MARAD/Great Lake LNG/Repowering Study: Phase II
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Phase II Report
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Natural Gas Re-Powering Study, Phase II Report

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Executive Summary

The international marine market is moving forward quickly and competitively to convert to Liquefied Natural Gas (LNG). The U.S. is seeing early adopters converting to LNG for vessel operations. Rail has also invested heavily in research and development into converting a percentage of their locomotives to either LNG or Compressed Natural Gas (CNG). The rail and trucking industry are facing natural gas (NG) availability issues, despite there being a surplus of NG. The problems are created by a NG supply chain still in its infancy and a regulatory process trying to catch up to a rapidly evolving new market.

This Phase II LNG report geographically expanded on the Great Lakes Maritime Research Institutes (GLMRI) Phase I report's regulatory analysis by including research into the regulatory structure in the Ohio River system. Because there are so many federal, state and local government agencies in the U.S. that have jurisdiction over some aspect of LNG, the analysis was divided into functional areas that conform to the study parameters. There are agencies that have jurisdiction over the vessel (ship) and agencies that have jurisdiction over the facility that stores and/or transfers LNG to the vessel. Facility types are further broken down into fixed facilities (storage tanks or liquefaction plant) and mobile facilities (LNG tank truck).

The primary regulatory issue that is unique to the River system is the likelihood of mid-stream fuel transfers. This process will have to be addressed as it is common in the rivers. Another factor to be considered is that there is the potential for a barge to carry LNG fuel for a tug that is pushing the raft of barges. The size of the tugs limits storage space for LNG tanks and the use of a barge as a tender is being considered. The barge may be dedicated for LNG service or transport one or more LNG containers that serve as the fuel tanks. Refueling by bunker barge was also examined as part of this project. Tables 1, 2 and 3 summarize these results.

The initial study of an LNG supply chain was expanded in the Great Lakes and the Ohio River system. Establishing a supply chain system along the Ohio River that can provide LNG to tow boats is critical to the success of conversion to LNG. This can be accomplished by tank truck, fixed facility (LNG storage tank or liquefaction plant) or by tank barge. There are a number of options for refueling:

- Tank truck fueling at the dock.
- Construction of designated facilities (either LNG storage tanks or liquefaction plants) along the Ohio River that the tow boat can refuel. This option would most likely require the tow boat to disconnect from their tow, conduct bunker operations then reconnect. This would most likely cause an operational delay. A cost/benefit analysis would need to be completed by the company before making a determination.
- Refueling by an LNG tank barge at a dock, anchorage area, fleeting area or while underway in the river. If approved, there will most likely be operational restrictions required by the Coast Guard that are not currently in place.

An analysis was made with companies of the requirements for establishing a liquefaction plant to provide the LNG for marine fuel. Siting of the plant also requires a market beyond just the marine industry. Additional markets were explored in depth. Other modes of transportation were evaluated, along with non-transportation user groups. Research was undertaken of LNG distribution systems by rail, truck, vessel and container. Literature about LNG distribution supply chains in Europe and Japan was gathered and analyzed. GLMRI continues to pursue initiatives to develop supply chains to support the use of LNG as a maritime fuel, along with identifying the training requirements to support the use of LNG for the industry and user communities.

The key to developing an LNG supply chain will be the reliable availability of LNG that serves a variety user groups. To do this, there will need to be liquefaction plants in locations that will allow the distribution of the product to user groups. The major deciding factor in determining the location of a liquefaction plant will be the availability of natural gas. This means the liquefaction plants will be located as close as possible to large natural gas pipelines that can deliver an abundant supply at a relatively high pressure. The second most important factor will be demand for the product. Developers building liquefaction plants as part of the LNG supply chain want to have as large a customer base as possible for two critical reasons: The larger the user base, the less volatility in sales due to economic factors impacting any single user group. Also the increased demand from an extensive user base allows the building of larger liquefaction plants that achieve better economies of scale. Plant developers have indicated that having a keystone customer or two is critical for startup, and then the user base will be expanded as LNG becomes more readily available.

This report looked more in depth at establishing an LNG marine fueling terminal in the Great Lakes through a case study analysis. The marine terminal in Duluth, Minnesota was found to have the potential to be converted to providing LNG fuel to vessels. This model can serve other ports that are considering an LNG fueling terminal. To be successful there needs to be adequate LNG storage tank space, a safe zone around the terminal, access to LNG, suitable docks and a large enough LNG marine market to justify the cost of conversion.

GLMRI prepared products, reports and articles and provided presentations and other outreach materials to educate and advocate the economic and environmental benefits of moving the maritime industry along with other industry sectors to natural gas. Also, GLMRI continued to support educational and outreach venues that advocate shipping and maritime commerce. GLMRI worked cooperatively with natural gas suppliers and developers, along with other modal segments to embrace the entire market for LNG use and supply chain synergies. GLMRI continues to work with federal, state and local agencies, and has regularly met with MARAD, The St. Lawrence Seaway Development Corporation (SLSDC) and the U.S. Coast Guard to support regulatory issues concerning natural gas fueling, operations and training in the maritime industry. Outreach program were held in various locations in the Great Lakes region. Presentations were made on the research in Great Lakes communities, Ohio River forums, Washington, D.C. and the Council of Great Lakes Governors.

GLMRI was limited in the scope of their work and provides recommendations for further research and action.

- Continue development of the Great Lakes and Inland Waterways LNG Supply Chain. Research needs to continue to further develop the LNG supply chains to support maritime operations and multi-modal use of LNG as a fuel to reduce energy costs, air emissions with a secure North American gas supply.

- Support Developing New LNG Container Transportation Corridors. The production and demand for LNG is increasing and the forecast is for even greater growth and the option of moving the product by ISO containers domestically could provide economic advantages.

- Study the refinement of the Integrated Electric Plant/LNG Option. Building on earlier research by GLMRI, research could be done on how Integrated Electric Plants could be improved with the use of LNG as a primary fuel and modular concepts.

- Research into the Feasibility and Benefits of Hybrid Mechanical-Electrical LNG Fueled Propulsion in Future Great Lakes Bulk Carriers. Coupled with the use of dual fuel LNG engines, a hybrid mechanical-electrical plant with batteries could provide the most efficient and greenest option for future coastal, inland river and Great Lakes vessels.

- Work through the CMTS to fund a federal program to convert government ships to LNG, with a long-term goal of funding a standardized new build of a fleet of ships.

- A comparative environmental study should be done to look at the entire fuel supply chain from well to stack for diesel fuel and NG.

- Diesel engines that use natural gas as a primary or sole fuel operate at lower decibel ranges than diesel engines that use diesel fuel as the primary or sole fuel. The GLMRI research team believes that there is need for research in two critical areas related to the noise reduction of natural gas fueled diesel engines.
    1. The environmental impact on humans and communities of the reduced decibel levels when operating trains, ships and other high horsepower systems on natural gas.
    2. The environmental impact on marine life of the reduced decibel levels when ships operate on natural gas.

- Support early adopters of improved LNG technology as they are taking the greatest risk. Support can be financial and or institutional.

- An ongoing program of public outreach and education is essential for stakeholder understanding of the potential benefits and issues related to conversion of marine vessels to NG.

- An engineering study needs to be conducted on all tow boat sizes that operate on the Ohio River to determine the feasibility of adopting LNG technology.

- A study should be undertaken to assess Scrubber HazMat Disposal Issues including MARPOL approved locations in the Great Lakes and inland waters and the process of disposal**.**

MARAD's continued leadership role in this public/private partnership is essential to moving forward with the transition, where appropriate, to NG as a marine fuel. MARAD is able to interact cooperatively with other key government agencies is able to engage foreign agencies who are also involved with developing NG as a marine fuel. The multi-modal nature of the supply chain as well as the fuel uses places MARAD in a pivotal role as the agency supporting the marine industry that can transport the bulk of the LNG.

Introduction

In August 2011, GLMRI received a five year cooperative agreement with the Maritime Administration (DOT/MARAD) to address environmental issues that face shipping and marine transportation. Specific study topics are directed by MARAD that will benefit not only maritime commerce in the Great Lakes region, but other transportation modes along with ports and vessels operating on the inland rivers and coastal waters.

In the second year of the cooperative agreement, MARAD supported a limited study to extend the analysis of the rules, regulations and safety for LNG, with specific focus on the midstream fuel transfer for the inland waters, including both the Great Lakes and rivers. This phase of the study included a review of the existing rules for midstream bunkering and analyzed the procedures for LNG barge bunkering that is on-going in other countries. Within the limited scope, a focus on the LNG supply for the Ohio River System was examined along with vessel to vessel design configurations for bunkering.

Additionally, GLMRI continued to pursue initiatives to develop supply chains to support the use of LNG as a maritime fuel, along with identifying the training requirements to support the use of LNG for the industry and user communities. GLMRI prepared products, reports and articles and provided presentations and other outreach materials to educate and advocate the economic and environmental benefits of moving the maritime industry along with other industry sectors to natural gas. Also, GLMRI continued to support educational and outreach venues that advocate shipping and maritime commerce. GLMRI worked cooperatively with natural gas suppliers and developers, along with other modal segments to embrace the entire market for LNG use and supply chain synergies. GLMRI continues to work with federal, state and local agencies, and has regularly met with MARAD, The St. Lawrence Seaway Development Corporation (SLSDC) and the U.S. Coast Guard to support regulatory issues concerning natural gas fueling, operations and training in the maritime industry.

Update on the Existing Maritime Usage of Liquefied Natural Gas (LNG)

The international marine market is moving forward quickly and competitively to convert to LNG. ***HHP Insight*** reported that AGA Linde announced plans in January 2013 to construct the first LNG tank barge in the world that will service LNG fueled vessels in Stockholm, Sweden (Piellisch, 2013). The LNG bunker boat *Seagas* will provide LNG to Viking Line's *Viking Grace*. The *Seagas* is a converted ferry from Norway, originally built in 1974, is 157 feet and can transport about 70 tons (50,000 gallons) of LNG but she would continue to run on diesel. (See Figure 1)

Figure 1: LNG bunker boat *Seagas* (Piellisch, 2013)

On March 19, 2013, Shell launched the first 100% LNG powered barge, the *Greenstream* (Shell Global, 2013). The *Greenstream* was built and designed at Peters Shipyards in The Netherlands to support LNG fuel industry on the Rhine River region, including The Netherlands, Belgium, Germany and Switzerland, with the potential to support inland barges, ferries, tugs and cruise ships.

Figure 2: LNG bunker barge *Greenstream* (Piellisch, Shell Launches All-LNG Barge, 2013)

The International Maritime Organization (IMO) has continued work to develop international standards to address the safety and security of LNG bunkering operations, and the training and qualifications of personnel involved in those operations. International standards that address LNG fueled engines on ships are found in IMO Resolution MSC 285(86), Interim Guidelines For Gas-Fuelled Engine on Ships. Most of the classification societies around the world have adopted these standards. In 2011, Working Group 10 (WG 10) within the Technical Committee 67 (TC 67) of the International Organization for Standardization (ISO) drafted international guidelines for bunkering of gas-fueled vessels focusing on requirements for the LNG transfer system, the personnel involved and the related risk of the entire LNG bunkering process. A draft technical report was released in June 2013. The goal of the working group is that the standards will be finalized in 2014.

To fuel the Great Lakes region, in March 2013, Shell announced their plans to build a liquefaction plant in Sarnia, Canada that will service the maritime industry on the lower Great Lakes. Other companies are evaluating other Great Lakes locations for building new liquefaction plants. In May 2013, Interlake Steamship Company (ISC) announced their decision to convert to LNG, and at the High Horsepower Summit in Chicago, Illinois on September 17, 2013 released the names of their conversion team companies and their plans to convert the *M/V Mesabi Miner* to dual fuel with LNG. Although, on March 20, 2014, Shell announced that they are "pausing" on their construction plans for the Sarnia, Ontario plant, along with the Geismar, Louisiana plant to allow them an opportunity to review LNG-for-transport opportunities in North America. Initial understanding is that Shell is still committed to supply their customers in the Gulf and Great Lakes regions with existing gas sources.

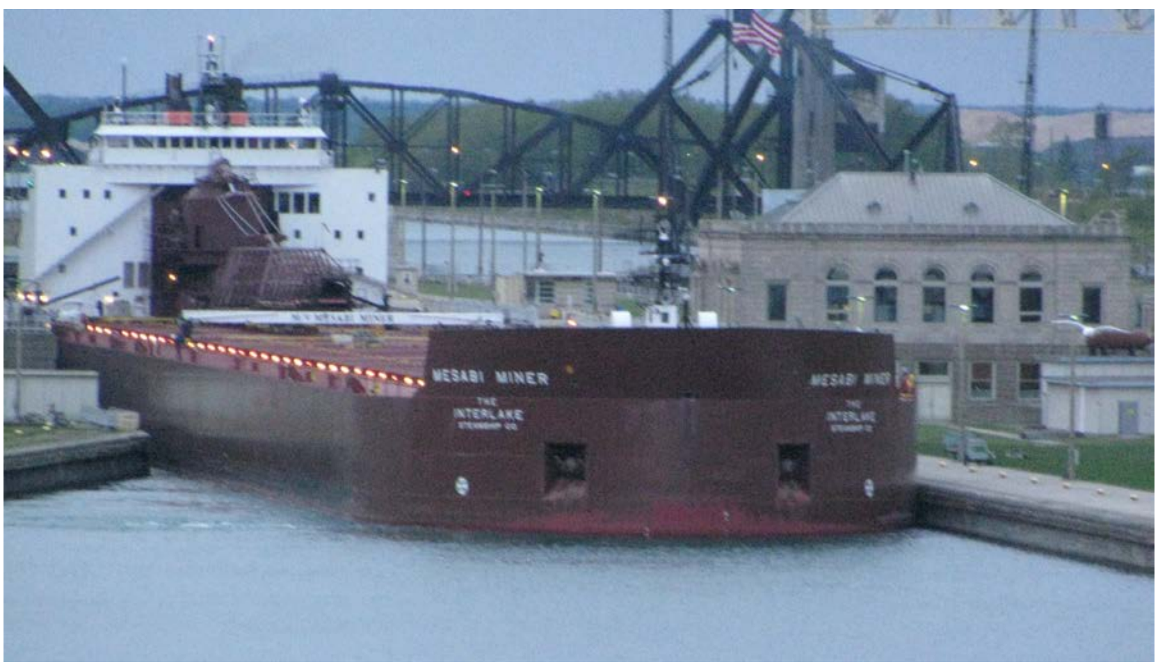


Figure3. *M/V Mesabi Miner,* exiting the Poe Lock, May 2012. (photo by C. Wolosz)

TOTE (Totem Ocean Trailer Express) is progressing with their LNG conversions. In February 2014, TOTE announced that Wärtsilä will supply main engines, generators and integrated LNG storage and fuel gas handling systems (LNGPac™) for the LNG conversions of two Orca Class roll-on/roll-off cargo ships – *M/V Midnight Sun* and *M/V North Star*. These vessels transport about one-third of all the goods required by the inhabitants of Alaska.

Figure 4. *M/V North Star* (Photo by Rich Piellisch, Fleets and Fuels (August 2012) www.fleetsandfuels.com *)*

TOTE is also having two new LNG state-of-the-art containerships for the Puerto Rico trade built, with options for three more vessels for additional domestic service with General Dynamics NASSCO in San Diego, California.

Figure 5. Artist's rendering. (General Dynamics NASSCO (www.nassco.com) December 2012)

Recently (February 24, 2014) Jensen Maritime, Crowley Maritime Corp.'s Seattle-based naval architecture and marine engineering company, was awarded a contract to design some of the LNG bunker barges in the U.S. for customer LNG America LLC, a Houston-based LNG fuel supply and distribution company. As of this report, there are no LNG bunkering barges in operation in American waterways. This is a significant step in the development of LNG bunkering infrastructure along the U.S. Gulf Coast and in delivering a new clean fuel to the maritime industry. The barges are expected to be delivered in late 2015, with a planned capacity of up to 3,000 cubic meters of LNG. Once in operation, the bunker barges will serve the dual purpose of moving LNG from LNG America's Louisiana supply source to coastal-based storage and distribution terminals and in directly bunkering large ships. (www.crowley.com)

Figure 6. Jensen Maritime, Design Rendition of LNG Bunker Barge. February 2014.

This development ties in with Crowley Maritime Corporations' petroleum services group acquiring Carib Energy in May 2013. Florida-based Carib Energy, founded in 2011, was the first company to receive a small scale, 25-year, LNG export license from the U.S. Department of Energy (DOE) for LNG transportation from the U.S. into Free Trade Agreement (FTA) countries. Their strategy is to leverage their extensive resources to serve the LNG market through LNG vessel design and construction; transportation; product sales and distribution, and full-scale, project management solutions. The acquisition of Carib Energy allows Crowley to provide LNG from the U.S. to both commercial and industrial customers within the Caribbean and Central and South America – all countries where LNG is an attractive commodity due to its low price. The barges will provide a reliable supply, transportation, and distribution of LNG via 10,000 gallon ISO tanks.

Ohio River Area – Case Study

The international community and U.S. government are making strides in developing standards and regulations for LNG bunkering. With the current price of natural gas along with pressure from the EPA, there is increased interest in the maritime industry for this technology. This part of the study analyzes the feasibility of implementing LNG as maritime fuel on vessels that operate on the Ohio River, and it addresses potential land-based and midstream refueling options.

- Background on Ohio River Towboat Shipping

The inland waters of the United States contain nearly 12,000 miles of water and approximately 192 locks. (See figure 3 below) A study conducted by the Texas Transportation Institute entitled A Modal Comparison of Freight Transportation Effects on the General Public stated the inland waterways move commerce to and from 38 states throughout the nation’s heartland and Pacific Northwest, serve industrial and agricultural centers, and facilitate imports and exports at gateway ports on the Gulf Coast (Texas Transportation Institute, 2011). Waterways transport more than 60% of the nation’s grain exports, about 22% of domestic petroleum and petroleum products and 20% of the coal used in electricity generation. These commodities are transported by tug and barge**.**

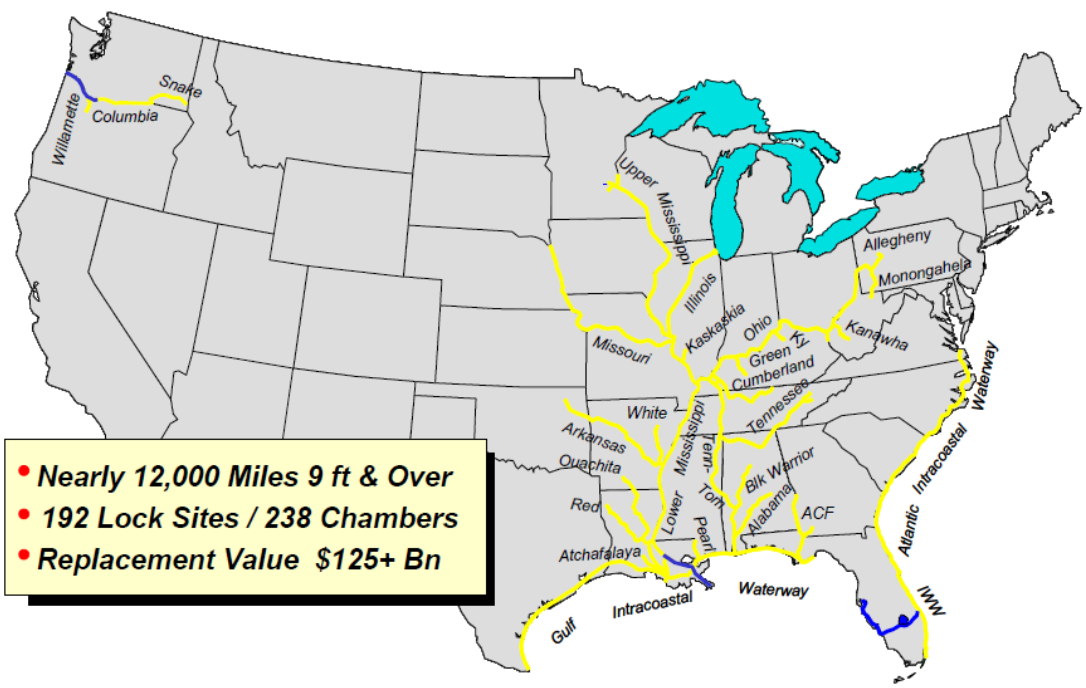


Figure 7: Inland River Figures for the U.S. (US Army Corps of Engineers)

The Ohio River is 981 miles long, starting at the confluence of the Allegheny and the Monongahela Rivers in Pittsburgh, Pennsylvania, and ending in Cairo, Illinois, where it flows into the Mississippi River. The Ohio River flows through or borders six states: Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. In addition, water from parts of New York, Virginia, North Carolina, Tennessee and Alabama drain into tributaries that empty into the Ohio River. The Ohio River system contains 19 locks and dams that span the area from Pittsburgh, Pennsylvania to Cairo, Illinois (See figure 4 below). While the Ohio River valley is home to almost 10 percent of the U.S. population, there are large sections of the river that are extremely remote.

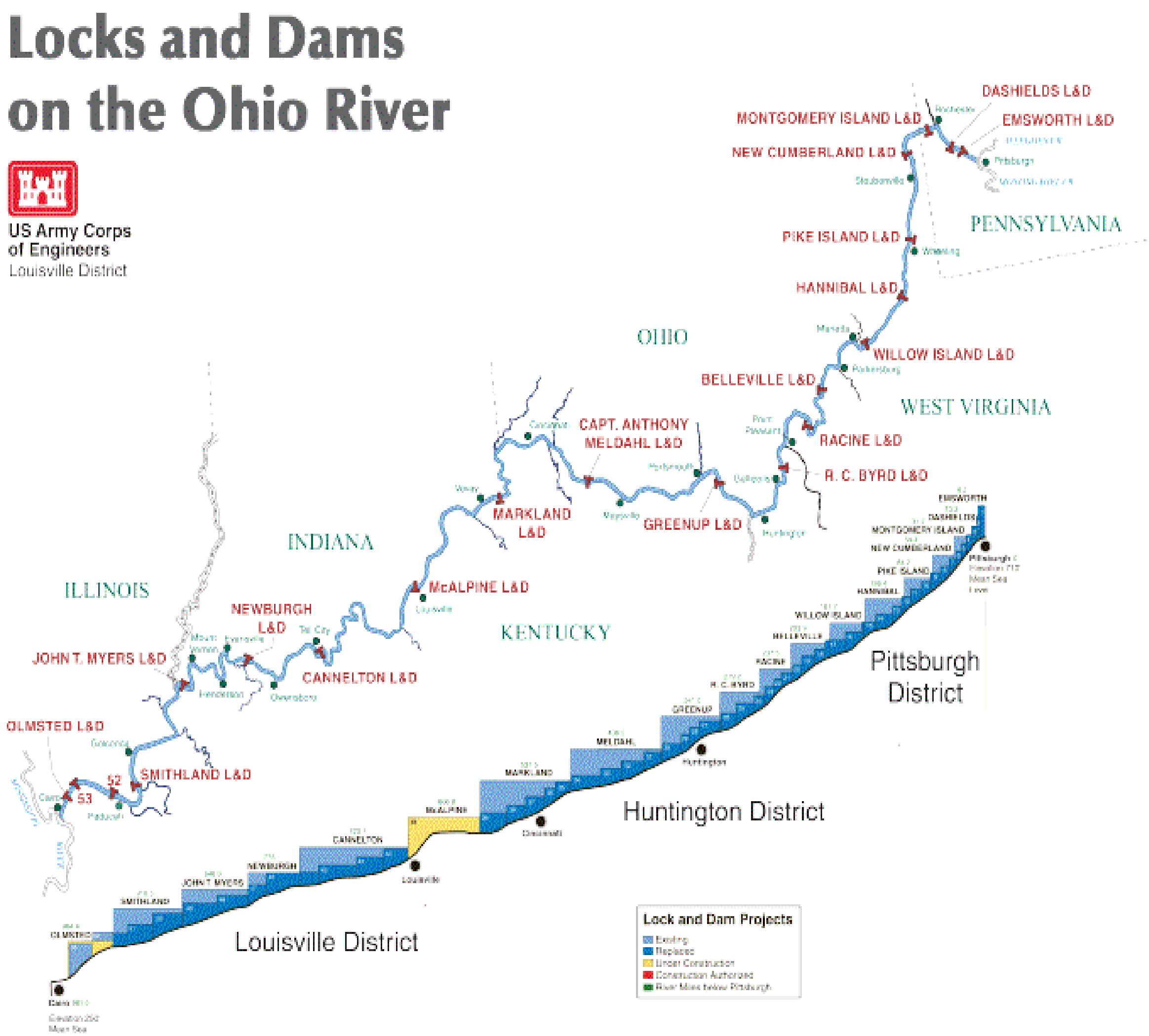


Figure 8: Army Corps of Engineers, Louisville District, Ohio River Locks and Dams (US Army Corps of Engineers)

The commercial industry that operates on these waters includes mostly tow boats with barges along with a few small passenger vessels. The tow boats vary in size and horsepower based on the location in the river and the size limitations of the locks. The U.S. Army Corps of Engineers prepared a study on the Upper Ohio River Navigation. The locks in the upper area were built prior to World War II, and the lock chamber sizes are well below the locks on the lower Ohio River. Many tows have to "double lock" through the chambers causing inefficiencies for both the locks and the tows. The navigation channels along the Ohio River are maintained to a minimum depth of nine feet. A large amount of the coal traffic out of West Virginia and Ohio will travel up the Ohio River to steel and power generation plants on the Monongahela River above Pittsburgh, Pennsylvania. Due to the length constraints of the lock chamber, the tow has to be split in half to transit the locks. This is a time intensive process.

Towboats that operate on the Ohio River generally range in size from 100 to 200 feet long, 26 to 35 feet wide and 1,000 to 9,000 horsepower. Because there are no locks below St. Louis, Missouri on the Mississippi River, tow boats on that part of the Mississippi are much larger (about 10,000 horsepower) and can accommodate larger tows as compared to the Ohio River traffic.

Many of the towboats, as they age, have to be repowered due to the obsolescence of the original engines. Below is a picture of an Ohio River towboat, the *W. Scott Nobel* that was retrofit with new EMD engines in 2011. When interviewing the company operations manager and engineers, they said that it was unlikely that they would consider converting to natural gas in the near future due to space considerations, tank locations, and bunkering. The towboat was originally built in 1966. (Kern, 2013)

Figure 9. *Towboat W. Scott Noble* on the Ohio River, October 22, 2011, Ingram Barge Co. (160 x 40 feet)

While tow boats would be a natural fit for the application of LNG propulsion technology, there are several significant hurdles that need to be overcome.

- Small tow boats bring space challenges for LNG engines and fuel tanks for retrofitting the existing fleets. Rolls Royce has released a design for an LNG fueled line haul towboat, but sized for the lower Mississippi River area. The USACE has been advocating for funding to re-construct and expand the locks on the Upper Ohio River. If that were to happen, barge companies might have the stimulus to update their towboat fleets, which would open consideration for new construction with LNG fuel power and technology.

- The location of the LNG fuel tank on the boat may be a limiting factor. The current Coast Guard policy prohibits the placement of LNG fuel tanks above or below accommodation spaces. Working closely with the Coast Guard and applicable classification society early on in the process is critical to success for both retrofit and new construction designs.

Along all U.S. waterways including the Ohio River, the U.S. Coast Guard has the statutory responsibility to administer vessel inspection laws which ensure that both U.S. flag and foreign flag vessels are safe and well equipped for their intended service. Inspections of vessel safety systems include the following: hull inspections, main/auxiliary power inspections, electrical systems inspections, lifesaving system inspections, firefighting systems inspections, navigation equipment inspections and pollution prevention inspections. The U.S. Coast Guard delegates this responsibility to the Officer in Charge, Marine Inspection. There are four basic categories of vessels subject to inspection. They are passenger vessels, tank vessels, cargo vessels and special use vessels such as offshore drilling units, offshore supply vessels, oceanographic research vessels, oil spill response vessels, nautical school vessels and sailing school vessels. Towing vessels are not currently included in the list of inspected vessels. However, as noted above, the Coast Guard has published a Notice of Proposed Rulemaking on August 11, 2011 which proposes safety regulations governing the inspection, standards, and safety management systems of towing vessels. Until that time, the Coast Guard implemented a Towing Vessel Bridging Program (TVBP) to ease the transition and ensure that both the Coast Guard and the towing vessel industry are informed and prepared to meet the new requirements. This is accomplished through an extensive outreach, education and voluntary uninspected towing vessel examination program.

The U.S. Coast Guard command responsible for the Ohio River is Sector Ohio Valley. Sector Ohio Valley includes three Marine Safety Units: Pittsburgh, Pennsylvania; Huntington, West Virginia; Paducah, Kentucky and two Marine Safety Detachments (MSD): Cincinnati, Ohio and Nashville, Tennessee. According to Coast Guard data, the tow boat fleet of responsibility for Coast Guard Sector Ohio River Valley is approximately 976. Even though

MSD Nashville is not on the Ohio River, tow boats from that area transit the river system, including the Ohio River.

- Regulatory Analysis

The tow boats that operate on the Ohio River do not need to comply with the code of federal regulations governing inspected vessels. However, the Coast Guard has published a Notice of Proposed Rulemaking on August 11, 2011 which proposes safety regulations governing the inspection, standards, and safety management systems of towing vessels. The date that the new rules will be published is unknown. Until that time, tow boat owners desiring to either convert existing engines or build new vessels with LNG fueled engines need to obtain Commandant, U.S. Coast Guard approval. The design criteria listed in Coast Guard CG-521 Policy letter number 01-12 dated April 19, 2012 would have to be followed for uninspected vessels.

There are a myriad of federal, state and local government regulations that address LNG safety and security requirements at facilities. The Army Corps of Engineers requires a permit for construction of LNG facilities (tanks and liquefaction plants) that complies with the Rivers and Harbors Act. Other federal agencies regulate production facilities that handle large quantities of LNG. The smaller amounts of LNG for refueling vessels do not currently meet production regulatory requirements. Those agencies that have regulations for LNG but do not include the smaller amounts for bunkering include: the Federal Energy Regulatory Commission (FERC) and the Department of Energy (DOE). FERC has jurisdiction over import and export of LNG. However, there is a provision in their regulations that provides an exemption for those companies that use LNG for transportation. Similarly, DOE has jurisdiction over import and export of LNG, but they do not have regulations that address small amounts of LNG for transportation.

The Environmental Protection Agency (EPA) has authority over marine engine emissions, and facility emissions and discharges. On October 30, 2009, the EPA published a mandatory reporting requirement for Greenhouse Gases (GHG) from large GHG emissions sources in the United States. EPA has also published emission standards in Title 40 CFR Part 1042 for replacement engines with engine power levels over 250Kw installed on commercial vessels operating in the U.S. For any LNG project that involves the discharge of pollutants into waters of the United States, EPA and, in some cases, a state, tribe or U.S. territory, administers applicable Clean Water Act (CWA) sections. EPA also evaluates whether the Marine Protection, Research, and Sanctuaries Act (MPRSA) applies to a project's activities.

For onshore LNG projects, as well as those located in state waters, the states or local air control agencies issue the applicable Clean Air Act permits (if EPA approves the state's program). The number of required permits will vary, depending on the design of the project, the air quality status of the area, and the amounts of different air pollutants to be emitted. States and local control agencies with authority for issuing federally-required construction and operating permits would also be responsible for issuing any air permits that might be needed to authorize construction and operation of associated pipelines in areas of state jurisdiction.

The Coast Guard exercises regulatory authority over LNG facilities that affect the safety and security of port areas and navigable waterways. The Coast Guard is responsible for matters related to navigation safety, vessel engineering and safety standards, and all matters pertaining to the safety of facilities or equipment located in or adjacent to navigable waters up to the last valve immediately before the receiving tanks. The Coast Guard also has authority for LNG facility security plan review, approval, and compliance verification as provided in 33 CFR Part 105, and siting as it pertains to the management of marine traffic in and around the LNG facility.

Coast Guard regulations in 33 CFR Part 127 (Waterfront facilities handling liquefied natural gas and liquefied hazardous gas) only applies to facilities that handle large quantities of LNG. However, there are no regulations that address LNG bunkering. Until regulations are developed and in order to address the increased interest and demand for using LNG as fuel, the Coast Guard drafted several policy letters in 2013. The first addresses Vessels and Waterfront Facilities conducting Liquefied Natural Gas (LNG) Marine Fuel Transfer (Bunkering) Operations and the other one addresses Liquefied Natural Gas fuel Transfer Operations and Training of Personnel using Natural Gas as Fuel.

There are state requirements pertaining to LNG fixed and mobile facilities. These requirements include permits for fixed facilities and compliance with the applicable National Fire Protection Association Code for mobile facilities. The states of Pennsylvania, West Virginia, Ohio, Indiana, Kentucky and Illinois require various permits to build a facility (storage tanks or liquefaction plants). They range from construction, air emission, storm, water/sewer, and NPDES permits. Facilities also need to comply with EPA's Spill Prevention Contingency and Countermeasures rules, if applicable.

Because there are so many federal, state and local government agencies in the U.S. that have jurisdiction over some aspect of LNG, the analysis was divided into functional areas that conform to the study parameters. There are agencies that have jurisdiction over the vessel (ship) and agencies that have jurisdiction over the facility that stores and/or transfers LNG to the vessel. Facility types are further broken down into fixed facilities (storage tanks or liquefaction plant) and mobile facilities (LNG tank truck). Refueling by bunker barge was also examined as part of this project. Tables 1, 2 and 3 summarize these results.

Table 1. Facility Requirements

Agency/Organization	NFPA	Regulations	Policy	IMO
USCG	YES	NO*	YES	NO
Federal Energy Regulatory Commission	NO	NO	NO	NO
Environmental Protection Agency	NO	YES	YES	NO
State of Ohio	YES	YES	YES	NO
State of West Virginia	YES	YES	YES	NO
State of Kentucky	YES	YES	YES	NO
State of Pennsylvania	YES	YES	YES	NO
State of Indiana	YES	YES	YES	NO
State of Illinois	YES	YES	YES	
Army Corps Of Engineers	NO	YES	NO	NO
Federal Motor Carrier Administration	NO	NO	NO	NO
Pipeline and Hazardous Material Safety Admin	NO	YES	NO	NO
Federal Railroad Administration	NO	NO	NO	NO
Department Of Energy	NO	NO	NO	NO

Table 2. Mobile (Tank Truck) Facility Requirements

Agency/Organization	NFPA	Regulations	Policy	IMO
USCG	YES	NO	YES	NO
Federal Energy Regulatory Commission	NO	NO	NO	NO
Environmental Protection Agency	NO	NO	NO	NO
State of Ohio	YES	NO**	NO	NO
State of West Virginia	YES	NO**	NO	NO
State of Kentucky	YES	NO**	NO	NO
State of Pennsylvania	YES	NO**	NO	NO
State of Indiana	YES	NO**	NO	NO
State of Illinois	YES	NO**	NO	NO
Army Corps Of Engineers	NO	NO	NO	NO
Federal Motor Carrier	NO	YES	NO	NO

Administration				
Pipeline and Hazardous Material Safety Admin	NO	NO	NO	NO
Federal Railroad Administration	NO	NO	NO	NO
Department Of Energy	NO	NO	NO	NO

Table 3. Vessel Requirements

Agency/Organization	NFPA	Regulations	Policy	IMO
USCG	YES	NO***	YES	NO
Federal Energy Regulatory Commission	NO	NO	NO	NO
Environmental Protection Agency	NO	YES	YES	NO
State of Ohio	NO	NO	NO	NO
State of West Virginia	NO	NO	NO	NO
State of Kentucky	NO	NO	NO	NO
State of Pennsylvania	NO	NO	NO	NO
State of Indiana	NO	NO	NO	NO
State of Illinois	NO	NO	NO	NO
Army Corps Of Engineers	NO	NO	NO	NO
Federal Motor Carrier Administration	NO	NO	NO	NO
Pipeline and Hazardous Material Safety Admin	NO	NO	NO	NO
Federal Railroad Administration	NO	NO	NO	NO
Department Of Energy	NO	NO	NO	NO

*The Coast Guard does not have regulations that apply to the transfer of small quantities of LNG from a storage facility to a vessel. The Coast Guard applies NFPA standards to their policy and regulatory efforts. The regulations in 33 CFR Part 127 applies to facilities that handle large quantities of LNG. They have drafted policy letters that are discussed below.

**The states of Pennsylvania, West Virginia, Ohio, Indiana, Kentucky and Illinois have no regulations that apply to the transfer of LNG from a tank truck to a vessel or facility. They do regulate the transportation of LNG over the roads of their respective states.

*** The Coast Guard does apply NFPA and IMO standards to their policy and regulatory efforts for inspected vessels. On the Ohio River, there are numerous tow boats and they are not inspected by the Coast Guard, however they would require Coast Guard approval for conversion to LNG fuel engines.

- Ohio River Supply Chain Analysis

Establishing a supply system along the Ohio River that can provide LNG to tow boats is critical to the success of this effort. This can be accomplished by tank truck, fixed facility (LNG storage tank or liquefaction plant) or by tank barge. There are a number of options for refueling:

- Tank truck fueling at the dock.
- Construction of designated facilities (either LNG storage tanks or liquefaction plants) along the Ohio River that the tow boat can refuel. This option would most likely require the tow boat to disconnect from their tow, conduct bunker operations then reconnect. This would most likely cause an operational delay. A cost/benefit analysis would need to be completed by the company before making a determination.
- Refueling by a LNG tank barge at a dock, anchorage area, fleeting area or while underway in the river. If approved, there will most likely be operational restrictions required by the Coast Guard.

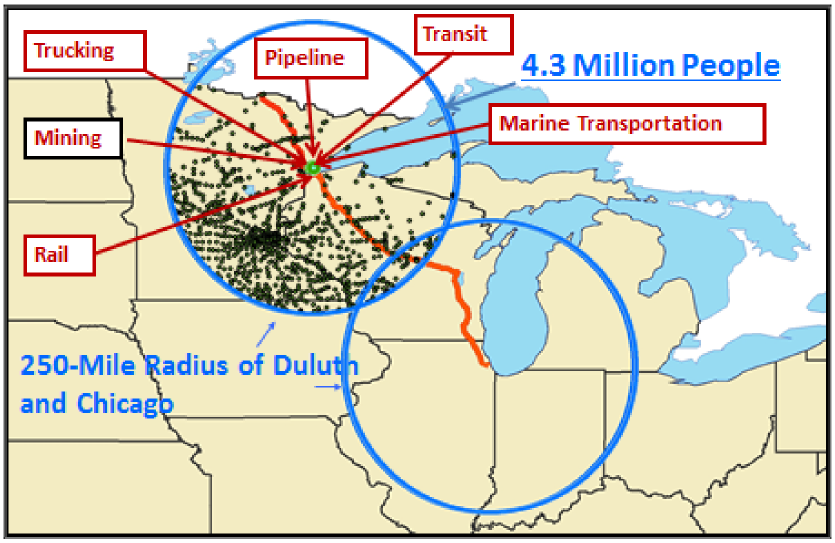
There is a significant supply of natural gas shale plays in the United States. The Marcellus play in the Pennsylvania area provides a huge supply that can be tapped for future use. An examination of the current supply chain on the Ohio River reveals no current infrastructure in place. There are a number of existing peak shaving plants, satellite peak shaving plants and import terminals around the U.S. The closest peak shaving plants to the Ohio River are located in the middle of Indiana (three locations) and one location each in Illinois and the eastern portion of Pennsylvania. There are no LNG facilities in West Virginia and Kentucky. This would be a detriment to the near term use of LNG, however, active development of the LNG supply is happening across the United States.

In the Gulf Coast Corridor, Shell Oil Company plans to install a small-scale liquefaction unit at its Shell Geismar Chemicals facility in Geismar, Louisiana. Once operational, this facility will supply LNG along the Mississippi River, the Intra-Coastal Waterway and to the offshore Gulf of Mexico and the onshore oil and gas exploration areas of Texas and Louisiana. In the Great Lakes Corridor, as mentioned earlier, Shell plans to install a small-scale liquefaction unit at its Shell Sarnia Manufacturing Centre in Sarnia, Ontario, Canada along the St. Clair River. Once operational, this project will supply LNG fuel to all five Great Lakes, their bordering U.S. states and Canadian provinces and the St. Lawrence Seaway. Although these plants will be significant contributors to support the maritime supply chain for LNG, it is unlikely that they would supply the Ohio River area due to their proximity. Also, with recent world events, Shell is pausing their plans for the short-term plant construction at both Sarnia and Geismar.

Developing the Supply Chain in the Great Lakes Region

As an extension of the GLMRI Phase I Study, GLMRI is continuing to pursue the development of the LNG Supply Chain in the Great Lakes Region. The Duluth/Superior region at the western end of the Lakes would provide a key location for a natural gas facility that could reach out to a 250 mile radius.

Twin Ports LNG Marketing Region



Key to developing a LNG supply chain will be the reliable availability of LNG. To do this there will need to be liquefaction plants in locations that will allow the distribution of the product to user groups. The major deciding factor in determining the location of a liquefaction plant will be the availability of natural gas. This fact means the liquefaction plants will be located as close as possible to large natural gas pipelines that can deliver an abundant supply at a relatively high pressure. The second most important factor will be demand for the product. Developers building liquefaction plants as part of the LNG supply chain want to have as large a customer base as possible for two critical reasons: The larger the user base, the less volatility in sales due to economic factors impacting any single user group; and the increased demand from an extensive user base allows the building of larger liquefaction plants that achieve better economies of scale. Plant developers have indicated that having a keystone customer or two is critical for startup, and then the user base will be expanded as LNG becomes more readily available. Several companies are considering building liquefaction plants in the Great Lakes and Rivers regions. These firms have supplied GLMRI with a list of general factors that are considered when planning to build a liquefaction plant.

- Physical Factors Impacting the Building of a Gas Liquefaction Plant

- Issues influencing plant size
  - Capital is major component of liquefaction cost
  - Capital efficiency improves with larger plant size generating economies of scale
- Gas Supply factors that impact building a liquefaction plant
  - Cost - Rate stacking at utility interconnect drives up LNG cost
  - Sufficient supply – A 100,000 gallons per day plant requires ~9,000 Mcf/d of gas
  - Quality-processing steps added to clean gas impurities prior to liquefaction will increase plant costs. Examples of impurities include: Heavy hydrocarbons, N_2, CO^2, H_2O, the odor additive Mercaptan
  - Pipeline pressure – Higher pressure pipelines can reduce plant compressor costs
  - There needs to be an available right of way with permitting for installing feed pipe to plant from the gas trunk lines. The cost will also be driven by the ease of interconnection along with lateral pipe ownership and the distance to plant from the trunk line.
- The need for significant electrical power access
  - A 100,000 gallon per day plant requires between 4-6 Megawatts depending on the plant's refrigerant cycle
  - Capital costs will be impacted by interconnectivity, available substations and the distance from existing power lines
  - There needs to be an exclusion zone meeting regulations that allows for vapor dispersion in the event of an LNG spill/release. Costs are lowest if the exclusion zone is best kept within property boundaries. The size and shape of the zone will be impacted by weather patterns.
- Potential plant locations need to have suitable subsurface geotechnical load bearing capacity to support LNG tanks.
- It is essential that there is access to multi-model transportation options to maximize market reach and plant efficiency. The carriers that can support the physical distribution of the product include marine, rail, and truck. GLMRI researchers have learned that the maximum distance for trucks to cost-effectively travel one-way with an LNG cargo is approximately 250 miles.

- Geo-Political Factors that Impact Liquefaction Plant Development

- A political climate that accepts the placement of a liquefaction plant in the region must exist. Incorporating education and outreach are key elements of a successful strategy to create an informed citizen body.
- Regulatory requirements drive development costs. Stringent regulations or a long lead time for regulators to make decisions will adversely impact development.

- There needs to be available industrial zoned areas that a liquefaction plant can be built in or suitable areas rezoned.
- State & federal tax regimes should not impede plant development.
- An informed local populous that is willing to have a safe liquefaction plant located in the region. This will require a stakeholder outreach program.
- The support of local business community will be necessary.
- Local and state tax incentives such as grants & loans may be a deciding factor in plant location.

Liquefaction plants come in a wide range of sizes. A medium size plant (150,000 gallons per day) will require 15-20 acres of land. Pictured below is a medium size plant located in Boron, California.

Figure 10: Clean Energy's Boron, CA 160,000 gallon per day LNG Plant. (Photo Courtesy of WESPAC Energy)

Historically, large liquefaction plants have been placed on waterfronts so that they could load large volumes of LNG onto specially designed tankers that carried the LNG to another large terminal where it was unloaded and stored for transportation or gasification. LNG marine terminals are large complexes with secure zones that could be a mile in radius. Coast Guard regulations in 33 CFR Part 127 (Waterfront facilities handling liquefied natural gas and liquefied hazardous gas) only applies to facilities that handle large quantities of LNG. GLMRI researchers do not believe that this type of waterfront based model will be used in most of the domestic LNG supply chains.   An exception may be where there might be large volume transportation by barge.

- Physical Distribution of LNG in the Supply Chain

The physical distribution of the LNG to user groups will require a suitable cost effective transportation system liquefaction plants will be located inland to avoid the high costs and taxes of waterfront land. In this regard they will be more like peak shaving liquefaction plants except that they will be able to liquefy at a faster rate. The physical distribution of the LNG to user groups will require a suitable cost effective transportation system.

Loading of LNG into carrier's equipment will take place at the liquefaction plant. The LNG will transported by truck or rail using LNG tank rail cars, trailers or containers. The transport of LNG is safer than gasoline because of LNG's low temperature, high ignition temperature and narrow range of ignition concentrations. LNG can be transported to marine terminals to be stored and loaded as vessel fuel or as cargo aboard vessels.

Japan imports natural gas and has created a hub and spoke system for the delivery of the LNG. The mountainous terrain and islands of Japan limit the use of pipelines. The Japanese hub and spoke system has been using truck, rail and marine coastal vessels for the distribution of LNG since 2000. The Japanese model offers insight into how a mature LNG physical distribution system can work.

- Marine Distribution of LNG:

The U.S. maritime industry is moving ahead in designing bunkering barges and distribution vessels. On January 14, 2014, GLMRI research team met with the U.S. Coast Guard (USCG) representatives at USCG headquarters in Washington DC. At the meeting one of the facts that the research team learned was that as of that date there were no USCG approved marine bunkering facilities. There were a couple of facilities that have applied for approval and the process was underway. On February 7, 2014 the USCG issued two draft policy letters addressing operating policies for LNG fuel transfer operations and training of personnel on vessels that use natural gas as fuel. The draft operations policy letter provides voluntary guidance for LNG fuel transfer operations on vessels using natural gas as fuel in U.S. waters, and training of personnel on those vessels. The policy letter is to apply to vessels equipped to receive LNG for use as fuel, but not to vessels carrying LNG as cargo that use boil-off gas as fuel.

The second draft operations policy letter provides guidance for bunker vessels and waterfront facilities conducting LNG fuel transfer operations. This letter is intended to provide guidance for LNG bunker operations in order to achieve a level of safety considered equivalent to the regulation applicable to traditional bunker operations. The draft policy is based on the interim guidelines contained in the IMO resolution, MSC.285 (86). The ABS policy letter provides guidance on equivalent standards for the following aspects of bunkering operations on gas-fueled vessels:

> "• Fuel transfer procedures as described in 46 CFR 154 and 33 CFR 127.319
> • Operations, emergency, and maintenance manuals as discussed in 33 CFR 127.309
> • Mariner training and drills
> • Transfer operations, including PIC designation and qualifications, Notification of Transfer, and transfer procedure requirements contained in 33 CFR 155 and 33 CFR 156
> • Simultaneous operations
> • Pre-transfer actions
> • Conduct during and after an LNG fuel transfer
> • Conduct after an LNG fuel transfer
> • Vessel equipment such as the bunkering system, deck lighting, personnel protection, portable gas detectors, radio and communications equipment, LNG fuel transfer hoses, the LNG bunkering manifold, emergency shutdown systems, and alarms and indicators."
> (Source: ABS Guide to LNG Bunkering Operations, 2014.)

Argent Marine in collaboration with Maersk Lines has patented a Bulk Articulated Tank Barge (AT/B). The bulk vessel design can carry from 4,000-20,000 m^3 with a specialized "boil-off" handling technique. The vessel is configured with interconnected tanktainers that can be loaded simultaneously at an LNG loading terminal in 6 to 8 hours through a specialized piping system The design of the vessel allows the barge to separate from the vessel so that a swap and drop operation can be undertaken.

Argent Marine has also developed a marine vessel (powered or unpowered) configured to load a number of interconnected ISO sized tanktainers. The tanktainers can be configured as standard 20 ft., 40 ft., or 45 ft. ISO container sizes. The exact container load plan depends on the targeted trade and over-the-road gross vehicle weight limits at the ports of departure and arrival. ISO container volumes range from roughly 20 m3 to 40 m3 liquid volume. Loaded volume depends on tank pressure rating, insulation effectiveness and desired LNG holding time. For typical ISO container tank pressure rating and insulation effectiveness, holding times can vary from 80 days, when loaded to 81% by volume, to 31 days, when loaded to 92% by volume. Both of the Argent designs can operate reliably in any weather condition and are capable of service speeds ranging from 11 to 14 knots.

In February 2014, Jensen Marine a Seattle-based naval architecture and marine engineering company, announced that it has been awarded a contract to design some of the first liquefied natural gas (LNG) bunker barges in the U.S. for customer LNG America LLC, a Houston-based LNG fuel supply and distribution company. The vessels, which are expected to deliver in late 2015, have an initial planned capacity of up to 3,000 cubic meters of LNG. (Crowley, 2014)

On March 28, 2014, GTT North America (GTTNA), a U.S. subsidiary of Gaztransport & Technigaz (GTT), announced that it has received approval in principle from ABS for the design of a 2,200 cubic meter LNG bunker barge. The GTT membrane LNG bunker barge will be capable of loading 2156 m3 (at 98%) or 570,000 gallons within 4.5 hours and towed at maximum speed of 8 knots in an efficient footprint: 64.2 m (212 ft.) overall length, 14.8 m (48.5 ft.) breadth, 7.2 m (15.7 ft.) depth, and 2.6 m (8.5 ft.) fully loaded design draft. The dimensions and a gross tonnage of approximately 1,440 GT afford the GTT membrane LNG bunker barge greater maneuverability and access throughout inland and intra-coastal waterways. Entrepreneurs, such as Carib Energy, are looking to move ISO LNG containers by vessel to Caribbean islands and Latin America to bring in relatively low cost natural gas.

- Rail Distribution of LNG

General Electric Co and Caterpillar Inc., the world's largest locomotive makers, are developing natural gas-powered models to be poised for a potential shift from rail's use of diesel to natural gas as the fuel of choice. Both of these manufacturers have engines that are used in the marine industry. The U.S. rail carriers Burlington Northern Santa Fe LLC, Union Pacific and Norfolk Southern are working with manufacturers on using gas as an alternative power source for freight trains. CSX Corp. is studying the technology and Canada based CN is testing LNG fueled locomotives.

Japan Petroleum Exploration Company (JAPEX), since 2000 has been using rail to distribute LNG. Originally, trucks were used but the company switched to rail to reduce costs and reduce the environmental footprint. LNG is distributed by rail using dedicated LNG tank railcars or containers. Movement by container allows LNG to be distributed from rail terminals to users that do not have rail access. The use of tank railcars requires that the receiver have a rail siding.

Figure 11: Natural gas marine-rail-truck supply chain Hokkadio Island, Japan. (Japan Petroleum Exploration Co., Ltd., 2014)

- Truck Distribution of LNG

The distribution of LNG by truck is completed in one of two manners. Either dedicated tank trailers are used or ISO containers designed for LNG are pulled by the tractor unit. The limiting factors that determine the modal selection of truck are:

- Customer requirements are for limited quantities and frequency of delivery
- The only access to the customer's location is by truck
- Highway weight limits may restrict the movement of the loaded trucks
- The distance for truck delivery of the LNG is relatively short (under 250 miles)

- Containerized LNG Distribution

There are a number of 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 user 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. The containers are U.S. DOT and ISO certified meeting regulatory requirements. Truck and marine currently deliver LNG containers.

Chart Industries, based in the U.S., is one of the manufacturers of ISO containers that 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 pounds) with a capacity of 43,500 liters (11,491 gallons) of LNG at a maximum pressure of 100 psi. The 40 foot container will be able to keep the LNG in a liquid state for up to 70 days.

Figure 12: LNG Containers. (Chart Industries)

Expanding the Market for LNG

- Marine LNG Markets

While marine use of LNG will be one of the principal markets there will be other user groups. The additional demand allows building of larger liquefaction plants realizing economies of scale lowering the cost for all user groups. A preliminary analysis of demand was undertaken for the Duluth/Superior region. Calumet terminal in Duluth, Minnesota is one of the major marine fueling terminals on the Great Lakes. The terminal transfers approximately 18 million gallons of fuel a year to Great Lakes vessels. Within 200 miles of the port of Duluth/Superior is the port of St. Paul, Minnesota on the headwaters of the Mississippi River. Riverboats currently fuel in this port with diesel fuel and represent a potential market for the liquefaction plant.

- Non-Marine LNG Markets:

Rail: One of the four class one railroads that operates in the Duluth Superior harbor area uses 19 million gallons of Diesel a year. Rail fuel consumed in the region is at least three times the level of marine fuel consumption. Diesel fuel is currently used for main line and switch locomotives.

Mining: Within 250 miles of the port of Duluth Superior are 5 active iron ore mines with proposals to open two others. Energy costs are estimated to represent more than 15% of the total cost of production in the mining industry in the US. All of these mines use a wide variety of high horsepower equipment. Ore-carrying haul trucks have a capacity of 250 to 300 tons of ore that is transported about 3-5 miles to a processing plant. They have a virtually round the clock operation of delivering loads and returning empty. Their engines are in the 1500 to 2500 horsepower range. The largest mine hauling trucks can each consume over 400,000 gallons (1.5 million liters) of fuel annually. Assuming an average of five trucks per mine the approximate annual diesel consumption for the 25 trucks would be approximately 10 million gallons. In addition to the haul trucks there are shovels, bulldozers, drills and other equipment at the mines currently using diesel. The major mining equipment engine manufactures, Caterpillar and GE, are already developing new natural gas fueled engines. In Wyoming and West Virginia the mining industry has converted mining trucks to burning natural gas. The mining industry's overall environmental footprint would benefit from the use of clean burning natural gas.

Agriculture: The use of diesel generators and pumps for agricultural operations is critical in remote locations. Farmers also use propone to dry agricultural products such as corn. Large farm machinery such as combines, harvesters and tractors are diesel powered. There may be opportunities to cost effectively shift to natural gas for some of this equipment.

Off the grid industrial users: Nationwide there are approximately 850,000 diesel-powered vehicles in use, bringing supplies, materials and workers to and from U.S. construction sites. Earthmovers, bulldozers, bucket loaders, backhoes, cranes, pavers, excavators, graders and other equipment with high horsepower engines have the potential to use LNG. Cement, asphalt and paper plants in remote locations where gas pipelines are not available could be switched to natural gas if the economics justify the conversion.

Evaluation of an Existing Great Lakes Marine Fueling Terminal

As noted above, Calumet Marine Fuel Terminal is located in Duluth, Minnesota and serves vessels that call at the head of the Lakes. Calumet obtains its fuel from the Calumet Refinery located in Superior, Wisconsin, an eight mile distance. The refinery obtains its crude oil from Canadian wells that arrive at the refinery by pipelines. The refined products are transported to the marine fueling terminal by truck. The Jeff Foster Trucking Company delivers most of the fuel. A diesel delivery truck and a heavy fuel delivery truck can unload their fuel at the same time since Calumet expanded their truck access two years ago. Having the refinery close to the fueling terminal enables Calumet to keep transportation cost low.

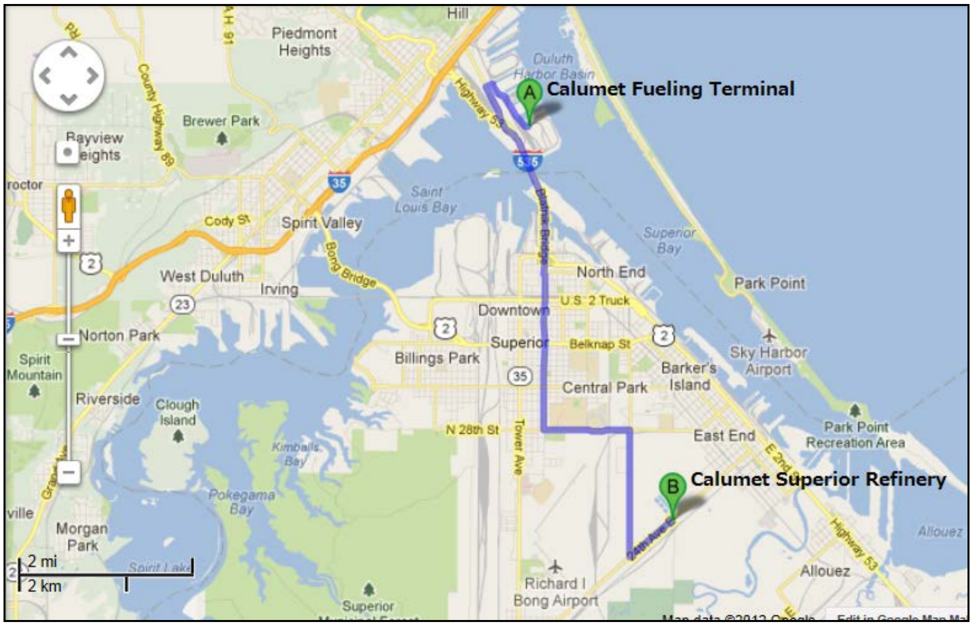


Figure 13: Refinery location to fuel terminal. (Source: Google Map)

- Low Sulfur Content Fuel

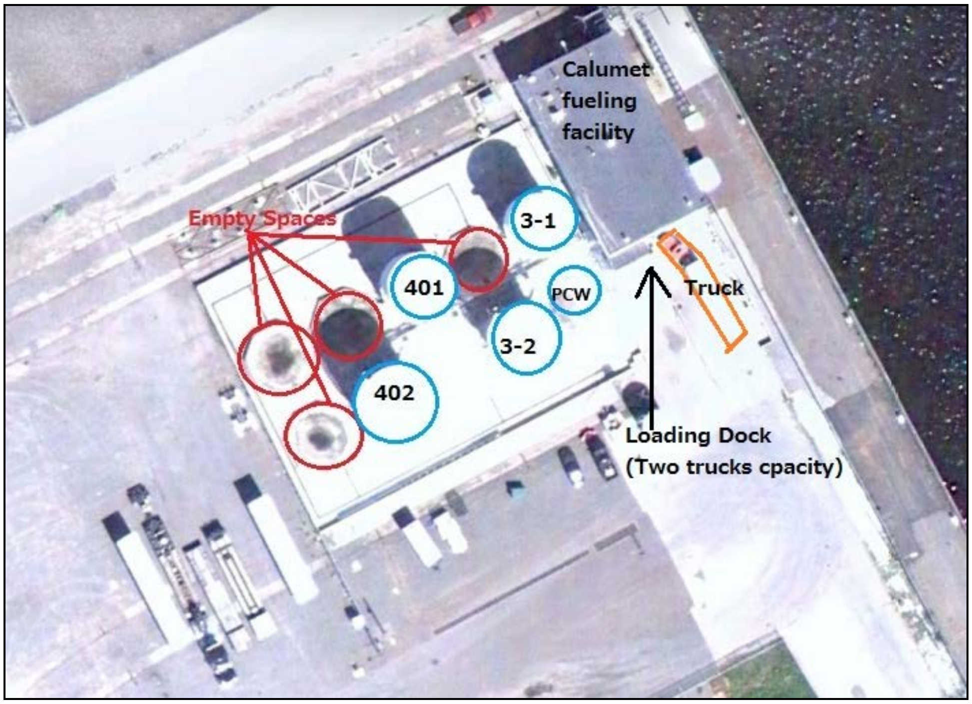
Sulfur dioxide (SO_2) is a toxic gas, a member of sulfur oxide (Sox), and is produced from burning fuels containing sulfur, such as coal or oil (EPA 3-3). Also, when the fuel burns at a high temperature, it generates nitrogen dioxide (NO_x). These SO_2 and NO_x are the major precursors of acid rain (EPA 3-3). Sulfur dioxide is also a major substance of fine particulate soot and causes negative health effects.

The sulfur content of fuel differs by the crude oil and the refining process. Calumet tests for viscosity, gravity, and sulfur contamination at the terminal. The refinery certifies the fuel before leaves the plant.

- The Storage Tanks and Capacities

Calumet has four tanks at their terminal. Figure 14 (from Google Earth) shows each storage tank location, empty spaces, and the truck loading dock. Figure 13 shows the facility view from the ground. Tank number 3-1 is for the #2 oil with a capacity of 3,000 barrels (42 gallons per barrel, tank. Calumet usually store 116,000 U.S. gallons. The tank number 3-2 is for IFO 320 and has the same capacity as 3-1 tank. Next to tank 3-2, there is small a tank to store the Petroleum Contaminated Water (PCW). The other two tanks (401 and 402) store 4,000 barrels each of Number 6 oil, which is also called Bunker C Oil.

With the exception for the diesel PCW tanks, each tank has three lines. The suction line used to pump to the ship, the fill line, which is used for filling the fuel into the tanks from the trucks, and the return line. The return line makes the fuel loop around the building which allows for uniform temperature inside of tanks in order to be able to load the fuel aboard the vessel.



- 3-1: Number 2 Oil
- 3-2: IFO 320
- PCW: Petroleum Contaminate Water
- 401: Blended IFO 320
- 402: Blended IFO 320

Figure 14: Calumet Superior, LLC., Duluth Marine Terminal Picture
Source: Google Earth

Figure 15: Calumet Superior, LLC., Duluth Marine Terminal Storage Tanks
Source: Dr. Stewart, Richard

- Possibility for LNG Storage Tanks

In the tank storage area, there are four empty spaces to build additional tanks. Calumet could build new storage tanks for LNG at their terminal using these empty areas. In the conversation with the research team, the Calumet representative indicated that the empty space between 3-1 and 401 is too close to build a new tank; however, the back three empty spaces are available.

To build LNG tanks in Calumet it is easier for ships to fuel at Calumet than go to a newly built facility because Calumet has received approval by the U.S. Coast Guard (USCG) for bunkering operation. The main issue LNG storage tanks are the USCG has not issued the regulations regarding LNG with building. After the regulation is revealed, Calumet may not build new tanks using their empty space that was mentioned above. However, Mr. Graham indicated in discussion with the research team that Calumet leases their land through Duluth Seaway Port Authority. If Calumet needs more space to build new storage tanks for LNG and comply with the regulation, they could lease additional space from the Port Authority. Photo 3 shows additional space to build new facilities.

Figure 16: Additional Potential Storage Tank Location. **Source:** Google Earth

- Competition

Calumet Marine Terminal has limited competition in the upper lakes. The Ore dock at Two Harbors, Minnesota, owned by Canadian National, has a fuel terminal but they only fuel Great Lakes Fleet vessels (Key Lakes). This terminal purchases fuel from the Calumet refinery in Superior, Wisconsin and is delivered by truck to Two Harbors.

- Discussion on Fuel Consumption

The then Murphy Oil, now Calumet Marine Terminal opened in November1998. The total fuel sales in thirteen seasons were approximately 245 million U.S. gallons, with the annual average of 18.8 million U.S. gallons. (Approximately 40% #2 oil and 60% #6 oil over the last three seasons)

Three seasons' detailed information is below:
<u>2006 – 2007 Season</u>

- Number 2 Oil: 10,270,881 U.S. gallons, which is 39.5% of the total fuel that Calumet sold
- Number 6 Oil: 15, 605, 330 U.S. gallons, which is 60.5% of the total fuel that Calumet sold
- Total: 25,876,211 U.S. gallons

<u>2007 – 2008 Season</u>

- Number 2 Oil: 7.686,173 U.S. gallons, which is 32% of the total fuel that Calumet sold
- Number 6 Oil: 16,304,659 U.S. gallons, which is 68% of the total fuel that Calumet sold
- Total: 23,990,832 U.S. gallons

<u>2010 – 2011 Season</u>

- Number 2 Oil: 8,817,750 U.S. gallons, which is 38.5% of the total fuel that Calumet sold
- Number 6 Oil: 14,086,623 U.S. gallons, which is 61.5% of the total fuel that Calumet sold
- Total: 22,904,373 U.S. gallons

- Conversion to LNG

According to the U.S. Department of Energy, one gallon of #2 oil (Diesel) has 113% of the energy (BTUs) of one gallon of gasoline. Whereas one gallon of LNG has 64% of the energy of one gallon of gasoline. LNG has less energy than diesel oil so that the ships burn LNG faster than diesel. This means when ships use LNG as a fuel, they have to fuel greater amounts of LNG than they fuel with diesel or bunker fuels.

To calculate how much LNG will be needed to replace the current fuel with LNG, we first need to convert each IFO's into British Thermal Units (BTU). A BTU is the amount of heat energy required to raise the temperature of one pound of water by one degree Fahrenheit (F˚). By using BTUs, we are able to compare different fuels with a common unit of measurement based on the energy content of each fuel.

As stated in the previous section, over thirteen seasons Calumet sold 7,520,000 U.S. gallons per average year for #2 oil (40% of average selling of 18.8 million per year), and 11,280,000 U.S gallons of #6 oil per average year (60% of average selling of 188 million per year).

According to the U.S. Department of Energy, #2 oil energy content (in LHV, lower heating value, which is close to the actual energy yield) is 128, 450 BTU per U.S. gallon, and LNG has 74,720 BTU per gallon. For #6 oil, Bartok mentions in his "Approximate Heating Value of Common Fuels", it has 153,200 BTU per U.S. gallon. Therefore, the 7,520,000 U. S. gallons of #2 oil are equivalent to approximately 955 Billion BTU. Also, 11,280,000 U.S. gallons of #6 oil have approximately 1,728 Trillion BTU. Therefore, if vessels use LNG as a fuel, Calumet will need to supply approximately 30.7 million gallons of LNG per average year (1 gallon of LNG = 87,600 BTU in LHV).

The advantages of building LNG storage tanks for fuel bunkering are (1) Calumet has already been approved by the USCG for bunkering operation, (2) Calumet is the largest U.S. fuel supplier in the head of the Lakes area, and (3) Calumet has empty areas to build new LNG storage tanks.

Supply Chain Summary

Researchers sponsored by GLMRI have established the viability of Liquefied Natural LNG as a marine fuel that lowers operating costs and significantly cleans air emissions of vessels. GLMRI researchers have further established that multiple LNG users, besides the marine industry, would gain lower operating costs, job creation and environmental benefits when they switch to a reliable abundant North American supply of LNG. A LNG supply chain can serve the following markets that have already adopted LNG as a primary fuel in other regions of the U.S. and the world.

- Marine
- Rail
- Transit
- Mining
- Trucking
- Agriculture

Other industries using diesel, heavy fuel or propane and are off the gas pipeline grid. In the test research area of the port of Duluth Superior preliminary estimates of high horsepower fuel consumption for just three of the seven industry groups that has the potential to be converted to natural gas are:

- Marine 18 Million gallons
- Rail 40-50 million gallons
- Mining 10 million gallons
- Subtotal 68 to 78 million gallons

A 150,000 gallon per day liquefaction plant will produce 52 million gallons of LNG annually. The maximum production of the plant will meet 75% of the energy consumption of these three user groups that are located in the immediate vicinity of the port of Duluth Superior. The potential market includes the other user groups located nearby and those within a 200 mile drayage radius. A market study would need to be done in assessing the potential size of a liquefaction plant. The potential to move LNG to more distant markets using ISO container transported by vessel or rail needs to be explored.

The key to developing an LNG supply chain will be the reliable availability of LNG that serves a variety user groups. To do this, there will need to be liquefaction plants in locations that will allow the distribution of the product to user groups. The major deciding factor in determining the location of a liquefaction plant will be the availability of natural gas. This means the liquefaction plants will be located as close as possible to large natural gas pipelines that can deliver an abundant supply at a relatively high pressure. The second most important factor will be demand for the product. Developers building liquefaction plants as part of the LNG supply chain want to have as large a customer base as possible for two critical reasons: The larger the user base, the less volatility in sales dues to economic factors impacting any single user group. Also the increased demand from an extensive user base allows the building of larger liquefaction plants that achieve better economies of scale. Plant developers have indicated that having a keystone customer or two is critical for startup, and then the user base will be expanded as LNG becomes more readily available. Several companies are considering building liquefaction plants in the Great Lakes and Ohio River regions.

Historically, large liquefaction plants have been placed on waterfronts so that they could load into specially designed tankers that carried the LNG to another large terminal where it was unloaded and stored for transportation or regasification. LNG marine terminals are large complexes with secure zones that could be a mile in radius. Coast Guard regulations in 33 CFR Part 127) only apply to facilities that handle large quantities of LNG. GLMRI researchers do not believe that this type of waterfront-based model will be used in most of the domestic LNG supply chains. An exception may be where there might be large volume transportation by barge

Liquefaction plant development will be driven by demand and the availability of suitable space. Research indicates that medium size liquefaction plants would best serve the Great Lakes fleet and other user groups if they were built in the following regions:

- Duluth/Superior area
- Detroit/Windsor area
- Chicago/Milwaukee area
- Cleveland/Erie area
- Toronto/Buffalo area
- Alpena/Charlevoix area

Education and Outreach: Building Interest in Natural Gas

GLMRI was established in 2004 to develop and improve economically and environmentally sustainable maritime commerce on the Great Lakes. A key component of GLMRI's mission is advocating for these improvements that will enhance shipping on the Lakes. A fuel conversion to using LNG would provide both economic and environmental improvements, while advocating for maritime transportation to reduce highway congestion and emissions.

- LNG Forum in Superior, Wisconsin

On May 21, 2013, GLMRI hosted a meeting with over 100 attendees at the University of Wisconsin-Superior to bring together members from the natural gas industry, along with current users of natural gas to meet with community and industry leaders to pursue building a liquefaction plant in the Duluth/Superior area. This meeting was on the tails of Shell announcing

in March 2013 that they would be building a plant in Sarnia that would support shipping and other industries that once it is operational, will supply LNG fuel to all five Great Lakes, their bordering U.S. states and Canadian provinces and the St. Lawrence Seaway. Earlier in May, Interlake Steamship Company (ISC) announced that they are working with Shell to supply LNG to support the conversion of its vessels to LNG as the main propulsion fuel with a goal of converting the first vessel by the spring of 2015. (Figure 17: LNG Meeting, May 21, 2013, University of Wisconsin-Superior. Source – K. Jeanne Hartwick)

The speakers at the meeting supported this concept and discussed several on-gong projects and some of the equipment needs to support a fuel transition to natural gas. This region is a multi-modal transportation hub servicing Class 1 Rail, shipping, trucking and pipelines. The transportation modes could not only be users of the gas but would provide the distribution network for Liquefied Natural Gas (LNG) to benefit the mining and agricultural industries. Kwik Trip Inc. opened a service station with natural gas in 2012 in La Crosse, Wisconsin, and the company has an aggressive plan to expand their alternative fuels stations. Trucking is already moving to NG for short haul and specific route fleets, and would likely benefit from a plant in Duluth/Superior.

- High Horsepower Summit in Chicago

At the High Horsepower Summit (HHP) that was held September 17-19, 2013 in Chicago, the president of Interlake Steamship Company (ISC), Mr. Mark Barker, provided an overview of their plans to proceed with converting their first steamship to LNG. When the North American ECA was announced, they started to review their alternatives. Their options to meet the ECA are going to #2 Diesel, adding scrubbers, or converting to LNG. LNG appears to be a viable plan, but without access to a fuel supply, it was not a practical solution. With Shell's announcement to build a plant in Sarnia, ISC is able to move forward with plans to convert. Mr. Barker announced that ISC will be using the MAK/Caterpillar engine and equipment, a German company, MS Services for the LNG systems design, Taylor-Wharton for the tanks, and Bay Engineering, Inc. for the vessel structure and non-LNG systems engineering.

- LNG Strategy Group

Since the May meeting, a ground swell of interest in the Duluth/Superior region has occurred, and several developers are pursuing specific siting possibilities. A working group from local economic development agencies, energy companies, port representatives along with GLMRI staff and researchers has been established. GLMRI is working with them to provide analytical support and interface with industry contacts. Numerous gas developers have taken an interest in the region, and continue to contact GLMRI on the outcomes of the GLMRI research funded under this cooperative agreement. The Strategy Group has formed a sub-group to focus on communication of the benefits of using LNG: both economic and environmental. LNG developers have presented to this group, and connected with the agencies to pursue potential siting options for a liquefaction plant. A local engineering firm provided a presentation on the permitting requirements for a plant, along with the agencies that would have to be involved in the process. The Strategy Group is also planning a trip to Burnsville, Minnesota to tour the Centerpoint Energy LNG liquefaction plant to better understand the operations, along with the safety considerations for the development of a plant in Duluth/Superior. The group has been meeting monthly since the May 2013 GLMRI meeting.

- Presentations and Partnerships

GLMRI staff and researchers have provided presentations at professional societies' meetings and maritime events. (Cumulative list included at Tab 3.) GLMRI partners with several professional associations to sponsor and develop sessions on the developments of LNG and industry use. The Great Lakes and Great Rivers Section of the Society of Naval Architects and Marine Engineers (SNAME) has continued to include LNG speakers in their technical meetings. In February of 2013, GLMRI worked with the Section for their meeting agenda, and a site tour was included to visit a truck fueling station in Seville, Ohio. The maritime industry participants, several who work in the LNG industry, were unaware that LNG was accessible at the truck stop/gas station just off the interstate highway. By providing this physical tour, many of the participants realized that LNG was an achievable goal, and the technology and equipment was in place to move ahead with the fuel conversions on a faster timeline.

GLMRI has been invited to present at many other meetings to advise agencies on the industry progress on moving LNG accessibility for the transportation modes. The GLMRI Co-Director met with the Council of Great Lakes Governors which include senior advisors from the eight Great Lakes' states to the governors. Also, GLMRI has provided updates to the Great Lakes port directors at various meetings and events.

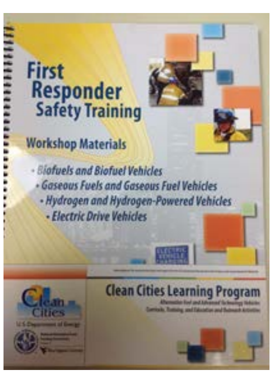
Updates to congressional and senate elected representatives and their staffs have also been provided by GLMRI along with individual meetings with government agencies. GLMRI is continuing to support governmental agencies in developing initiatives that would incentivize companies to invest in the cleaner technology of using NG. The Committee on Maritime Transportation System (CMTS) is a multi-agency presidential level committee that examines strategic opportunities for improving the U.S. Maritime Transportation System. GLMRI provided the CMTS Coordinating Committee with a list of proposed initiatives to expand the use of LNG in maritime sector that were a direct result of the research process. GLMRI was asked if it would it be timely and appropriate to begin pursuing a federal policy resolution to urge federal agency civilian vessels to convert to alternative fuels that help reduce air emissions and reduce dependency on oil. GLMRI provided a paper that addresses the benefits of providing a government funded fleet of U.S. built natural gas standardized vessels could jump start production jobs to re-tool a long term industrial base for the country's transportation industry along with the U.S. Defense industrial complex with economic and environmental benefits. The program recommends a cooperative standardized program across government agencies' maritime assets that would repower to LNG while supporting the development of a cost effective Jones Act coastal and Great Lakes NG fleet. The proposed program would fund research and projects for technology design along with training and education programs. A construction program to build a series of ships could tie in modular building components, which could support small shipyards with final assembly at the larger shipyards with drydock facilities. Capitalizing some of the research and tooling costs on components that could be used for other modes would reduce the costs for the projects and supply chains.

- Materials, Products and Reports

A public web-based portal for the literature review, research results, and presentations was developed and is continually update with information on LNG. Current LNG projects and informational materials have been compiled and organized for public access. Tutorials on LNG, along with technical information on engine conversions, are included on the web site. Links to YouTube videos on LNG information and performance are available along with tutorial information on hydraulic fracturing. The site is regularly updated as new reports are released. (www.glmri.org/research/)

GLMRI publishes and disseminates in-print and on-line a quarterly newsletter and an annual report along with a project reports on the LNG and other Institute projects. The annual report is provided to approximately 3,000 agencies and individuals, and all of the material is accessible on the GLMRI web page. Articles have been prepared and published in professional journals, and reach an ever-widening base of readers. It is imperative to disseminate information on LNG and to enlighten industry, legislators, governmental agencies and communities on the benefits of moving to natural gas, along with an improved environmental profile to advocate U.S. shipping.

- Education and Training for Communities and First Responders



The Department of Energy (DOE) Clean Cities Program through their National Alternative Fuels Training Consortium (NAFTC) out of the West Virginia University has developed curricula for a First Responder Safety Training Program that addresses alternative fuels and vehicles including biofuels, gaseous fuels (including liquefied and compressed natural gas and propane), hydrogen and electric (Consortium, National Alternative Fuels Training, 2013). The material covers properties of the specific fuel and how it works in the vehicle engines. It also exposes the students to the

LNG (fuel) components on the vehicle and how to identify and recognize LNG (alternative fuel) vehicles from conventional gasoline fueled vehicles. A separate section in the curricula addresses the training for LNG infrastructure, transportation tanks and fueling stations. This program was designed to raise awareness and understanding of alternative fuels and their use in vehicles, and to better implement petroleum reduction technologies.

Conclusions

The international marine market is moving forward quickly and competitively to convert to Liquefied Natural Gas (LNG). The U.S. is seeing early adopters converting to LNG for vessel operations. Rail has also invested heavily in research and development into converting a percentage of their locomotives to either LNG or Compressed Natural Gas (CNG). The rail and trucking industry are facing natural gas NG) availability issues, despite there being a surplus of NG. The problems are created by a NG supply chain still in its infancy and a regulatory process trying to catch up to a rapidly evolving new market.

The continuing research by GLMRI has occurred because of cooperative leadership from MARAD, with support from the U.S. Coast Guard, the Lake Carriers' Association and interest from the natural gas industry. Since the commencement of the cooperative agreement in 2011, the movement to convert to LNG has picked up the pace with Shell's announcement to build a liquefaction plant, and Interlake Steamship Company's announcement that they are moving ahead with plans to convert their fleet to LNG.

The review of the towboat industry and supply chain for the Ohio River indicates that it faces greater challenges than other regions due to lack of existing access to LNG supply, and the number of and the engineering constraints to retrofit the existing towboat fleets. While the primary focus of the GLMRI efforts are in support of maritime, all facets and use of LNG must be considered since a supply chain based solely on maritime consumption is unlikely, particularly for the Great Lakes and the Ohio River valley.

Internationally, LNG is aggressively being transitioned into existing fleets and new construction. The U.S. government has an opportunity to enhance and encourage the maritime industry to step forward with the capital investments to convert to LNG while supporting the ECAs and eliminating the need to dispose of the hazardous waste from stack scrubbers. As other modes of transportation move to LNG, the maritime industry should continue to share information and learn from adoption of other modes both in the U.S. and in other countries.

MARAD's continued leadership role in this public/private partnership is essential to moving forward with the transition, where appropriate, to NG as a marine fuel. MARAD is able to interact cooperatively with other key government agencies is able to engage foreign agencies who are also involved with developing NG as a marine fuel. The multi-modal nature of the supply chain as well as the fuel uses, places MARAD in a pivotal role as the agency supporting the marine industry that can transport the bulk of the LNG.

Recommendations

GLMRI provides the following topics for further consideration:

- **Development of the Great Lakes and Inland Waterways LNG Supply Chain**. Research needs to continue to further develop the LNG supply chain in the GL region to support maritime operations and multi-modal use of LNG as a fuel to reduce energy costs, air emissions with a secure North American gas supply. This would be the continuation of GLMRI research and outreach for the development of an LNG supply chain to provide fuel for vessels and other user groups.
  - Countries such as Norway and Japan are significantly more advanced in all areas of using NG as a marine fuel and LNG supply chains. Tapping into their expertise can reduce costs and time.
  - The shipyard, supply chain, training and regulations that have evolved over a decade of use in these countries could provide extremely useful insight and possible adoption in the U.S.
  - MARAD can consider interacting with the Council of Great Lakes Governors in drafting a Memorandum of Understanding supporting the development of a LNG supply chain. The MOU between multiple states created to support CNG development can be used as a prototype for supporting LNG development. http://www.naspo.org/documents/RFI12NASPO0001JW_Exhibit_A.pdf

- **Developing New Liquefied Natural Gas (LNG) containerized Transportation Corridors.** The production and demand for Liquefied Natural Gas is increasing and the forecast if for even greater growth. Liquefaction plants benefit from economies of scale and may not be located on the waterfront. LNG is currently shipped by ISO Containers. There is the potential, especially in ports, to increase the movement of LNG in ISO containers without the same level of regulation required for bulk transfer of LNG. Emerging LNG markets are seeking unit delivery in the container size range. The proposed research would examine the options for:
  - The movement of LNG by container from liquefaction plants by barge
  - Research into the viability of expanding intermodal links for the movement of LNG by container

- **Research into the Refinement of the Integrated Electric Plant/LNG Option**. Building on earlier research by GLMRI there need to be additional research into how Integrated Electric Plants could be improved with the use of LNG as a primary fuel and modular concepts. The benefits of this study could lead toward the reduction of air emissions in the ports while addressing alternative fueling options.

- **Feasibility and Benefits of Hybrid Mechanical-Electrical LNG Fueled Propulsion in Future Great Lakes Bulk Carriers.** Hybrid mechanical-electrical propulsion systems have begun to appear in marine applications in the west coast and Europe. These vessels are able to operate on batteries during idle and low power demand situations in order to reduce air emissions, most often in areas of congestion such as restricted channels, locks, and ports where the emissions are the greatest problem. Coupled with the use of dual fuel LNG engines, a hybrid mechanical-electrical plant could provide the most efficient and greenest option for future coastal, inland waterways and Great Lakes vessels.

- **Work through the CMTS to fund a federal program to convert government ships to LNG**, with a long-term goal of funding a standardized new build of a fleet of ships.
    - MARAD could consider initiating a project to demonstrate a dual-fuel engine conversion on one of the maritime academy training ships that could provide direct information on the conversion process, while providing a learning environment for the next generation of mariners, both deck and engineering. GLMRI believes that this would be ideal for the Great Lakes, since there is already commercial movement to LNG.
    - Shipyards need to be supported in gaining the expertise and technology needed to build, maintain and repair natural gas fueled vessels.

- **A comparative environmental study** should be done to look at the entire fuel supply chain from well to stack for diesel fuel and NG.

- **Assessing the Potential Environmental Benefits of Noise Reduction.** Diesel engines that use NG as a primary or sole fuel operate at lower decibel ranges than diesel engines that use diesel fuel as the primary or sole fuel. The noise reduction is because the engine cycle is created through spark ignition rather than a compression cycle. We have found some information on the impact of noise reduction in gas fired truck operations. According to Baruch College with Council on the Environment of New York City, "Neighborhood Noise and its Consequences, Dec. 2004, Diesel refuse trucks have been known to generate noise levels of 100 decibels. Converting refuse truck engines to NG had a significant impact on noise reduction levels outside and inside the truck.

"The noise reduction alongside the truck is 79.5 to 69.3 decibels. The noise reduction behind the truck is 72.2 to 66.9 decibels. Natural gas refuse trucks also offer a noise reduction of 82.8 to 71.3 decibels inside the cab." (Source: 'Natural Gas Refuse Trucks: Driving Change in New York City', Informs, April 2006 www.informinc.org/FS_ST_NYC_Refuse.pdf)

However, our research has not uncovered any substantial research as to the environmental benefits that may be accrued when using NG for the primary fuel in vessels or railroads. Noise reduction may be mentioned as a benefit of converting to gas, but no quantifiable data is available. A 2013 paper, (Lowell, 2013) assessing the greenhouse gas impacts of using NG on vessels did not address noise pollution or vibration. The 2010 and 2012 studies on the benefits of converting the Washington State ferries do not even mention noise pollution or vibration reduction.

Research is essentially non-existent related to the impact of gas fueled vessels' noise reduction on marine life. A fairly recent study on reducing vessel noise pollution from large commercial vessels, (Renilson Marine Consulting, 2009), did not even consider the option of vessels operating on NG. A 2013 paper, (Lowell, 2013) assessing the greenhouse gas impacts of using NG on vessels did not address noise pollution or vibration.

The GLMRI research team believes that there is need for research in two critical areas related to the noise reduction of NG fueled diesel engines.

3. The environmental impact on humans and communities of the reduced decibel levels when operating trains, ships and other high horsepower systems on NG.
    a. Measuring decibel levels in different engine types and conditions
    b. Determining the noise signature – range and intensity
    c. Determining the impact of the new noise signature on humans and wildlife.
    d. Comparing current diesel fueled engine noise signatures to gas fueled engine noise signatures
    e. Assessing the cumulative environmental impact of the change in noise signature if there is large scale adoption.
4. The environmental impact on marine life of the reduced decibel levels when ships operate on NG.
    a. Measuring decibel levels in different engine types and conditions
    b. Determining the noise signature – underwater range and intensity
    c. Determining the impact of the new noise signature on marine mammals and other marine life.

d. Comparing current diesel fueled engine noise signatures to gas fueled engine noise signatures
e. Assessing the cumulative environmental impact of the change in noise signature if there is large scale adoption in sensitive areas.

- **Support early adopters** of improved technology as they are taking the greatest risk. Support can be financial and or institutional. MARAD's research team can support companies applying for federal, state and local grants that enable early adoption. Shippers will be a key factor in companies adopting NG. Studies need to be done on how improving the environmental footprint of the marine segment of a supply chain improves the shipper's supply chain and their green image. Environmental agencies and classification societies enhance shipper support of environmental improvement from adopting NG. This is done through the formal recognition to marine carriers such as ABS Energy Management Certification and the Clean Excellence Award from the EPA in Transportation Efficiency Innovations. MARAD can be proactive in this process.

- **A program of public outreach and education** is essential for stakeholder understanding of the potential benefits and issues related to conversion of marine vessels to NG.
    - Many stakeholders have misconceptions of NG or lack any detailed knowledge to make informed decisions.
    - Most stakeholders are unaware that U.S. flag NG carriers have used NG as a marine fuel for over four decades with an exemplary safety record, or that it is being used in Europe for ferries and Coast Guard Cutters.

- **An engineering study needs to be conducted on all tow boat sizes that operate on the Ohio River** to determine the feasibility of adopting this technology. The study needs to include, but is not limited to the engineering requirements of an engine retrofit, determining the size and location of the LNG fuel tank, stability requirement and any operational requirements that may be placed on the vessel.

- **Assessing Scrubber HazMat Disposal Issues.** Vessels may elect to use scrubber systems to meet ECA standards and reduce air emissions. Scrubber effluent can only be disposed of in a MARPOL approved reception facility. The research would determine: 1. typical scrubber residue makeup, 2. MARPOL reception facility requirements, 3. Establish a list of current MARPOL approved reception facilities in the Great Lakes and St. Lawrence Seaway System (if any) and disposal costs, 4. Reach out to stakeholders to assess where new/additional reception would be needed and what locations would be open to establishing approved reception facilities. This research model can be adopted for use on the coasts and other ECA areas with the potential to benefit both U.S and international shipping.

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