Development of the Adoption of Liquefied Natural Gas as a Fuel for Shipping on the Great Lakes

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ABSTRACT

The adoption of the International Maritime Organization's Emission Control Areas by the United States and Canada compelled short sea vessel operators on the Great Lakes to seek alternatives to the current fuel usage. The concurrent discovery and extraction of large quantities of natural gas in the United States and Canada has resulted in a unique opportunity for ship owners to consider switching to natural gas. Converting to a new fuel is a complex process involving research and changes in operations, engineering, supply chains, and training. The Great Lakes Maritime Research Institute has been involved in a multi-year study supported by government agencies and industry to prepare for the adoption of natural gas as a primary fuel for United States (U.S.) Great Lakes vessels. This paper discusses the research process including marine engineering studies, vessel operational issues, investigating regulatory issues, the development of supply chains, public outreach, and the analysis of fuel alternatives for vessels. The environmental benefits that accrue with conversion, as well as the potential operational costs, are compared. Future steps in the conversion process, including siting of natural gas liquefaction plants and fuel taxation, will be proposed.

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BACKGROUND

The United States (U.S.) is a large continental land mass with a geographically dispersed population requiring an extensive transportation network to interconnect producers, consumers and ports of entry. The vast majority of freight carriers in the U.S. rely on liquid petroleum fuel to power their primary engines. There are some exceptions in the form of electric trucks and trains along with a few coal powered ships, but the numbers are small in comparison and have no statistical impact. The primary domestic movement of freight takes place by truck, rail, marine, pipeline and air. In pre-recession 2007, the combined movement of freight in was 4.6 Trillion ton miles (BTS, 2013). In 2007, the transportation sector of the U.S. consumed 28.7% of all the energy used in the nation. The energy required for transportation was 29.12 Quadrillion British Thermal Unit (BTU) with 27.76 Quadrillion BTU of the energy consumed being supplied by liquid petroleum that includes a tiny fraction of ethanol (BTS, 2013).

Within the space of a few years, the U.S. has changed their position in world energy market from a country dependent on others for their liquid petroleum energy supplies to a nation with proven energy reserves of 7,299 trillion cubic feet of natural gas (NG) that may last for the next hundred years (EIA, 2013). The differences in storage, availability, and use between a liquid and gas source have fundamental and major implications for an industrial society, especially one that is wedded to liquid petroleum to run their transportation system.

Another driving force for change was the U.S. and Canada becoming signatories of the treaty for the International Maritime Organization's International Convention for the Prevention of Pollution from Ships (MARPOL) by extending the Emission Control Areas (ECA) to 200 miles. The North American and Caribbean Emission Control Areas address Nitrogen Oxide (NO_x), Sulfur Oxide (SO_x) and Particulate Matter (PM) emissions, primarily from large marine engines. Ocean vessels will have to comply when they enter the two hundred mile zone. The entire Great Lakes region is in an ECA zone and Great Lakes vessels will have to continuously comply with the standards. The regulations call for reducing sulfur content in fuel to 0.1% in 2015. To meet future standards, vessel operators will either have to change to a cleaner fuel and/or clean the emissions coming from the engine. Fuel prices are driven by supply and demand. Currently, most Great lakes vessels use a blend of heavy residual fuel oil (IFO-380) and/or distilled Marine Diesel Oil (MDO) for propulsion. The U.S. steamships use straight bunker-C or, in the case of one vessel, coal. The distillate MDO and Marine Gas Oil (MGO) fuels are sold at a premium over the price of residual blends or bunker C fuel. These distillates have characteristics comparable to highway fuels and consequently have higher price volatility than marine blended fuels. A 2009 study predicted that the fuel cost increase associated with the low sulfur fuel that will be required by the ECA regulations could result in a 20% modal shift to highway of stone products carried by the Canadian Lakers (English, 2009).

Scrubbers provide an option for meeting ECA requirements by addressing the pollutants coming out of the stack. This process carries its own costs and issues. Many Great Lakes ships have limited space for a scrubber system. There is a capital cost for purchase and installation. There will be annual maintenance costs and the waste stream must be disposed of onshore for vessels operating on the Great Lakes. This potential increased cost and shortages of low sulfur distillate fuel and scrubbers have ship owners considering alternatives.

When new opportunities or technologies become viable options they are not always embraced, no matter how obvious the benefits appear. The change may be resisted, and even those who undertake change fairly early in the process usually suffer angst and doubt. The philosopher Eric Hoffer referred to this tense and uncertain process as the ordeal of change. He said that "We are usually told that revolutions are set in motion to realize radical changes. Actually, it is drastic change which sets the stage for revolution" (Hoffer, 1967). In the U.S. there is a drastic change in energy supplies and a revolution in use will follow.

A Great Lakes vessel can operate for eighty years in the fresh water environment and technological change can be slow. In the 1940s, 50s and 60s, the Great Lakes vessels transitioned from largely coal-fired vessels to using oil as the primary fuel. This was a costly endeavor as bunkers, engines, stacks and the supply chain had to be developed. The railroads were making the same conversion over a 30 year period (Blomerus, 2013). Converting the Great Lakes fleet to NG will require the same effort as the conversion from coal to oil. Although Compressed Natural Gas (CNG) had been considered by some operators, initial studies indicated that the stowage advantages of LNG would make it the most practical type of gas for most Great Lake carriers' operating parameters.

In the fall of 2011, the Great Lakes Maritime Research Institute (GLMRI) was funded by the U.S. Maritime Administration (Department of Transportation) with support from the Lake Carriers' Association, a group of owner/operators of Great Lakes licensed vessels, to research the potential of converting a portion of the Great Lakes fleet to NG as a primary fuel. There appeared to be significant benefits to pursuing this change. The parties involved understood that this would be possibly a decade long process and that many of the possible obstacles were unknown.

Benefits of Liquefied Natural Gas (LNG) Adoption

The concept of converting the existing fleet of approximately fifty-five large U.S. flag commercial Great Lakes vessels to using LNG as their principal fuel source appears to have significant merit. LNG would be a clean burning fuel that would make the U.S. flag fleet a world leader in reducing harmful air emissions including greenhouse gases. The looming issue of a probable shortage of low sulfur diesel fuel would be resolved. The Great Lakes vessels that are vital to the national steel supply chain would be using a reliable and relatively low cost domestic fuel source. The long life of the hulls of Great Lakes vessels enables the owner to spread the conversion costs over a longer period of time than ocean carriers. The conversion process may provide opportunities for carriers to gain fuel efficiency, increased productivity and operational improvements. Vessel conversion and operations would create and keep employment in the Great Lakes region not only for vessels but all companies served along the supply chain. A significant number of vessel conversions should result in lowering the incremental costs for LNG and related engines, and may precipitate new shipbuilding. The use of LNG as the main fuel for Great Lakes vessels has the potential to benefit the carriers, shippers, and public, along with the environment. (Note, for this study, due to the long life of the Great Lakes' vessels of over 60 years, GLMRI only addressed conversions of the existing fleet with a remaining useful life in excess of 20 years)

Challenges of Fuel Conversion

Conversion of a vessel's main power plant is expensive, complex, and engineered for a specific vessel. The existing laws and regulations do not reward carriers or their shippers for the substantial additional cost of moving beyond minimum environmental compliance. A carrier that is an early adopter of a cleaner fuel such as LNG may be penalized in the market place for being environmentally pro-active. The capital costs of conversion will have to be recovered through improved performance and lower operating costs Increases in freight rates were deemed unlikely because without incentives, shippers may elect to move cargo to vessels that, while meeting current minimum air emissions standards have not incurred the capital expenditure for LNG conversion and will charge lower freight rates. Carriers will have difficulty obtaining financing for conversions if there are not clear monetary benefits that translate into income for debt repayment. Currently, there are no LNG fuel ports on the Great Lakes and the fuel distribution system would have to be developed. The Great Lakes shipyards would have to adopt new technology, update equipment, and provide training for their workforce to perform LNG conversion fuel conversions. LNG has a lower BTU rating than petroleum based fuels on a per pound basis. This means that vessels must not only have cryogenic LNG tanks, but also have adequate storage space for intended voyages. Depending on vessel design, the addition of the LNG tanks may also result in a reduction of cargo carrying capacity.

DEVELOPING THE CONVERSION PROCESS

NG appears to provide a solution for some of the vessels. In August of 2011, GLMRI held a meeting with the Lake Carriers' Association and Maritime Administration representatives in Cleveland, Ohio to discuss how to assess the feasibility of moving to NG as a primary marine fuel. A joint decision was made to take a seven step approach to assess the conversion potential.

1. Perform a literature review of studies related to NG fuelling of transportation assets in general and specifically the marine mode.
2. Study converting the ten existing Great Lakes steam-powered ships to reduce air emissions and fuel consumption.
3. Complete an engineering study modelling the *S.S. Badger* to assess the trade-off between a CNG and an LNG conversion.
4. Prepare a comparative analysis of the emissions from NG and other fuel alternatives using the *S.S. Badger* as a model.
5. Review the supply chain of regional gas availability, liquefaction facilities, capacity, and transportation gas supplies in the Great Lakes region.
6. Research the regulatory requirements for fuelling vessels with LNG and CNG at terminals, docks and midstream.
7. Develop education and outreach venues for industry and the public.

LITERATURE REVIEW

An extensive literature review was undertaken and is ongoing. The scope of the project and the limits of the TRB paper format do not allow a write up of the literature. The literature review has three key purposes:

1. To update the research team about the key components and current developments of using NG as a marine fuel. Literature on natural gas use by truck, rail and marine were studied. The use of LNG as marine fuel for ferries in Norway was explored including visiting facilities in Norway.
2. To provide an accessible source of information for the U.S. Maritime Administration and other stakeholder. A compendium of articles, reports, video links and other material pertaining to LNG is available on the GLMRI website: www.glmri.org/research/
3. The on-going literature review enabled the research team to assess which subject-matter experts should be contacted in order to provide research material and support the outreach portion of the project.

A program of public outreach and education was considered essential for stakeholder understanding of the potential benefits and issues related to conversion of marine vessels to NG. Most stakeholders were 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 passenger and car/truck ferries, as well as Coast Guard Cutters.

STEAM VESSEL LNG CONVERSION STUDIES

At the August 2011 meeting, the shipping industry representatives felt that the existing steam ships that used bunker-C should be the first examined. While these vessels are legally exempt from the new emission requirements, the owners recognize that the best environmental solution would be to replace the steam engines that have poor thermal efficiency and high emissions. The Great Lakes fleet operated by Key Lakes, Inc. offered to provide information and assistance to Dr. Michael Parsons, to study the potential to convert their three AAA class vessels to NG.

AAA Vessels

The peer reviewed engineering study determined that the conversion of the AAA class of steamships on the Great Lakes from oil fired steam ships to diesel engines running on NG can, from an engineering perspective, be accomplished.

1. The general research findings are transferable to the other steam and diesel powered vessels on the Great Lakes. However, vessel-specific conversion plans would be necessary.

2. The majority of the Great Lakes fleet would have the greatest operating flexibility and cargo carrying capacity using LNG as their primary fuel.

3. An emissions analysis was developed for fuel option comparisons to support conversion decisions.

Table 1 shows the annual air emission comparison made between the vessel class's existing steam plant and a conversion of the same vessel to a Diesel plant fuelled by LNG, Diesel or a Dual Fuel using LNG and Diesel (Parsons, 2012).

TABLE 1: Annual Air Emissions Comparison [metric tonnes]

	Existing Steam	Single Fuel LNG	Dual Fuel LNG	Diesel
main engine fuel	2% S Bunker C	LNG	LNG/0.1% S MDO	0.1% S MDO
generator fuel	0.45% S MDO	0.1% S MDO	0.1% S MDO	0.1% S MDO
notes	turbogenerators			no SCR
HC w/o CH4	4.26	64.52	91.05	14.52
CH4	n.a.	93.59	152.15	n.a.
NOx	76.71	70.19	73.44	307.76
CO	8.38	36.67	64.44	15.73
PM	36.28	0.64	2.54	3.97
PM-10	36.28	0.64	2.54	3.97
PM-25	35.19	0.62	2.46	3.85
SOx	371.05	1.60	1.65	11.45
CO2	30722.7	15091.0	15540.1	18156.6
CO2 equivalent GHGs	30722.7	17056.3	18735.2	18156.6

Conceptual designs were developed for both the single fuel and dual fuel conversions. The most challenging naval architectural issue is to obtain enough volume within the vessel to store the LNG since it requires three to four times as much gross hull volume as an equivalent amount of petroleum fuel. Removing the boilers and bunker tanks allowed enough space for the tanks and single Diesel engine. The research team in consultation with tank manufacturers decided to propose vertical rather than horizontal tanks. This allowed sufficient space for the tanks and enabled the vessels to obtain an adequate range with a safe margin.

THE *S.S. BADGER* CONVERSION STUDY

A demonstration project modeling the *S.S. Badger* was developed as the platform for comparative analyses. The *S.S. Badger* travels between Ludington, Michigan and Manitowoc, Wisconsin, carries passengers, cars and trucks, and specializes in over-sized cargo. It was originally built in the 1950s as a ferry for railroad cars, and its route is designated as federal highway Route 10. The Lake Michigan Carferry Service (LMCS), owners of the *S.S. Badger*, had been reviewing options for using NG as an alternative fuel to replace coal. LCMS provided critical data for the researchers to use for their analyses. The GLMRI study by Ziyan Zhang, P.E. and Joseph P. Fischer, P.E., from Bay Engineering Inc. included an engineering design to look at converting the Skinner Uniflow steam engines to using Compressed or LNG and the tank size and placement, fueling, and special handling requirements. Also, as part of the study a regulatory analysis was prepared. Although the vessel and the cargoes are quite different from the bulk cargo fleet, natural gas issues with regulations, engineering, supply chain and emissions benefits transfer across all U.S. Great Lakes vessels.

CNG vs. LNG Conversion

The peer reviewed engineering study determined that the conversion of the *S.S. Badger's* historic Skinner coal powered steam engine to using NG as fuel can, from an engineering standpoint, be accomplished. There were benefits and detriments to either form of conversion - CNG or LNG - along with design parameters that would need to be approved by the U.S. Coast Guard.

Although the Skinner engines could be converted to use either CNG or LNG, the fuelling logistics are a critical factor. Based on the routing model used in the study, CNG would have to be filled every 1-2 days, whereas LNG would be 3-4 days. Depending on the regulatory decisions on bunkering procedures, this could be a limiting factor. CNG as well as LNG may be viable options for this vessel on its fixed route, but the operating schedule of the vessel may be adversely impacted if fuelling is not allowed during loading and unloading.

Emissions Study

GLMRI believed that a comparative emissions study would assist in the decision making process and inform stakeholders about the potential of NG. Dr. James Winebrake and Dr. James Corbett developed a case study for a consistent comparison route for the *S.S. Badger*, and modelled the emissions based on factors published by the EPA (AP42 Compilation of Emissions Factors) for coal, IFO, MDO, LNG, CNG and Bio-Diesel (BD-20).

To determine energy consumed by the *S.S. Badger* engines, the research team first determined how much fuel the engines currently consume per trip. They then converted fuel consumption to BTUs based on fuel energy content. The current consumption of coal is based on the reported fuel consumption in a year and normalized by the number of trips taken in a year. The research team used the Geospatial Intermodal Freight Transportation (GIFT) model to compare emissions on the vessels standard routes (See Table 2). The routes were evaluated in the GIFT model based on transporting the cargo on truck, via the highway system (All Truck Route), transporting the cargo on the *S.S. Badger* with the existing coal-powered steam plant, and then various alternative fuel options as depicted in Table 2.

TABLE 2: Total trip emissions for the two alternative routes on the *S.S. Badger* using conventional and alternative fuels. Source: (GLMRI, 2012)

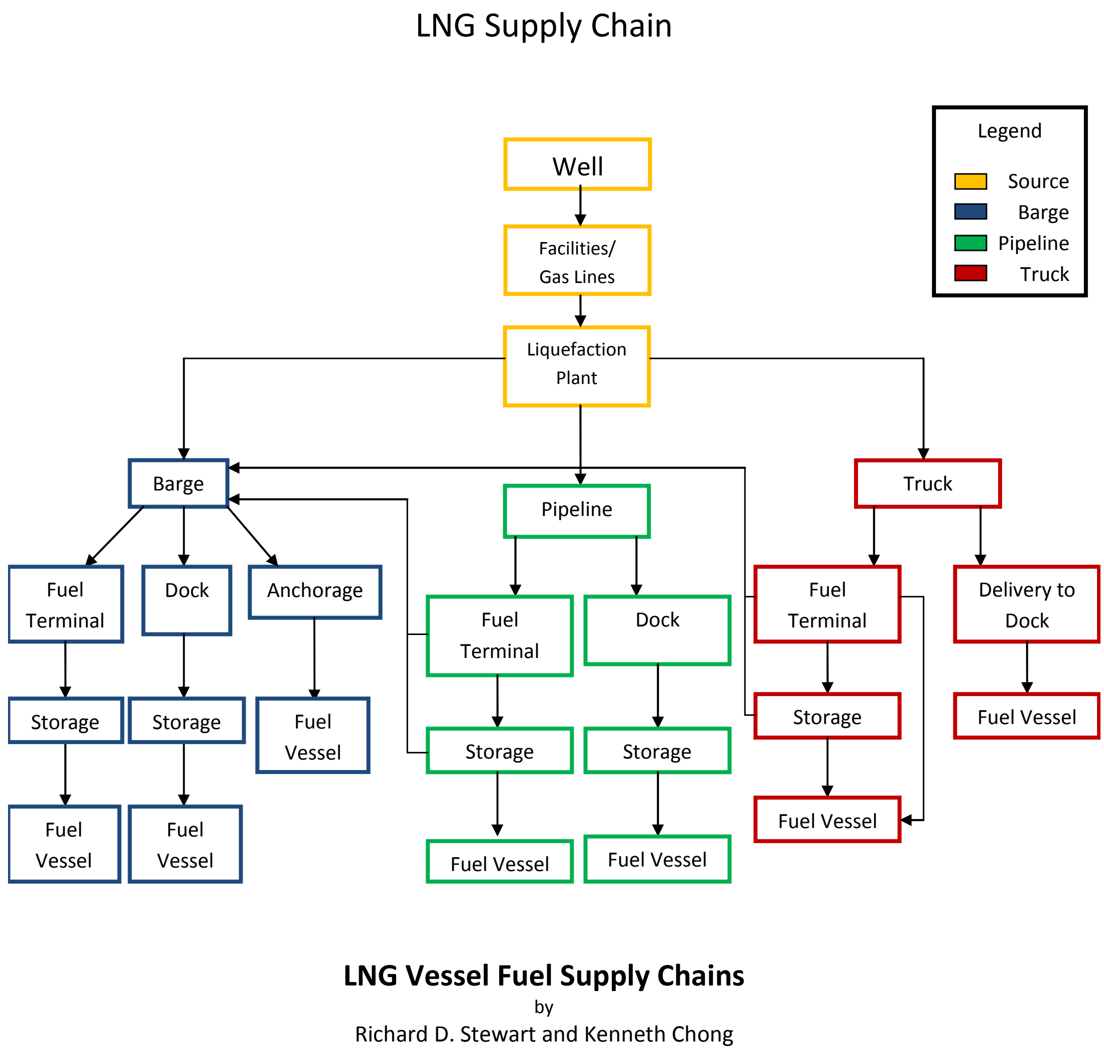
	Total Trip Emissions (kg per TEU-trip)					
	CO2	SOx	NOx	PM10	CH4	CO
All Truck Route (Full)	400	0.004	0.17	0.0084	0.0012	1.0
Car Ferry route using Coal	590	3.6	91	110	0.50	42
Car Ferry route using IFO	530	630	81	41	1.5	7.9
Car Ferry route using MDO	520	130	27	3.0	0.081	7.9
Car Ferry route using LNG	410	0.003	0.26	0.018	0.0081	0.65
Car Ferry route using CNG	410	0.003	0.26	0.018	0.0081	0.65
Car Ferry route using Bio-Diesel	500	11	3.9	0.44	0.053	1.6

DEVELOPING THE LNG SUPPLY CHAIN

Key to operating any converted or new vessel on LNG will be the availability of LNG. The supply chain location of fuel stops must allow for the vessels to engage in normal operations and not spend excessive time fuelling. A flow diagram was developed for LNG supply to vessels (see Figure 5) and then the potential availability of LNG in the Great Lakes system was assessed. The NG supply chain in the Great Lakes regions for all modes of transportation is in its infancy and currently could not supply a major fleet transition of the vessels to NG.

At the start of the study it was found that the only existing large scale (over 30K gallons per day) liquefaction plants in the Great Lakes region were peaking plants (EIA, 2008). These plants are designed to provide a reservoir of LNG for utility companies when demand for NG peaks such as during an intense sub-zero cold spell. These plants principal purpose is for utilities, and their ability to sell excess LNG is governed by Public Utility Commissions. They would be able to provide very little, if any, LNG for transportation consumption. Major gas pipelines run through the Great Lakes region and could supply additional demand for NG but the liquefaction plants will need to be constructed in order to supply vessels and other modes that convert.

FIGURE 1: LNG Supply Chains for Great Lakes Vessels (Source: GLMRI, 2012)



At present there are no approved fuelling docks for transferring NG to vessels. The lack of regulations focused on NG as a vessel fuel and the absence infrastructure adds to the uncertainty for early adopters.

The existing supply of LNG in the Great Lakes to serve vessels is limited but there is industry interest and potential for new liquefaction plants in key locations. The marine industry was the focus of this study but rail, highway, mining, agriculture, and transit are all interested in expanding the use of NG as a transportation fuel. Another potential use would be "off-grid facilities", such as wood products companies, that currently use Diesel fuel because they are not located near natural gas pipelines. LNG could be delivered by truck, rail or marine in ISO containers. The adoption of NG by multiple modes could reduce cost by realizing economies of scale and the transfer of diesel technology between modes.

Two liquefaction plant models were examined:

<u>Small/Medium Sized Liquefaction</u>: Construction of new small and medium sized liquefaction (up to 150 thousand gallons per day) and/or compression plants in key locations that would cost effectively serve multiple markets by realizing economies of scale. In most cases they would serve markets up to 250 miles away with the potential for longer hauls where it was cost effective. The LNG/CNG could travel to a final destination on multiple modes if the locations were well served by truck, rail, and marine.

1. This model can provide competitive pricing from multiple sources.

2. This model lowers the risk of a loss of supply due to a very large plant being shut down.

3. The model may not realize the lowest possible prices as the maximum economies of scale for liquefaction will not be achieved.

4. This model fits into the cost-effective truck drayage limits.

5. This model can provide year round transportation when the Great Lakes are closed due to ice and lock maintenance.

Large Liquefaction: A European model where LNG is moved from a central waterfront terminal that is connected to a very large liquefaction plant to multiple fuelling locations was considered. The conceptualized supply chains for this model include LNG supply vessels, containerized LNG transported by multiple modes of transportation moving LNG from the central terminal to other locations. This supply chain that could stretch for hundreds of miles would require significant volumes to be cost effective.

1. This model limits competitive pricing from multiple sources.

2. This model increases the risk of a loss of supply due to a very large plant being shut down.

3. The model will realize the lowest possible prices as the maximum economies of scale for liquefaction will be achieved.

4. This model may not fit into the cost-effective truck drayage limits for some users.

5. If this model relies on marine transportation for moving product to key markets it will be unable to provide year round marine transportation when the Great Lakes are closed due to ice and lock maintenance.

6. The facility may be able to move product by rail during the ice season but history has indicated that railroads charge premium rates for service that switches between rail and marine when the product is captive to the railroads during winter.

Both of these models are best served with pipelines from the wells to the liquefaction/compressing facilities of a sufficient size to meet demand. These models will require significant capital investments, long term contracts with users, and public acceptance of the liquefaction/compressing facilities and supply chain. Initial evaluations of the models indicate that the model with the smaller liquefaction plants may be the one best suited to the region, with allowing enough land/space /real estate to expand if or when the future markets develop.

REGULATORY REQUIREMENTS

There are many federal, state and local government agencies in the U.S. that have jurisdiction over some aspect of LNG. Some agencies that have jurisdiction over the vessel and others 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 International Maritime Organization (IMO) has continued to 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 fuelled engines on ships are found in IMO Resolution MSC 285(86), Interim Guidelines For Gas-Fuelled Engine Installations in 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-fuelled 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 yet in 2014.

The research methodology encompassed a literature review, interviews with regulatory agencies and site visits to the ports of Manitowoc, Wisconsin and Ludington, Michigan to speak with local agencies. The two ports selected for regulatory evaluation are ports of call for the *S.S. Badger*.

Federal Regulatory Issues

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 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

The U.S. 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.

U.S. Coast Guard regulations in 33 CFR Part 127 (Waterfront facilities handling LNG 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 LNG Marine Fuel Transfer (Bunkering) Operations and the other one addresses LNG fuel Transfer Operations and Training of Personnel using NG as Fuel.

State and Local Regulatory Issues

In addition to the federal agencies, 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. Local fire marshals have jurisdiction over the local areas, and training for First Responders should be considered in any bunkering alternative.

Tables were created to provide readers with a clear idea of what agencies and what regulations (if any) would pertain to marine vessels using LNG. Table 3 is an example of one of the tables created as part of the research process.

TABLE 3: Agencies Involved In Establishing LNG Vessel Fueling (GLMRI, 2012)

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 Michigan	YES	NO	NO	NO
State of Wisconsin	YES	NO	NO	NO
Army Corps Of Engineers	NO	YES	NO	NO
Federal Motor Carrier Administration	NO	NO	NO	NO
City of Ludington	YES	YES	NO	NO
City of Manitowoc	YES	YES	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

*The USCG does not have regulations that apply to the transfer of small quantities of LNG from a storage facility to a vessel. The USCG 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. (GLMRI, 2012)

THE EDUCATION AND OUTREACH PROCESS

A program of public outreach and education was considered essential for stakeholder understanding of the potential benefits and issues related to conversion of marine vessels to NG. Most non-maritime stakeholders were 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 passenger and car/truck ferries as well as Coast Guard Cutters.

The education and outreach process consisted of six on-going actions:

1. A public web-based portal for the literature review, research results, and presentations was developed. Current LNG projects and informational materials were 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 were added as the project progressed along with tutorial information on hydraulic fracturing. The site is regularly updated as new reports are released.www.glmri.org/research/

2. Co-host public forums related to the research and subject. GLMRI has hosted three events to promote the discussions on moving industry to LNG. In June of 2012, GLMRI with support from the Duluth Seaway Port Authority, held a meeting in Superior, Wisconsin to bring together current users and suppliers of NG with potential user industries. Presenters participated from NG companies, pipelines companies, engine conversion equipment manufacturers, along with gas fuelling stations for trucks and trucking lines that were already using NG.

GLMRI hosted a second meeting in May 2013 that focused on siting a liquefaction plant in the western Great Lakes region that would supply the user industries in a 250 mile radius from the Duluth, Minnesota/Superior, Wisconsin area. This meeting had over one hundred attendees and motivated several developers to pursue specific real estate for plant construction possibilities Out of this meeting, a local area group of economic development agencies along with regional planning associations and financial developers was formed and continues to move forward with developing the market for a liquefaction plant.

A third meeting in May 2014 focused on educating the city, state and federal representatives from the Great Lakes region, along with fire marshals and first responders to better understand the embedded safety culture with NG. The Department of Energy, Clean Cities program participated and highlighted their training program for alternative fuels, and the slate of speakers were able to provide information to the attendees in preparation for the expanding use of NG.

3. Presentations at Professional Societies' Meetings and Maritime Events

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) held an LNG themed meeting in February 2012 in Cleveland, Ohio, where a half-day session was held on an LNG tutorial, and the second day was full of speakers from engine companies, classification societies and other LNG industry experts. In February of 2013, GLMRI again worked with SNAME for their meeting agenda, and a site tour was included to visit a truck fuelling station in Seville, Ohio.

GLMRI also provided presentations and updates at many other professional venues, such as: Council of Logistics Management; Institute of Supply Managers; Transportation Associations; Propeller Club and Ship Operations Cooperative Program

4. Presentations at Stakeholder Events to Reach a Broader Audience

GLMRI researchers have been invited to present at many other meetings to advise federal, state and local agencies on the industry progress on moving LNG accessibility for the transportation modes. GLMRI made a presentation to the Council of Great Lakes Governors which include senior advisors from the eight Great Lakes' states to the governors. Also, GLMRI provided updates to the Great Lakes port directors at various meetings and events.

5. Exploration of the existing use of LNG and supporting equipment development

GLMRI staff and researchers have sought out active projects using LNG to better understand the industry and to develop new industry relationships to continue to develop the maritime market for the Great Lakes region. In 2012, GLMRI sent a team of five researchers to Norway to visit LNG powered ferries, engine manufacturers, bunkering facilities and shipyards. The team members were able to tour and observe the bunkering of LNG from the tank truck to the dockside storage, then also the actual bunkering of the ferry.

6. Publish and disseminate in print and on-line

GLMRI has produced a project report, along with a widely distributed annual report, and also quarterly updates on the LNG and other Institute projects. The annual report is provided to approximately 2,000 agencies and individuals, and all of the material is accessible on the GLMRI web page.

CONCLUSIONS

LNG has taken off as a fuel in certain parts of the US with both economic and environmental benefits. In March 2013, Shell announced plans to build a liquefaction plant in Sarnia, Canada to service the maritime industry on the lower Great Lakes. In the spring of 2014, Shell put their plans on "pause" for this plant.

Other companies are actively evaluating Great Lakes locations for building new liquefaction plants. In May 2013, Interlake Steamship Company 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 for converting the *M/V Mesabi Miner* to dual fuel with LNG.

Before Industry is willing to step aggressively forward, the supply chain for NG needs to be developed and accessible to support bunkering alternatives. The regulators will need to publish policies and standards for NG fuelling, operations, and training. Repowering the existing Great Lakes vessels to NG appears to have significant environmental and economic benefits, for the region and the country. The U.S. Maritime Administration in October 2013 awarded a contract to DNV to study bunkering options along the U.S. coasts and rivers. Additional studies should be pursued to expand the supply chain, coordinate cross modal opportunities for NG, and move the technology forward.

Upon request, GLMRI proposed initiatives to the U.S. Committee on Maritime Transportation System (CMTS). The GLMRI proposed initiatives were a direct result of the research process.

PROPOSED ACTIONS TO SUPPORT THE ADOPTION OF LNG

U.S. Government should provide assistance for the conversion of U.S. flag vessels to using NG as a primary and secondary fuel by bringing together relevant agencies to:

1. Fund research and development in:
    - Ship design
    - Engine design
    - LNG Tank designs for vessels
    - Training and education programs
2. Support the rapid development of safe and cost effective regulations.
3. Build a series of ships. A government funded fleet of US built NG standardized US Flag vessels could jump start production jobs to re-tool a long term industrial base for the country's transportation industry along with economic and environmental benefits. The marine field could capitalize on economies of scale and R&D improvements in high horse power engines used by rail and other industries.
4. Shipyard Operations: Support U.S. shipyard training and building /equipment infrastructure including technology transfer from more advanced nations.
5. Maritime Training: Support safety training for mariners and first responder training in NG bunkering ports.
6. Title XI and other support: Provide loans, grants or tax incentives to support conversion of commercial ships.

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