In the small- and mid-scale LNG fueling market it is very difficult to recreate the less than six-month paybacks the industry was fortunate to briefly experience in late 2013. However, there are still many successful developers experiencing strong returns on their LNG fueling infrastructure investments and, in the process, building social capital in their communities through their environmental stewardship. To be successful at $60 Brent crude oil pricing the financial model requires close nit collaboration by the developer with their vendors and EPCs, accountability and trust on the part of all those partners, and innovation by suppliers allowing developers to decrease operational costs, increase reliability & safety performance over the project lifecycle, and increase the LNG throughput through fewer fixed asset investments by designing assets to serve multiple applications.
Chart Industries built their first LNG truck fueling station and vehicle tanks in 1993, the first LNG rail tender car in 1994, and their first LNG marine bunkering facility and ship fueling system in 2003 & 2006. The expertise in providing and consuming LNG fuel in the truck, rail, and marine markets is mature and the bleeding edge adopters have already provided years of feedback that have contributed to creating the viable technologies that exist today. There is no longer a question of “can it be done”. The conversation has evolved to “how can I get a return on my investment”. This has been a greater challenge since the crude oil price collapse in 2014. With the return of cheap(er) diesel, and a lean spread between that fuel and LNG, many companies put their plans for LNG adoption on the back burner. However, forward thinking companies continue to be creative in finding ways to innovate and collaborate on technology adaption and financial models to achieve returns on their investments in order to have a jump start on the market and reap significant returns when a larger spread returns. The following are a few examples of industry successes stories shared with the hope they can stimulate ideation on how your company can develop positive ROI conversion projects while positioning yourself to meet environmental initiatives / regulations and mitigate risks of future diesel price hikes.

Heavy-Duty Truck / Mine haul vehicle fueling

In over-the-road LNG vehicle fueling one of the greater technology innovations has been the vehicle fuel tank itself. Over the past two decades the tank has been redesigned to include all of the value enhancing functions in a single compact package. Through collaboration with the OEMS many needs were identified including:

- Simplify and accelerate installation process
- Reduce space claim, but increase tank size
- Improve cold-weather performance.
- Take less claim on space required of the haul truck

By integrating the heat exchanger, control valves, and economizer system all on one end of the tank, the compact nature of the fuel system allows the maximum amount of natural gas energy density to be incorporated into the minimum amount of space on the vehicle. This revolutionary design has accelerated adoption in markets including:

- European and other cab-over-engine truck markets. Where available space on the heavy-duty truck is already as compact as possible, HLNG tanks maximize the range of those trucks
- Mine haul conversion. Forward-thinking operators leverage existing compact tank technology to save on capital expenditures and minimize retrofitting costs by fitting the LNG fuel tanks in existing free space on the haul vehicle. Thus, diesel and lube oil capacity are able to be maintained and the ability to displace diesel use with LNG, in addition to being cost and emissions reducing, increases vehicle operating time between fueling events.
By saving space the mine operator saves costs on the conversion as well as save time required to implement LNG solutions in their vehicle fleet. This means quicker savings and a lower threshold to meet in achieving a company’s rate of return requirements, setting developers up to capitalize on bigger windfalls as diesel prices and environmental requirements increase.

Collaboration and innovation have also worked their way into the systems that fuel these vehicles. In 2018 Chart introduced Europe to 3-in-1 LNG compact vehicle fueling stations (“cold” LNG, saturated LNG, and CNG) with many new technical features, like saturation-on-the-fly with immediate fueling response, minimal station footprints with short installation times, and intuitive LNG dispenser fueling. This lowers the capital investment and increases the developers return as the design increases the LNG throughput by allowing the use of a single asset for a wider range of applications, improves safety, and decreases risk to protect one’s investment model.

Mobile LNG vehicle fuel stations have been in use in the over-the-road market for two decades, and have now made the more recent transition to off-road mine vehicle fueling. Mobile fuelers designed for fueling over-the-road trucks are able to fuel converted LNG mine haulers with a simple change of the fueling nozzle, but the chassis they are mounted on are not optimal for difficult and demanding off-road conditions. In addition, operating separate LNG and diesel fuelers creates a logistical headache. The solution was bringing together an LNG process and equipment manufacturer, a mine support equipment manufacturer, and the voice of the customer to create an innovative dual fuel mobile fueler intended for mine haul trucks. An LNG fueling system AND diesel system were mounted together on a Kenworth T800 chassis to create a vehicle that could perform a single, simultaneous fueling event with a haul truck anywhere in the mine or quarry. Having a single, mobile fueling event means mine haul operators do not lose the haul truck’s 20-minute drive back out of the pit to fuel, they do not have to operate two independent fuelers, and they do not increase total fueling time by adding an LNG fueling event to their current diesel fueling operations. Therefore, the mine manager captures the spread between diesel and LNG, increases their asset utilization and moves towards doing more work with fewer haul trucks.
Rail fueling

Tender car trials have been going on for the past 25 years across various major Class 1 railroads in North America. Committing to a complete rollout has been difficult amidst slow regulatory change and the large amount of investment required to place strategic assets over the whole continent. However, through innovation and collaboration railways in the Southeast region of the U.S. have seen over 2 million gallons of LNG consumed in over 15 million kilometers of successful operation. In that region Florida East Coast Railway (FEC) has received the 2017 Environmental Achievement Award from the Jacksonville Environmental Protection Board (EPB) for pioneering the use of LNG (Liquefied Natural Gas) as a locomotive fuel. FEC purchased and converted 24 new GE ES44C4 locomotives not only to demonstrate leadership in environmental stewardship, but also for minimizing the initial investment required for the fueling infrastructure of regular and captive rail routes. By maximizing the projects ration of LNG throughput / capital expenditure rail is able to achieve quicker paybacks and higher returns even with lower diesel prices.

Learn more on those rail successes at the following link.

Another key to success in Rail, and for that matter Marine and Road, is innovation in automation of those systems delivering fuel to the fuel tanks / tender cars. For a system to pay back at its highest rate of return it needs to balance maintaining a high utilization while minimizing the man-hour efforts required to meet those targets. Due to the nature of the dramatic thermal cycles LNG equipment will see there is often a very specific sequence of valve openings and closings, cooling loops, vapor management, etc. and different modes for offloading from supply tankers to filling vehicles.
Automating the theory of operation for LNG fueling facilities has allowed customers to significantly add to a project's long term success and profitability by:

- Adding an additional level of safety
  - Minimized chance for operator error
  - Set Operational limits for decreased asset damage and increased system efficiency and time between overhaul.
- Facilitating smoother HAZOP execution which leads to a more rapid and a less onerous approval process with the local authorities having jurisdiction
- Allowing for simpler operator training and reduced experience / skill set requirements.
- Minimizing the number of required operators on site. Often times a site can even mature to the point that drivers can operate their own fueling events without local supervision.
- Facilitating integration of SCADA remote monitoring systems

Overall, well thought out automation of the more complex elements in LNG fueling stations can be the single greatest return on the incremental capital the developer invests when examining the processes it affects from permitting, operator costs, risk, and long term asset utilization and life.

**Marine Fueling**

When evaluating the Road, Rail, and Marine markets, the LNG maritime market has the highest potential for rapid expansion of collaboration and innovation in the near term. The 2020 IMO regulations on sulfur emissions will have a large effect on fuel options, availability and pricing and may not only cause a need for rapid adoption of LNG and other technologies in the Marine market, but may cause supply issues for ultra-low sulfur diesel that ripples out to all other markets that rely on #2 fuel oils for their fueling, heating, and power needs. With all these uncertainties, many ship operators - whether inland, near-shore, or trans-oceanic, have chosen to sit on the sidelines and take a wait-and-see approach. However, there are proactive adopters of LNG ship fueling and, as thought leaders in their industry, they have relied on collaboration and innovation with the LNG industry, or in some cases, build out entire supply chains to realize the benefits of LNG. Those that can develop a project that clears their internal financial requirements today are poised to potentially capitalize on large windfalls if ultra-low sulfur diesel supply impacts refined product pricing.

One good example of collaboration in the marine market is that of a developer, a ship operator, and a cryogenics company collaborating on developing tank technologies that allowed one freighter to site 2000 cubic meters of LNG on a two-acre plot in the middle of an active container loading and unloading lot. In order to mitigate impacts to their existing schedules the ship operator had a requirement for simultaneous fueling and container loading operations. By submerging a twelve hundred gallon per minute pump in each of two columns inside of 1000 m³ vacuum insulated pressure vessels, the collaborators were able to remove bottom penetrations from the design and instead pump LNG out the top of the vessels. Removing bottom penetrations gave local Authorities Having Jurisdiction (AHJs) assurances that there would be no possibility for guillotine events of the penetrations that could
lead to large leaks. Furthermore, the tank was designed with a stainless-steel outer jacket to operate as additional containment for the LNG contents of the inner vessel should there manage to be some sort of breach of the inner tank. With these provisions in place, the client was able to get approval to safely site LNG in the middle of an active port. In this case the ROI may have been the difference between having an operating shoreside bunkering facility or having to pay for a much more expensive barge.

The implications of this design innovation are far reaching because now developers / projects can fit more storage into smaller areas for marine fueling, power generation facilities, or truck load out depots in more densely utilized areas. This design innovation saves the customer land acquisition costs, vapor mitigation costs, LNG containment costs, and may be the only way the project can move forward.

Another unique marine innovation is the Power Barge. A forward-thinking developer collaborated with their equipment OEMs to lead the way with this innovation. At the time the developer noticed that when cruise ships pulled in to port they still needed power to run their climate control and other systems. The ship either had to operate their diesel generators at a penalty (if they were even allowed) or connect to shore power, though often that was limited or not available. The Power Barge was an innovative idea that uses LNG ISO Containers as LNG fuel tanks and five gas generators producing 8MW of power. The barge could pull along-side incoming cruise ships and supply their ancillary power. Since the cruise industry is seasonal, in order to reduce their payback period and optimize their return on investment the operator would push the barge to shore in the winter and supplement grid power to a container terminal during times of high demand. With this innovative model, the developer is able to create a mobile environmental benefit for the port and nearby communities while generating a profit for their investors.
Multi-purpose terminals

A key element for the financial viability of small-scale LNG projects is versatility. Without the obvious economies of scale of much larger projects a key to small-scale success may be an ability to serve multiple sectors. Small-scale facilities are also nimble and able to respond quickly to fluctuations in market conditions and demand. Chart has designed and built a number of such projects with some notable examples highlighted below.

The Klaipedos Nafta LNG reloading station has created a small-scale LNG operational infrastructure and developed the LNG market in the Baltic Sea region. The cryogenic equipment section comprises five horizontal storage tanks, two truck loading bays, one LNG bunkering jetty and the regasification plant. Gas from a floating LNG storage and regasification unit is delivered to the storage tanks by a gas tanker and can be loaded into road tank trucks or vessels for onshore distribution, used as vehicle fuel for boats and trucks, and distributed by pipeline for local energy requirements.

The cryogenic storage tanks, each capable of holding 1000m³ of LNG, were shop built and a key feature in the plant’s modular construction that dramatically reduced civil requirements, installation costs and overall schedule. Modularization also made it possible to factor into the original design a doubling of the station’s capacity in the future with modular, incremental capital investment to match the demand curve. Another benefit of shop building skiddled, modular components is the ability to simulate operation of the electrical systems before installation even further reducing installation time/cost, start-up time/cost, and ensuring successful plant operation and longevity for beyond the lifecycle the financial modelling of the developer required the site to last.
Right down the road from this LNG19 conference in Shanghai is another example of using innovation and collaboration to design a system that has multiple uses that increase the ability of a facility to produce higher financial returns to the develop. That example is a Shanghai Port bunkering AND truck fueling station. The site consists of one 60m3 tank, four pumps, two vehicle fuel dispensers, two bunker fuel dispensers.

With the promulgation of a number of policies by the Chinese Government, such as the Implementation Plan of the Special Action for the Prevention and Control of Pollution in Ships and Ports (2015-2020), the 13th Five-Year Plan for the Development of Energy Conservation and Environmental Protection in Transportation, and the Opinions on Accelerating the Development of Inland Water Transport in the Yangtze River, vigorously promoting energy conservation and emission reduction and clean energy substitution in the field of transportation has become the focus developing direction of clean energy.

In 2015, the Shanghai Municipal People's Government transmitted the Circular of the "Three-year Plan of Action for Shanghai Green Port (2015-2017)" formulated by the Shanghai Municipal Communications Commission to encourage ships to use LNG pilot applications. We will promote the pilot demonstration of LNG power for inland cargo ships and expand the scale of application to 300; pilot LNG power vessels for coastal transportation; pilot LNG filling stations for ships to form a supply and support system for LNG power vessels.

In order to promote the application of clean energy and complete the clean energy substitution work of Shanghai construction waste transporter, a LNG ship filling demonstration station is built in Shanghai port base. It mainly serves LNG ships in navigable waters such as rivers and lakes, and has the function of filling LNG vehicles LNG vehicles in ports.
In this project, the manufacturer collaborated globally to transfer best practices and adopt many ways to optimize equipment operation, personnel operation and automation system, and strictly control BOG generation and emission waste:

- Siphon system is adopted to improve the operation efficiency of submersible pump and reduce BOG generation
- Storage tank adopts multi-layer winding insulation technology
- Vacuum pipeline with excellent thermal insulation performance is adopted
- The high flow aerator for ship's aeration is adopted, which greatly improves the aeration efficiency
- Reasonable selection of valves to reduce pipeline resistance
- Use Chart Patent Differential Pressure Flowmeter without pre-cooling
- Special ship aeration boom, reduce the burden of staff aeration

Overall, the project successfully solved a series of problems such as LNG long-distance transportation and gasification, low gas filling efficiency, water level drop and so on, providing reliable guarantee for the efficient operation of the station. More importantly, it saves the land resources of customers and maximizes the return of capital invested by developers in all processes that consider the cost, risk of operators and the impact of long-term asset utilization and lifetime.

Ultimately, in the small- and mid-scale LNG fueling market it is very difficult to recreate the less than six-month paybacks the industry was fortunate to briefly experience in late 2013. However, there are still many successful developers experiencing strong returns on their LNG fueling infrastructure investments and, in the process, building social capital in their communities through their environmental stewardship. To be successful at $60 Brent crude oil pricing the financial model requires close nit collaboration by the developer with their vendors and EPCs, accountability and trust on the part of all those partners, and innovation by suppliers allowing developers to decrease operational costs, increase reliability & safety performance, and increase the LNG throughput through fewer fixed asset investments by designing assets to serve multiple applications.

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Facility at a quarry provides natural gas to aggregate dryers and reciprocal engines, and has LNG dispensers to fuel the mine haul trucks carrying the aggregate back from the quarry.