000 m$^3$ LNG Taurus to serve Hokkaido during winter peak demand. These tiny LNG vessels are equipped with IGC Type B or Type C containment storage tanks, cargo pumps and boil-off gas (BOG) handling systems. Some are equipped with large flap rudders and bow thrusters, allowing these vessels to berth alongside larger vessels without tug support.

**Bunker vessels**

Bunker vessels are being developed to serve the new classes of vessels equipped with LNG fuel systems to comply with the new ECA regulations. Older LNG carriers were designed to consume the BOG produced inside their LNG storage tanks as fuel. Consequently, the concept of using natural gas for ship fuel has been proven for over 40 years. Norway has pioneered LNG bunkering and currently operates the largest small scale LNG bunkering network in the world. Liquefaction, storage and bunkering facilities are available at Tjeldbergodden, Kollsnes, Karmøy, Øra, Risavika, Alesund, Sunndalsøra, Høyanger, Mosjøen, Ågotness, Halhjem terminal, and Florø. These facilities provide truck-to-ship and shore-to-ship LNG bunkering for ferries. Small LNG carriers operated by Knutsen, Anthony Veder and Norgas are equipped to provide larger STS bunkering volumes as new vessels are built. The world is rapidly following suite; Japan, the Netherlands, the US and the UK are pursuing LNG bunkering.

The surplus of natural gas in the US has created an excess supply of LNG and natural gas liquids (NGL), ethane, propane and butane. These products are bringing higher value in foreign markets. Several players including Evergas, Navigator and Gaschem are building fleets of flexible small scale liquid gas carriers capable of transporting LNG, ethane, ethylene, and LPG to this market.

The experience and capability of these new classes of vessels will directly transfer to the small scale LNG and bunkering market.

Conrad Shipyard recently announced an order for the first US LNG bunker barge for WesPac Midstream/Clean Marine Energy. The 2200 m$^3$ barge will be equipped with Gaztransport & Technigaz (GTT) membrane tanks to briefly serve TOTE’s Orca class container vessels at the Port of Seattle and later relocate to the Port of Jacksonville, Florida to provide LNG bunkering. All bunkering vessels serving at US ports will require US shipyard construction and US crews to meet Jones Act requirements for operation in US territorial waters. Several others have concepts ready or under development.

**Conclusion**

The international LNG industry has grown in scope and scale. The industry started with a small commercial liquefier in West Virginia in 1917 followed by a larger peakshaver in Ohio in 1944. In the 1950s, a small export liquefier in Louisiana and a converted World War II ship (Methane Pioneer) demonstrated safe ocean shipment of LNG. The industry continued its growth, serving European, Japanese and Korean markets as it strived for higher efficiencies and economies of scale by building larger liquefaction trains and carriers. Today, there are 4 – 8 million tpy liquefaction trains and 255 000 m$^3$ LNG carriers. It is fascinating to see the LNG world change and return to its small scale roots and serve new non-traditional fuel markets.

With the new availability of low cost natural gas from coal bed methane (CBM), shales, and tight sands, the world is awash in natural gas. As other countries begin to develop these vast resources, natural gas will become more abundant and cost-effective, resulting in growing fuel switching practices and increased global demand. The environmental benefits of consuming natural gas will continue to displace petroleum-based fuels, pushing more consumers into this market. The future for natural gas and LNG is bright, the scope is broad, the markets are increasing, and regulations and standards are constantly developing as the technology is ever evolving. In a world of very large ships, liquefaction and regasification facilities, there is also amazing growth at the other end of the spectrum.