

Japan Liquefied Natural Gas (LNG) Intermodal Container Operations: Applicability to U.S. Operations

Richard D. Stewart, Ph.D., CTL
Professor, Department of Business and Economics
Director, Transportation and Logistics Research Center
Co-Director, Great Lakes Maritime Research Institute
Erlanson 105, University of Wisconsin-Superior
Superior, WI 54880 United States
Office 715-394-8547
Fax 715-394-8374
rstewart@uwsuper.edu

Hiroko Tada
Researcher, Great Lakes Maritime Research Institute
Erlanson 105, University of Wisconsin-Superior
Superior, WI 54880
United States
c20hiroko@hotmail.com

ABSTRACT

Liquefied Natural Gas (LNG) has proven advantages as a transportation fuel. However in the United States the use of this abundant product as a transportation fuel is limited by the number of liquefaction plants and the undeveloped supply chains that can distribute the product. One potential option for the distribution of LNG is by shipping it in containers either by truck, rail or aboard a vessel. Japan has operated a containerized LNG rail truck intermodal distribution systems since 2000. The results of field research in 2015 on the rail truck containerized intermodal system are given. An analysis is made of the operational characteristics, equipment and safety protocols used in Japan. An evaluation of the applicability of the Japanese LNG container model to the United States rail/truck intermodal container network is presented.

Background

The United States has become a world energy leader with proven energy reserves of 7,299 trillion cubic feet of natural gas (NG).¹ There is the possibility to expand the use of Liquefied Natural Gas (LNG) as a transportation fuel and also to serve markets currently using propane or diesel.² While Compressed Natural Gas is a growing market, LNG is the predominate fuel used in the U.S. for high kilowatt engines because of its higher energy content per unit. The U.S. and Canada have become Emission Control Areas (ECA) and that is also driving change in marine fuel usage, and natural gas is one option.

While the supply of natural gas is abundant there are few liquefaction plants. In many cases the existing liquefaction plants (peak shavers) are hundreds of kilometers from new potential markets and are designed to serve utilities and not the transportation or off the grid sectors. Key to the expanded use of LNG is the development of a supply chain to deliver the product to end users from liquefaction plants. Currently the U.S. LNG supply chain is not in place and will need to be developed.³

New liquefaction plants to serve the transportation sector should be as large as possible to realize economies of scale. A new large scale liquefaction plant will need a robust and agile distribution system for LNG that includes truck, rail and marine. While the highway system in the U.S. is very good, the cost effective range to truck LNG is about 402 kilometers which in the U.S. is a relatively short distance. According to a LNG Truck Distribution Costs study prepared by TIAx for America's Natural Gas Alliance in 2013, at a drayage of about six hundred miles the cost of truck transportation equals the combined cost of the natural gas and liquefaction.⁴

The high cost of distribution raised the research question: Could LNG be transported by intermodal container to lower the distribution cost and extend market reach of a liquefaction plant? In the U.S, LNG containers have not been transported by rail so the research team decided to examine a rail truck intermodal system that has been operating in Japan for over 14 years.

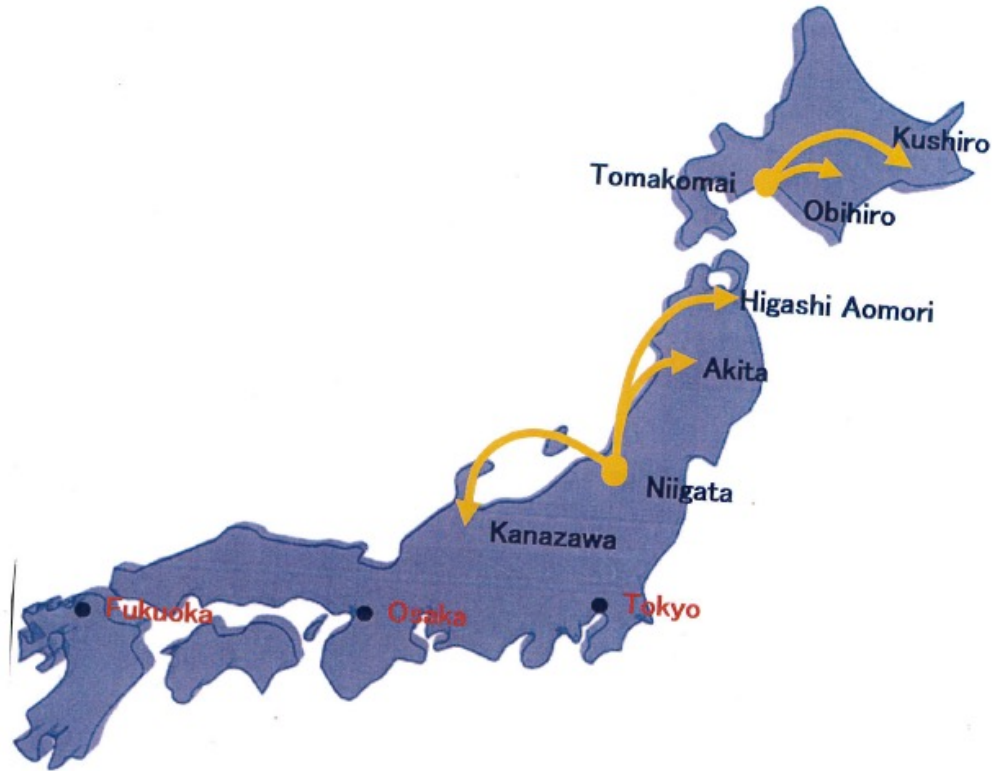
There are a number of potential advantages in moving LNG to markets using ISO containers. The LNG can be distributed to users who do not have a high volume demand but cannot gain access to a natural gas pipeline. This option opens new markets for LNG, increasing the user groups for a liquefaction plant. The customer can use the container as a storage tank reducing the need for a costly onsite storage tank. With frequency of delivery by container, the user may need a smaller storage tank.

Existing truck intermodal trailers can be used to haul ISO containers. Existing rail intermodal cars can be used if carrying LNG containers is approved by the Federal Railroad Administration (FRA). A container distribution system simplifies operations and reduces startup costs. Containers are not regulated as a bulk transfer of LNG by the U.S. Coast Guard. The containers are U.S. DOT and ISO certified meeting regulatory requirements. Truck and marine currently deliver LNG containers.

As of January 01, 2016, the U.S. has not transported any LNG by bulk tank rail car, by container on rail, or by container on vessels in the Great Lakes or inland waters. According to Dr. Phani Raj of the Federal Railway Administration (FRA) Office of Safety, there are regulations in place that could allow the transportation of LNG in containers by rail in the U.S.⁵

Japan's LNG Intermodal Container Supply chain

Since 2000 Japan has operated successful intermodal LNG supply chains using containers in rail and truck system. The Japanese LNG intermodal container operation studied operates along several routes. The route that was researched was between Niigata city, Niigata Prefecture and Kanazawa city Ishikawa Prefecture, (See Map 1).



Map 1: Japan JR Freight Rail Intermodal Routes. Courtesy JR Freight

After correspondence with the principal parties and exchange of information a trip was taken to Japan in June 2015 to study the LNG intermodal operation. The principal parties involved in the LNG intermodal supply chain are: Japan Petroleum Exploration Co., Ltd (JAPEX) who supplies the LNG. JAPEX receives the majority of the gas by sea bringing in about four vessels per month in the port of Niigata. Japan Oil Transportation Co., Ltd provides the containers and drayage services. Nihonkai LNG Co. Ltd maintains the containers and trains the drivers. Japan Freight Rail Way Company (JR Freight) operates the trains and intermodal terminals. The LNG is delivered to Kanazawa Water & Energy and Komatsu Gas.

Upon arrival in Tokyo the research team met at JAPEX headquarters with representatives from JAPEX⁶ and Japan Oil Transportation Co., Ltd (JOT)⁷. The research team was briefed about the LNG operations, its history, principals and the safety culture. The research team provided background on the U.S. Maritime Administration LNG research that the Great Lakes Maritime Research Institute has been involved with since 2011. The research team also visited the Japan Freight Rail Way Company Head Quarters (JR Freight) and had similar discussions with their representatives⁸.

LNG Drayage Equipment: Niigata city, Niigata Prefecture:

The first location visited was the truck parking area, truck driver training facility, and truck maintenance facility of Nihonkai LNG Co., Ltd (LNG)⁹. There were LNG trucks and chassis with LNG containers at this facility. (See photos 1 and 2 respectively).

The capacity of the bulk LNG tank trucks in use are 11, 12, 13 and 15.7 metric tons depending on the model. These trucks are used for transport of LNG by highway only and are not

designed or capable of piggy back rail operations. The normal one-way operating range of the vehicles is 300 to 500 kilometers. The Labor Standard Act stipulates that a driver can drive for four hours, then must take a one hour break and then can drive for another four hours. Truck drivers can only drive nine hours per day including one hour break. Loading and unloading operations are part of the nine hour period. The bulk truck delivery system has been in operation for 15 years. For distances longer than 200 KM, Japanese regulations call for two persons to operate a truck carrying LNG, gasoline or diesel, making such transports not commercially viable compared to rail transport.

The LNG containers are manufactured in Japan and are not equivalent to ISO tank containers. The containers and chassis are owned by JOT. Two companies manufacture these LNG containers in Japan. Seventy-four of these have been supplied by the company Air Water Inc. (<http://www.awi.co.jp/english>) and the rest from J-TREC (<http://www.jtrec.co.jp/eng>). There are two container designs. One has square bracing and the newer type has rounded bracing. The rounded bracing was developed to reduce stresses during the rail and truck transfer operations, while reducing weight. The container observed was 9.125 meters long by 2.5 meters high and 2.488 meters wide. Tare weight is 9.05 metric tons, net weight 10.95 metric tons, and gross weight 20 metric tons with a capacity of 21,347 cubic meters. According to JOT there are 136 of these containers dedicated to intermodal transport. As designed, these containers are not expected to be stacked. In order to produce a stackable LNG container there would have to be an endurance test, and would add unnecessary cost for the existing Japan LNG container supply chain.

The trucks and container construction is regulated by federal government with the involvement of the prefectural government and must meet the standard of an ordinance of METI.¹⁰ The container depreciation is fifteen years. However, it does not mean they cannot be used after fifteen years. During the fifteen years, there is a regulation that the company has to conduct container re-inspection every five years. After fifteen years, the interval of the re-inspection duration is shortened to every two years. Unless the pressure inside the container drops, the container can continue to be used after fifteen years, and they expect to continue to use the containers.

Truck drivers are required to have specialized training in order to transport LNG. Part of the training is learning how to load and unload the container or tank car as this is the driver's responsibility. JOT uses a full scale simulator as part of their training program. The simulator is an actual control system from a tank truck that is operated using compressed air. The training simulator (See Photo 3), is not a regulatory requirement but is another example of the robust safety culture that the Japanese LNG supply chain embraces at all levels.

The transport of LNG by truck and rail is regulated in Japan. However it must be noted that all individuals that the research team interviewed had a very strong safety ethic that moved them beyond compliance with regulations. The authors believe that the long standing trust and close working relationship between the partners contributes to the smooth and safe operations. The cooperative dedication to continuous improvement and safety has meant that since the operations started in 2000 there have been no accidents in any part of the intermodal container supply chain.



Photo 1: Intermodal LNG Container. Photo by Richard D. Stewart



Photo 2: LNG 15 metric ton Bulk Tank Truck. Photo by Richard D. Stewart



Photo 3: Simulator for training truck drivers in loading and unloading operations for LNG from containers and trucks. Photo by Richard D. Stewart

Loading LNG Containers

JAPEX receives most of its natural gas from vessels that are importing it from a number of different countries. LNG is unloaded from the vessels to storage tanks. Some is vaporized and sent out by pipeline. The facility also loads LNG into trucks and containers for distribution to areas not served by pipelines. The container/truck loading station is fed by an underground pipeline from the LNG storage tanks. The pipeline has leak detection systems and each loading island has two gas detectors. The system is designed to be able to operate with only one truck driver. However, two persons always operate the loading operation at the facility for safety. The truck driver loads the LNG into the container wearing safety glasses and gloves designed for frigid operations. A safety officer monitors the operations, checking to ensure that safety procedures are followed and that there is no detectable gas leaking during the process. Each island also has a TV monitoring box and it is placed at an angle to watch the truck and gages. The pressure vessels have a design pressure of 0.96 MPa and the safety valve opens at 0.8 MPa. Operations will be shut down if the wind speed exceeds 10 meters per second or if there is lightning. Safety drills are held on the plant on a regular basis and once a year the local fire department trains with plant employees. The maximum loading rate of the facility is 40 metric per hour. A 10 metric ton LNG container is completely loaded in about 40 minutes from preparation safety checks to scaling and final close out. A maximum of 60 trucks a day can load LNG, but the average is 20 trucks a day using four islands. The facility can load up to six vehicles at once but typically they are loading about three at a time. The facility operates from 9 AM to 5 PM depending on customer demand. JOT can load LNG after normal operation hours if their client requests. The facility distributes LNG to their customer by truck and railway.

They also distribute LNG to a thermal electric power plant too. Ninety percent of the LNG sent to the thermal electric power plant is shipped by pipeline.



Photo 4: Loading LNG into container at JAPEX Niigata facility. Photo by Richard D. Stewart

Intermodal transfer of LNG Containers to Rail in Niigata

The research team met at the JR Freight Rail Way Company Niigata Cargo Terminal Station with their JR Freight Rail Way Company representatives¹¹ and others from JAPEX and JOT. The research team was given a presentation about the terminal and then toured the Niigata Cargo Terminal and observed the loading operations of LNG containers onto and off of rail cars.

JR Freight is regulated by the Ministry of Land, Infrastructure, Transport and Tourism.¹² Under the ordinance the safety management section requires rail companies to appoint a Chief Safety Management Officer and notify the Ministry when the individual is appointed. The Ministry can also dismiss the Chief Safety Management officer if the Ministry believes that the individual is not doing their job properly.

Japanese trains operate on a rail track with a 1,067 millimeter, (3 feet 6 inch gauge) compared the U.S./ standard gauge of 1,435 mm (4 feet 8 1/2 inch) gauge. Over 95% of JR Freight's track is electrified and diesel propulsion is only used in the northern islands. The overhead line or catenary wire suspended from poles or towers along the track or from structure or tunnel ceilings, feed electricity to the locomotives through pantographs on the locomotive's roofs. These wires, along with tunnel height restrictions, prohibit the use of double stack container operations.

LNG rail intermodal operations started in 2000. They move about 5 LNG intermodal containers per day on mixed freight trains. There is a small increase in volume in the winter when demand is increases due to increased heating. The rail cars used for the LNG container operations carry two containers fixed to the rail car using locking cones (See Photos 6 and 7). The Koki 100 series flat container cars are 20 meters long with a maxim payload of 40.7 metric tons. The

maximum speed allowed for the rail car is 110 km/h. The rail cars are designed to handle LNG or other container types including ISO and small specialty containers used for just-in-time deliveries in Japan. There are multiple securing points and systems on the rail cars. A top pick is used to load and offload the containers, (See photo 5). The dedicated service means that the loaded containers are placed directly on the rail cars and the drayage truck immediately picks up the empty containers either from the rail car or from storage.



Photo 5: Rail Intermodal train with LNG Containers and storage area. Photo by Richard D. Stewart

Niigata cargo terminal station has a designated LNG container storage area and they can store a maximum of 24 containers. The LNG container yard layout is established based on the High Pressure Gas Safety Act. Loaded and unloaded LNG containers are treated the same. All LNG containers are one high, and not stacked while in storage. Other (non-LNG) containers in the terminal are stacked. The LNG container yard has four signs which indicates that this is a Class 1 storage place. The sign say “high pressure gas class first storage”, fire strict prohibition”, “entrance strict prohibition without permission”, and “high pressure gas tank storage (Flammable)” in red-letters.

Intermodal Transfer of LNG Containers from Rail to Truck in Kanazawa

The intermodal trains arrive at the JR Freight Rail Way Company Kanazawa Cargo Terminal Station where they are offloaded and empty containers loaded back on the trains. The total terminal area is 109,000 m². Container storage area including LNG is 27,000 m²). The research team was given a tour by Freight Rail Way Company representatives.¹³

Located almost in the center of Hokurikusen, the terminal has expanded operation as a logistics base in the Kanazawa urban area. It is the only container handling station in Ishikawa prefecture. Furthermore, it plays an important role as a container transshipment base for the Takaoka district. In addition, this is the only station that does dispatch operations by direct

management employees in Kanazawa branch. The station also has as part of its mission training for its employees and others involved with container operations.

The terminal's LNG operations are approximately 100 meters from passenger rail train operations. One of the safety measures followed is that the drayage trucks are routed so that they never have to back up in the terminal with an LNG container. When the trucks arrive the drivers are responsible to make certain the cones on the truck are unlocked. Level gauge and pressure is checked before unloading LNG container from the truck. The pressure safety valve is mounted to the right of the back corner of the container. This means that methane released through the valve will be spilled away from rails and electric lines. The container is designed to withstand being dropped fully loaded from 3 meter height, which is the typical height to which the top loader lifts it. All containers have safety information stored along with safety equipment in red a box on the bottom side of the container.

IT-FRENS & TRACE System

This is a position management system for containers using GPS and ID tag (RFID tag) and booking management to identify which car of the train the container is loaded onto. The top picks are quipped GPS system to manage its position, and the containers and freight cars have electronic ID tags attached, (See Photograph 6). Transportation companies use IT-FRENS & TRACE system to request information and to track cargo via the internet. The data is sent to IT-FRENS servers via internet and distributed to cargo stations' system and to driver system via internet. The data is also shared with top picks at the rail terminal. The ID tag reader with top pick will automatically read the information of the ID tag mounted onto a container. At the same time, the current location information is sent to the center from a GPS device mounted top pick with the containers unique number and the truck or rail car ID number

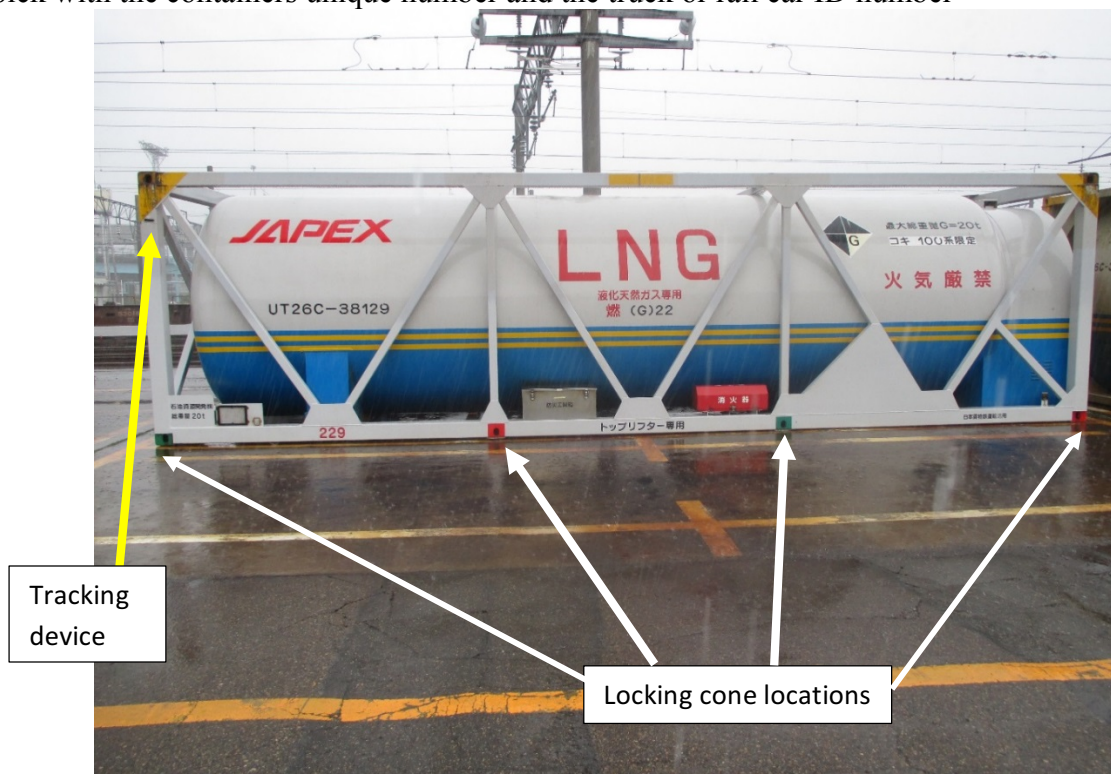


Photo 6: LNG storage area (newer containers) at Kanazawa JR Freight Terminal. Photo by Richard D. Stewart



Photo 7: LNG Container on car. Photo Richard D. Stewart

Unloading LNG from LNG Containers to Storage Tanks in Kanazawa

The containers are drayed from the JR Freight Terminal about 20 kilometers to the Kanazawa Water & Energy Center Minato Plant. Minato Energy Center is located Minato city, Kanazawa. The city gas produced at Minato Energy Center is distributed to households, plants, hospitals, and business via pipe which is buried under the roads. The center implemented a computerized operation system which controls all of the operations from receiving LNG, producing gas and distribution. The operators supervise the system which operates 365 days a year 24 hours a day. The facility is able to unload up to four LNG containers at a time but typically does two, (See Photo 8). Unloading time is approximately 40 minutes. The driver is responsible for unloading with a safety person standing by. The facility has remote TV monitors as well as gas detector systems at each station. The terminal has never had an accident.¹⁴ Komatsu Gas is a principal user of the delivered gas and feel that the system is very cost effective and safe.



Photo 8: Unloading LNG Containers at Distributorship in Kanazawa: photo Richard D. Stewart

Adaptability of the Japan LNG intermodal container supply chain to the U.S. market:

The Japanese intermodal LNG container model is one of dedicated service, with a collaborative partnership that maximizes container use. The entire operation is driven by a robust safety culture adhered to by all parties. The supply chain has operated accident free since 2000 in some of the most densely populated areas of the world. The LNG intermodal service operates in close quarters with some of the most heavily used passenger rail services in the world. Japan has been the leader in the movement of LNG containers by rail. Their system is unique in using non-ISO containers. The ISO LNG containers are widely used in the marine trade and available on the open market.

The safe movement by rail of liquefied gasses in containers is not uncommon in the United States. An analysis was undertaken of Surface Transportation Board (STB) rail waybill data for 2013 looking at liquefied gases (coal or petroleum) that were identified as falling under the Standard Transportation Commodity Code (STCC) 29121 designation. This designation includes, among others, flammable gases such as propane, butane and liquefied petroleum gas. For a full listing see table 1. The type of rail car carrying the containers were listed under either the old Interstate Commerce Commission (ICC) Code 46 for Trailer on Flat Car (TOFC) and Container on Flat Car (COFC) or the rail cars met American Railroad Association (AAR) designations of Intermodal low profile or Intermodal stack cars. Table 2 lists the car types, quantity of cargo shipped and on how many rail cars. This table does not include the STCC 29121 cargo that was shipped by bulk rail tank car. Bulk tank cars moved a far larger quantity of this type of cargo.

- STCC 29121 'LIQUEFIED GASES COAL OR PETROLEUM '
- 2912110 'BUTANE GAS LIQUEFIED '
 - 2912111 'PROPANE GAS LIQUEFIED '
 - 2912112 'ISOBUTANE GAS LIQUEFIED '
 - 2912116 'DICHLOBUTENE (1 3-DICHLORO-2-BUTENE) '
 - 2912120 'ETHYLENE CRYOGENIC LIQUID '
 - 2912122 'BUTENE (BUTYLENE) GAS LIQUEFIED OR ISO- '
 - 2912122 'BUTENE (ISOBUTYLENE)LIQUEFIED '
 - 2912125 'PETROLEUM ISOPENTANE OR PENTANE '
 - 2912128 'PROPYLENE '
 - 2912130 'COAL GAS '
 - 2912131 'PINTSCH GAS '
 - 2912190 'LIQUEFIED PETROLEUM GAS NEC COMPRES'

Table 1: Commodities Captured in STCC 29121

ICC Car Type Code	ICC Car Type Name	STCC	Number of Public Waybills 2013	Expanded Carloads	Expanded Tons
46	TOFC/COFC	29121	131	5,240	83,520
AAR Car Type Code	AAR Car Type General Code	STCC	Number of Public Waybills 2013	Expanded Carloads	Expanded Tons
Q730	Intermodal, low profile	29121	2	80	1,600
Q752	Intermodal, low profile	29121	2	80	1,080
Q753	Intermodal, low profile	29121	2	80	1,440
S162	Intermodal,Stack	29121	1	40	840
S342	Intermodal,Stack	29121	116	4,640	72,520
S635	Intermodal,Stack	29121	8	320	6,040

Table 2: Waybill Sample of Containerized Liquid Gases STCC 29121 shipped by rail for 2013.¹⁵

From this data it is evident that in 2013 the U.S. railroads carried tens of thousands of tons of cargo that is as dangerous as LNG in containers and in bulk tank cars.

ISO LNG Containers

LNG ISO containers are available on the market that could be used in a U.S. LNG intermodal supply chain. Chart Industries, based in the U.S., is one of the manufacturers of ISO containers that are designed to carry LNG. A Chart ISO 20 foot LNG container will have a tare weight of 7,600kg (16,755 pounds) and a capacity of 20,360 liters (5,378 gallons) of LNG at a maximum pressure of 150 psi. The 20 foot container will be able to keep the LNG in a liquid state for up to 80 days. A Chart ISO 40 foot LNG container will have a tare weight of 11,500kg (25,353 lbs.) with a capacity of 43,500 liters (11,491 gallons) of LNG at a maximum pressure of 100 psi. The 40 foot container (See Photo 9) will be able to keep the LNG in a liquid state for up to 70 days depending on the ambient air temperature.



Photo 9: LNG ISO Containers. (Chart Industries)

These containers are relatively costly and would need to be in a dedicated trade with a high use rate to realize an acceptable return on investment as is done in the Japanese model. The long life of the containers, with proper handling and maintenance, would mean that the payback period would cover 20 years or more. There are other nations, including the U.S., that are advancing the use of ISO LNG containers in intermodal service.

Rail transportation of LNG in Europe

Rail transportation of LNG by ISO container has been proposed for Sweden and Finland. Swedish railcar manufacturer Kiruna Wagon has developed plans for a railcar concept suitable for LNG ISO containers. Ragner's 2014 report noted, as in earlier Great Lakes Maritime Research Institute (GLMRI) studies, that a key factor in developing LNG transportation nodes will be the multiple user groups driving the market. The Ragner study cited possible containerized LNG users as:

"This indicates that industries of particular interest should be found among the following groups:

- Forest industries
- Mining industries
- Steel industries
- Aluminum industries
- Foundries
- (Chemical) process industries
- Ports
- Filling stations for heavy duty trucks"¹⁶

Unlike Sweden's standard gauge of 4' 8 1/2 " (1435 mm), Finland has a broad gauge rail system of 5 foot, (1524 mm). This means that railcars cannot roll between Sweden and Finland without changing bogies at the border. U.S., Canadian and Mexican railroads do not face this issue. In Europe LNG rail tank wagons (rail cars) are being built to transport LNG by VTG Aktiengesellschaft. The LNG will be delivered to Brunsbüttel, Germany's first LNG terminal, which is situated at the intersection between the river Elbe and the Kiel Canal. VTG is building two prototypes rail cars to transport LNG by rail with its Czech partner, Chart Ferox, that will build the tank. VTG is responsible for the development. The cryogenic LNG can potentially remain in the tank wagon for up to six weeks. "As an additional safety measure, the tank wagons are being equipped with 25t wheelsets instead of the 22.5t which is legally required and a GPS monitoring option for the tank."¹⁷

U.S. Rail Transportation of LNG

U.S. railroads have expressed an interest in the transportation of LNG by container that was driven by shipper requests. Union Pacific Railroad in early 2015 applied for permission to the Federal Railway Administration (FRA) to haul liquefied natural gas.¹⁸ The U.S. Code of Federal Regulations Title 49 permits the transportation in commerce of LNG in portable tanks on rail, however a sub section imposes certain other requirements.^{19 20} According to Dr. Phani Raj of the Federal Railway Administration Office of Safety, ultimately the decision to transport or not under these rules lies with the carrier or under special approval from the FRA. Florida East Coast Railroad is also exploring the movement of LNG by container.²¹

In November 2014, Alaska Railroad approached the FRA about obtaining approval to move LNG in portable tanks via container-on-flat car service in both unit and manifest trains. In February 2015, the railroad submitted a formal request for approval. The agency then conducted a thorough review and analysis of the proposed LNG operations.²² In October 2015 the Alaska Railroad Corporation received Federal Railroad Administration approval to transport liquefied natural gas via ISO containers from liquefaction facilities to customers in the interior of the state. The transportation option was strongly supported by state agencies wanting to find a less expensive way to deliver clean fuel to communities such as Fairbanks. This is the first time that the FRA has approved the movement of ISO LNG containers by rail in the U.S. In the U.S., LNG rail cargos currently are not permitted without a waiver from the FRA under Federal Emergency Management Agency (FEMA) rules. The FEMA requirement is based on FEMA3A for LNG Accident Consequence Analyses. The two year FRA approval given to Alaska Railroad includes eleven requirements that the railroad must comply with. Examples of these include:

- Operate only up to two trains carrying eight portable tanks of LNG per week;
- Perform at least one track geometry car inspection and four internal rail-flaw inspections annually;
- Provide initial training to all crews operating LNG-carrying trains and emergency responders along an LNG route;
- Prohibit double stacking of the portable tanks; and
- Issue a report each month to the FRA on the number of portable tank loads and other data.²³

Another Federal entity that will be involved as LNG is shipped as cargo will be the Transportation Security Administration (TSA). The TSA's Transportation Sector Network Management (TSNM) program covers railroads, highway motor carriers, ports and intermodal facilities, mass

transit facilities, pipelines, air cargo, commercial and general aviation. The Intermodal Security Training and Exercise Program (I-STEP) supports TSA's Transportation Sector Network Management (TSNM) Modal Security Managers with exercises and training. The Homeland Security Information Network (HSIN) – Freight Rail Portal has been designed to provide consistent, real time information sharing capabilities in an integrated, secure, web-based forum and will no doubt be used during the transportation of LNG.²⁴

In addition to the FRA and FEMA regulatory requirements, there is the possibility of existing and future state regulations regarding the transportation of LNG by rail. In 2011 the State of New York contracted a study to examine the future of LNG transportation and determine what state regulations may be required. The report provided background information and assessed the proposed NY state regulations, (6 NYCRR Part 570 [Part 570]), to regulate liquefied natural gas (LNG) facilities pursuant to Article 23, Title 17 of the New York State Environmental Conservation Law (ECL). In the conclusions the report recommend the promulgation of Part 570 which would establish procedures for permitting LNG facilities, intrastate routing of LNG transport vehicles, and the assessment of emergency response capabilities.²⁵ Part 570, which like all States (except TX) will rely on nationally recognized protocols for the regulation of LNG facilities.

The State of Texas LNG regulatory requirements are found in the "Regulations for Compressed and Liquefied Natural Gas" by the Texas Railroad Commission. The Railroad Commission of Texas (RRC) administers the rules and regulations for the construction and operation of LNG facilities and to an extent, the transportation of LNG within the state of Texas. The Texas regulations require permits, training, exams, licensing and assess penalties for noncompliance.²⁶

Demand for ISO LNG Containers:

Expanding the use of ISO LNG containers is dependent upon the demand of the markets. Several markets are evolving that could be expanded and served by intermodal operations. In The U.S. Department of Energy in 2011 authorized Carib Energy to export LNG to Free Trade Agreement countries. The authorization will allow Carib to export LNG in approved ISO containers transported by ocean-going vessels from the Gulf and southeast states up to the equivalent of 11.53 bcf (0.23 million tonnes) annually for 25 years. Carib plans to load the ISO LNG containers at liquefaction plants and transport them by truck or rail to marine terminal to be loaded aboard a ship. Liquefaction is a Bergen Norway based company that transports ISO LNG containers. Their containers are approved for transport by truck, rail and marine. Liquefaction has offices in Singapore and Vancouver, Canada.²⁷

Rail Locomotive LNG Fuelling using ISO LNG Containers:

According to the U.S. Energy Information Administration's (EIA) Annual Energy Outlook 2014, in 2012 the seven Class-1 railroads consumed more than 3.6 billion gallons of diesel fuel. For several years two options have been considered for supplying railroad locomotives with LNG for fuel. The two options are: a 10,000-gallon ISO tank, or a 25,000-gallon tender that closely resembles a tank car. An LNG-powered freight train using 25,000-gallon LNG fuel tenders should be able to operate, for example, between Los Angeles and Chicago one-way without a refuelling stop, improving locomotive utilization.²⁸ The ISO LNG container, offers more operational flexibility and a potentially lower cost but has half the capacity. The 40 foot ISO LNG Container can be mounted in a modified well cars, (doublestack intermodal), located behind the locomotive. The container can, with a top pick, be removed when empty. A drayage

system between the liquefaction plant and the rail yard would enable the exchange of containers and eliminate the cost and logistical constraints of a dedicated LNG fuelling station on rail property. ISO containers could also be as for rail locomotive fuelling stations in a rail yard provided the station meets federal, state and local regulations.

Vessel fuelling by ISO LNG Containers:

ISO LNG containers can be used in two ways to provide vessel fuel. They may be used to deliver the fuel dockside and the fuel is then pumped into the vessel or they could be loaded onto the vessel and hooked up the vessel's fuel supply. The first option has been selected by Tote Maritime who will be using ISO LNG containers obtained from Applied Cryo Technologies. The 25 containers from ACT will be used to transport LNG from Georgia to Jacksonville where the Tote vessels will fuel. The plan is to safely and effectively fuel the ship in under six hours.²⁹ Each of Tote's new LNG vessels has twin 900-cubic-meter (238,000-gallon) tanks. On January 8, 2016 the M/V Isla Bella was bunkered by ACT ISO container at the same time that cargo was being loaded.³⁰

Conclusions:

ISO LNG container transportation by rail/truck intermodal systems is operationally feasible. LNG transportation by rail has been done in Japan, Norway and the U.S. either by specially designed freight rail cars or by intermodal container. The Japanese model had a very safe long term record of operating in densely populated areas and in close proximity to high speed passenger rail service. The intermodal service would also have a lower environmental impact than all truck operations.

An LNG tank car has the potential to be more cost effective for shipping large volumes of LNG over long distances and time periods. The Alaskan railroad's transport of LNG containers will provide a model for other railroads to expand from.

A container-based system has advantages of flexibility, including the introduction to new markets with smaller quantities. The ISO intermodal system would allow existing liquefaction plants with excess capacity to serve markets that would be too expensive to supply by all truck transportation. The ANGA and GLMRI studies cited earlier estimates the optimum distance for conversion to rail intermodal at approximately 300 miles or greater depending on congestion, as well as road and rail networks.

At this time the shipment of LNG by bulk rail car in the U.S. has not been approved by the FRA. Many other hazardous materials are currently shipped by bulk rail car. LNG bulk tank cars would have to be designed, tested and approved before any shipment could take place. If there were sufficient long-term demand that provided railroads with a viable return on investment then LNG bulk rail cars would be considered. In addition to safe operations factors such as distance, demand and economies of scale will determine if the LNG is best shipped by bulk tank car or by ISO Container. Table 3 captures many of the considerations that will be key factors in selecting bulk tank cars or container.

ISO LNG container by rail	LNG rail tank car
Small volume units.	Large volume rail cars.
Transport by rail approved by special permit from Federal Railway Administration. Some states may have a regulatory impact on the transportation of LNG.	No rail car has yet been designed, tested, and approved for use in the U.S.
Containers can be drayed by truck from between rail terminals and liquefaction plants.	Rail sidings to LNG liquefaction plants is required for loading of LNG rail cars.
Alternative truck delivery may be an option if there is rail network failure.	Rail network closure stops transportation of rail cars.
A loading/unloading system is required at terminals. Top picks, cranes or straddle carriers. Additional handling increases risk of accidents.	No special off track equipment required to load.
Containers can be used for storage at the end users location(s).	Rail car could be used for storage by customer if approved rail sidings are available.
Containers are approved and can be transferred to marine and truck modes as well as rail.	Unable to transfer rail cars to truck. Approval would be required for transfer to marine car ferries.
Containers carry less than a dedicated LNG truck. The rail ISO LNG containers require less highway mileage than all truck transport for the same movement of cargo. This means less traffic congestion, lower environmental pollution and lower costs.	Tank rail cars remove the equivalent of two and half or three trucks off the highway. This means less traffic congestion, lower environmental pollution and lower costs.

Table 3: Comparison of rail transport of ISO LNG containers and LNG rail tank cars

Rail transportation of LNG ISO containers also provides expanded options for the siting of new liquefaction plants. The plants could be built in less populated areas where suitable gas, power, road and rail service is available. The ISO LNG containers also provide increased opportunities for LNG to be supplied to vessels. Tote's use of ISO LNG containers to supply fuel can be applied in areas of the Great Lakes and the inland waterways. Vessels can be fuelled from LNG containers that arrive at nearby rail intermodal terminals and are drayed to USCG approved waterfront fuelling locations. There may also be the option, (that was not explored in this study), of placing ISO LNG containers on barges that can provide mid-stream refuelling from the ISO LNG containers to vessels alongside.

Stacking of the ISO LNG containers is done aboard ship and should be possible on rail cars and where necessary in terminals. This would allow for greater economies of scale. A successful supply chain will have a robust safety culture, a dedicated route to maximize containerized cargo, minimizing lifts, and a customer base that has year round demand. A rail/truck intermodal system in the U.S. should reduce the distribution costs, compared to all truck, over distances of 300 miles or greater where the supply chain fits the railroad's network.

Critical to the successful operation of an LNG ISO Container Supply chain will be the adoption of a robust safety culture. Based on the observation of the Japan LNG Intermodal System a safety culture must be collaborative among all supply chain partners. The safety culture must be a paramount objective in all planning, construction, training, financial consideration and operations.

ACKNOWLEDGMENTS

The authors would like to thank the support given by: The U.S. Maritime Administration, the University of Wisconsin-Superior. Dr. Denver Toliver and Douglas Benson from North Dakota State University. Ms. Yoshiko Araki, Mr. Yuji Kobayashi, Mr. Yuki Goto from JAPEX, Mr. Koji Nishimura, Mr. Takashi Nakamura, Mr. Tetsuya Morita, Mr. Manabu Tamura and Mr. Takashi Nakamura

from JR Freight, Mr. Mitsuru Ouchi, and Mr. Tamio Nishio, from JOT, Mr. Hideo Aoki from Kanazawa Water & Energy, Mr. Koei Yasui, from Komatsu Gas. Representatives from all of the Japanese companies assisted with the tours, were forthright in answering questions and were very gracious hosts. They set aside their normal duties to travel to the locations and participated in the multi-day tour.

Endnotes

¹ United States Energy Information Administration, (EIA), “Technically Recoverable Shale Oil and Shale Gas, An Assessment of 137 Shale Formations in 41 Countries Outside the United States” June 13, 2013.

² Stewart, Richard, Wolsz, Carol. and Helland, Randall. "MARAD/Great Lake LNG/Repowering Study: Phase II Cooperative Agreement # DTMA1H11002 Final Report." Liquefied Natural Gas (LNG) Fuel Supply Meeting. Accessed July 6, 2015. <http://www.glmri.org/research/LNGPhaseII.php>.

³ "LNG Opportunities for Marine and Rail." American's Natural Gas Alliance. October, 2014. Accessed July 21, 2015. [http://anga.us/media/blog/2C4CAA90-5056-9F69-D4A529A12FD0D7D4/files/LNG Opportunities for Marine and Rail.pdf](http://anga.us/media/blog/2C4CAA90-5056-9F69-D4A529A12FD0D7D4/files/LNG%20Opportunities%20for%20Marine%20and%20Rail.pdf).

⁴ TIAx for America's Natural Gas Alliance "U.S. and Canadian Natural Gas Vehicle Market Analysis: Liquefied Natural Gas Infrastructure, Final Report" page 52, 2013.

⁵ Dr. Phani Raj FRA Office of Safety, E-mail message to Author, May 14, 2014

⁶ Ms. Yoshiko Araki, (Manager LNG Satellite Group Marketing & Sales Dept. I Marketing & Sales Division) and Mr. Yuki Goto, (Media and Shareholder Relations Group Media and Investor Relations Dept.) in discussion with author.

⁷ Mr. Mitsuru Ouchi, (General Manager LNG Transport Dept.) and Mr. Tamio Nishio, (Chief LNG Transport Dept.) in discussion with author.

⁸ Mr. Koji Nishimura, (General Manager Overseas Business Office Administration Dept.), Mr. Takashi Nakamura, (Manager Energy & Chemical Group) Mr. Tetsuya Morita, (Marketing Management Dept. Sales Dept.) in discussion with author.

⁹ Mr. Shigeyuki Mogami, (LNG Receiving & Shipping Section) in discussion with author.

¹⁰ 高圧ガス保安法 High Pressure Gas Safety Act (昭和二十六年六月七日法律第二百四号) (Act No. 204 of June 7, 1951)

¹¹ Mr. Manabu Tamura (Assistant Stationmaster), Mr. Takashi Nakamura (Manager Energy & Chemical Group Marketing Management Dept.), and Mr. Kazunori Hirasawa (Niigata branch) in discussion with author

¹² Railway Business Act (昭和六十一年十二月四日法律第九十二号) (Act No. 92 of December 4, 1986) Japan Regulations Article 183 (1)

¹³ Mr. Hideki Terabayashi, (Stationmaster) and Mr. Yukio Tsuchiya, (Assistant Stationmaster with Mr. Takashi Nakamura, Manager Energy & Chemical Group Marketing Management) in discussion with author

¹⁴ Mr. Hideo Aoki, (Chief of Gas Section gave a briefing and tour of the facility with JOT, JAPEX and Komatsu personnel participating) in discussion with author

¹⁵ Benson, Douglas. "Railroad Movements of 'Liquefied Gases Coal or Petroleum' STCC 29121 Surface Transportation Board Public Waybill Examination of Railroad Car Types Utilized in 2013", Great Plains Institute, University of North Dakota, Fargo, North Dakota. 2015.

¹⁶ Ragnar. Martin, "Rail transportation of liquid methane in Sweden and Finland", *SGC Rapport 2014:295*, Svenskt Gastekniskt Center AB, Malmö, 2014. www.sgc.se

¹⁷ LNG World News "VTG, Brunsbüttel Ports target LNG infrastructure development" accessed January 30, 2015. <http://www.lngworldnews.com/vtg-brunsbuttel-ports-target-lng-infrastructure-development/>

¹⁸ Hubbard, Russell. "Union Pacific aims to be first railroad to haul liquefied natural gas" *World-Herald*, March 19, 2015.

¹⁹ Title 49 Code of Federal Regulations Chapter, 1. I (10–1–12 Edition) § 172.101 and § 172.102 iii) T50. "When portable tank instruction T50 is referenced in Column (7) of the § 172.101 Table, the applicable liquefied compressed gases are authorized to be transported in portable tanks in accordance with the requirements of § 173.313 of this subchapter. (iv) T75. When portable tank instruction T75 is referenced in Column (7) of the §

172.101 Table, the applicable refrigerated liquefied gases are authorized to be transported in portable tanks in accordance with the requirements of § 178.277 of this subchapter.”

²⁰ Title 49 Code of Federal Regulations, Chapter 1. I (10–1–12 Edition) § 174.63, “Portable tanks, IM portable tanks, IBCs, Large Packaging, cargo tanks, and multi-unit tank car tanks. (a) A carrier may not transport a bulk packaging (e.g., portable tank, IM portable tank, IBC, Large Packaging, cargo tank, or multi-unit tank car tank) containing a hazardous material in container-on-flatcar (COFC) or trailer-on-flatcar (TOFC) service except as authorized by this section or unless approved for transportation by the Associate Administrator for Safety, FRA.”

²¹ Meeting with Florida East Coast Railroad officials in Ft. Lauderdale, FL September 21, 2015

²² Piellisch, Rich, “Alaska Railroad Cleared to Move LNG” HHP Insight, October 26, 2015.

²³ Fisher, Joe, “LNG by Rail Now an Option For Interior Alaska”, *Natural Gas Intelligence*, October 14, 2015.

²⁴ Transportation Security Administration, Accessed October 02, 2015. https://www.dhs.gov/xlibrary/assets/pso_cat_tsa.pdf

²⁵ Vantor, David and Jeremy Dockter, “NYS Liquefied Natural Gas (LNG) 6 NYCRR Part 570 Promulgation Support Study”, prepared for the *New York State Energy Research and Development Authority, Expansion Energy LLC*. September 20, 2011.

²⁶ Texas Commission for Railroads “Regulations for Compressed Natural Gas and Liquefied Natural Gas” January 2013.

²⁷ Torine Elisabeth Lie, “LNG Bunkering – From Idea to Operations”, TINV / MarTech LNG Conference, Copenhagen, October 22, 2013.

²⁸ Vantuono, William C. “Experts weigh in on LNG”, *Railway Age*, September 06, 2013.

²⁹ Piellisch, Rich, “25 IMO Units ‘A Critical Part of the LNG Supply Chain”, *LNG, Marine*, April 17, 2015.

³⁰ Pielisch, Rich, “Perla Joining Isla Bella In Florida” February 8, 2016, *Marine, Milestones, HHP Insights*, http://hhpinsight.com/marine/2016/02/totes-perla-joins-sister-isla-bella-in-florida/?utm_source=HHP+Insight+February+11%2C+2016&utm_campaign=HHP+Insight+Newsletter+Jan+14&utm_medium=email. Accessed February 9, 2016

References:

Benson, Douglas. “Railroad Movements of ‘Liquefied Gases Coal or Petroleum’ STCC 29121 Surface Transportation Board Public Waybill Examination of Railroad Car Types Utilized in 2013”, Great Plains Institute, University of North Dakota, Fargo, North Dakota. 2015

Hubbard, Russell. “Union Pacific aims to be first railroad to haul liquefied natural gas” *World-Herald*, March 19, 2015.

LNG World News “VTG, Brunsbittel Ports target LNG infrastructure development” accessed January 30, 2015.

<http://www.lngworldnews.com/vtg-brunsbittel-ports-target-lng-infrastructure-development/>

LNG Opportunities for Marine and Rail." American’s Natural Gas Alliance. October, 2014. Accessed July 21, 2015. [http://anga.us/media/blog/2C4CAA90-5056-9F69-D4A529A12FD0D7D4/files/LNG Opportunities for Marine and Rail.pdf](http://anga.us/media/blog/2C4CAA90-5056-9F69-D4A529A12FD0D7D4/files/LNG%20Opportunities%20for%20Marine%20and%20Rail.pdf).

Meeting with Florida East Coast Railroad officials in Ft. Lauderdale, FL September 21, 2015. Conference call with CN supply chain and LNG managers November 18, 2015

Piellisch, Rich, “25 IMO Units ‘A Critical Part of the LNG Supply Chain”, *LNG, Marine*, April 17, 2015.

Pielisch, Rich, “Perla Joining Isla Bella In Florida” February 8, 2016, *Marine, Milestones, HHP Insights*, http://hhpinsight.com/marine/2016/02/totes-perla-joins-sister-isla-bella-in-florida/?utm_source=HHP+Insight+February+11%2C+2016&utm_campaign=HHP+Insight+Newsletter+Jan+14&utm_medium=email. Accessed February 9, 2016

Ragnar. Martin, “Rail transportation of liquid methane in Sweden and Finland”, SGC Rapport 2014:295, Svenskt Gastekniskt Center AB, Malmö, 2014. www.sgc.se

Railway Business Act (昭和六十一年十二月四日法律第九十二号) (Act No. 92 of December 4, 1986) Japan Regulations Article 183 (1)

Stewart, Richard, Wolosz, Carol, and Helland, Randall. "MARAD/Great Lake LNG/Repowering Study: Phase II Cooperative Agreement # DTMA1H11002 Final Report." Liquefied Natural Gas (LNG) Fuel Supply

Meeting. Accessed July 6, 2015. <http://www.glmri.org/research/LNGPaseII.php>

Texas Commission for Railroads “Regulations for Compressed Natural Gas and Liquefied Natural Gas” January 2013.

TIAX for America’s Natural Gas Alliance “U.S. and Canadian Natural Gas Vehicle Market Analysis: Liquefied Natural Gas Infrastructure, Final Report” page 52, 2013

Title 49 Code of Federal Regulations, Chapter 1. I (10–1–12 Edition) § 174.63, “Portable tanks, IM portable tanks, IBCs, Large Packaging, cargo tanks, and multi-unit tank car tanks. (a) A carrier may not transport a bulk packaging (e.g., portable tank, IM portable tank, IBC, Large Packaging, cargo tank, or multi-unit tank car tank) containing a hazardous material in container-on-flatcar (COFC) or trailer- on-flatcar (TOFC) service except as authorized by this section or unless approved for transportation by the Associate Administrator for Safety, FRA.”

Meeting with Florida East Coast Railroad officials in Ft. Lauderdale, FL September 21, 2015. Conference call Torine Elisabeth Lie, “LNG Bunkering – From Idea to Operations”, TINV / MarTech LNG Conference, Copenhagen, October 22, 2013

Transportation Security Administration, Accessed October 02, 2015. https://www.dhs.gov/xlibrary/assets/pso_cat_tsa.pdf

Vandor, David and Jeremy Dockter, “NYS Liquefied Natural Gas (LNG) 6 NYCRR Part 570 Promulgation Support Study”, prepared for the New York State Energy Research and Development Authority, Expansion Energy LLC. September 20, 2011.

Vantuono, William C. “Experts weigh in on LNG”, *Railway Age*, September 06, 2013.

United States Energy Information Administration, (EIA), “Technically Recoverable Shale Oil and Shale Gas, An Assessment of 137 Shale Formations in 41 Countries Outside the United States” June 13, 2013.