LIQUEFIED NATURAL GAS AS MARITIME FUEL ON THE GREAT LAKES:

A Regulatory Evaluation

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Executive Summary

With stricter emission standards forthcoming from the Environmental Protection Agency (EPA) and the International Convention for the Prevention of Pollution from Ships (MARPOL), there are companies interested in converting existing main propulsion systems from diesel, steam or even coal to Liquefied Natural Gas (LNG).

The Great Lakes Maritime Research Institute (GLMRI) received a cooperative agreement from the U.S. Maritime Administration to analyze the feasibility of converting U.S. Great Lakes bulk carrier commercial ships (known as Lakers) to LNG propulsion. The Lake Michigan Carferry SS *Badger* was chosen as the demonstration project. The SS *Badger* is the only coal-fired steamship in operation in the United States. The project is divided into the engineering analysis and the regulatory analysis. The regulatory part of the study will address current federal, state and local regulations regarding LNG propulsion on commercial vessels and LNG fueling facilities and operations.

There are many federal, state and local government agencies in the U.S. that have jurisdiction over some aspect of LNG. 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 international standards that address LNG fueled engines on ships are found in the International Maritime Organization (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. Domestically, the U.S. National Fire Protection Association Code (NFPA 59A: Standard for the Production, Storage, and Handling of Liquefied Natural Gas) is the standard that had been adopted by fire departments around the country.

There are a myriad of federal, state and location government regulations that address LNG safety and security requirements at facilities. The Army Corps of Engineers require 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 don't 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 provide 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.

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 apply to facilities that handle large quantities of LNG. Similarly, Coast Guard Navigation and Vessel Inspection Circular 01-2011 (Guidance Related to Waterfront LNG Facilities) and Commandant Instruction (COMDTINST 16010.3 Risk Based Decision-Making Guidelines) only apply to LNG facilities and tank ships that transport LNG as cargo. The Coast Guard is working on policy that will apply to the transfer from a fixed or mobile facility to the vessel.

The Coast Guard has also been working on policies that address training requirements for LNG bunkering, and the Merchant Marine Personnel Advisory Committee (MERPAC) recently formed a working group to advise the Coast Guard on Standards of Training Certification and Watchkeeping (STCW) qualifications and licensing requirements. Similar to facilities, vessels need to comply with MTSA and the accompanying regulations in 33 CFR 104 (Maritime Security: Vessels). Compliance with these requirements will be to the satisfaction of the cognizant Coast Guard Captain of the Port.

There are state and local 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.

Since the use of LNG as maritime fuel is new in the United States, it was important to learn from countries that have successfully implemented this technology. Over the past decade, Norway has built natural gas powered ferries and are currently building additional natural gas powered vessels to support the North Sea oil and gas industry. This initiative was undertaken in part because of the strict emission standards in Europe and the establishment of Emission Control Areas. The primary government agency that has jurisdiction over commercial shipping is the Norwegian Maritime Authority (NMA). NMA has similar authorities to the U.S. Coast Guard in that they are responsible for ensuring that Norwegian vessels meet the highest level of safety and environmental standards, that mariners are properly qualified (licensing), and that foreign ships that enter Norwegian ports and territories meet applicable international rules. Norway adopted

IMO Resolution MSC 285(86), Interim Guidelines For Gas-Fuelled Engine on Ships and all Norwegian flagged ships must comply with those standards

The future of LNG fueled vessels on the Great Lakes is extremely positive. The U.S regulatory and policy framework is being developed, and there is an opportunity for the maritime industry to provide input in the development of governmental regulations and policy.

Introduction

U.S. regulatory requirements for Liquefied Natural Gas (LNG) transported as cargo on ships and handled at production facilities have been established for quite some time. That includes LNG tank ships using cargo boil off as fuel for main propulsion engines. With stricter emission standards forthcoming from the Environmental Protection Agency (EPA) and the International Convention for the Prevention of Pollution From Ships (MARPOL), there are companies interested in converting existing main propulsion systems from diesel, steam or even coal to LNG. However, the technology is so new in the U.S. there are not many companies who have made the conversion, and only a few federal, state and local government agencies that have regulations that are applicable to ships using LNG as fuel and facilities that store small quantities of LNG (storage tanks and liquefaction plants).

In order to potentially move forward with this technology on the Great Lakes, the Great Lakes Maritime Research Institute (GLMRI) received a grant from the U.S. Maritime Administration to analyze the feasibility of converting U.S. Great Lakes bulk carrier commercial ships (known as Lakers) to LNG propulsion. The Lake Michigan Carferry SS *Badger* was chosen as the demonstration project. The SS *Badger* is the only coal-fired steamship in operation in the United States. The 410' ferry, which entered service in 1953, is 6650 tons displaced, averages 15.6 kts, and transports up to 600 people and 180 vehicles. It is designed specifically to handle the rough conditions that it would likely encounter during year 'round sailing on Lake Michigan. The SS *Badger* sails daily between Manitowoc, Wisconsin and Ludington, Michigan from mid-May through mid-October.

The project is divided into the engineering analysis and the regulatory analysis. The engineering analysis will model the Badger's consumption, routes, shore-fueling station(s) and viability of using natural gas. The regulatory part of the study will address current federal, state and local regulations regarding LNG propulsion on commercial vessels and LNG fueling facilities and operations. The analysis includes gaps in current regulations, roadblocks to moving ahead with this initiative and recommendations for successful implementation. Further, the study looks at the current supply chain availability that could support the SS *Badger* conversion.

Since LNG propulsion technology is so new in the U.S., it was important to look at those countries around the world where it has been successful. The GLMRI identified Norway, who for a decade, has operated natural gas powered ferries and are building other natural gas powered vessels. They have also implemented regulations for ships that use LNG as fuel and facilities that handle small amounts of LNG. The GLMRI study team traveled to Norway and observed LNG propelled vessels, their bunkering operation, and met with Norwegian government officials to discuss the keys to successful implementation of this technology.

Federal, State and Local Regulatory Framework

Since there are so many federal, state and local government agencies in the U.S. that have jurisdiction over some aspect of LNG, the study 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 not examined as part of this project but will be researched in future research efforts. After identifying the agencies that have jurisdiction over LNG, the study examined whether the agency had regulations and/or policy in place or if they have they adopted an international or national standard. Tables 1, 2 and 3 summarize these results. A more detailed analysis of the regulatory requirements is in subsequent sections.

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 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

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

City of Manitowoc	YES	NO	NO	YES
Pipeline and Hazardous Material Safety Admin	NO	NO	NO	NO
Federal Railroad Administration	NO	NO	NO	NO
Department Of Energy	NO	NO	NO	NO

Vessel Requirements

Agency/Organization	NFPA	Regulations	Policy	IMO
USCG	YES	NO***	YES	YES
Federal Energy Regulatory Commission	NO	NO	NO	NO
Environmental Protection Agency	NO	YES	YES	NO
State of Michigan	NO	NO	NO	NO
State of Wisconsin	NO	NO	NO	NO
Army Corps Of Engineers	NO	NO	NO	NO
Federal Motor Carrier Administration	NO	NO	NO	NO
City of Ludington	YES	NO	NO	NO
City of Manitowoc	YES	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.

**The States of Michigan and Wisconsin 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 to their policy and regulatory efforts.

International and National Standards

The international standards that address LNG fueled engines on ships are found in the International Maritime Organization (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. Domestically, the U.S. National Fire Protection Association Code (NFPA 59A: Standard for the Production, Storage, and Handling of Liquefied Natural Gas) is the standard that had been adopted by fire departments around the country. There are other international and national standards for LNG, however the ones noted above are most applicable to the parameters of this study.

Facility Requirements (Storage Tanks/Liquefaction Plants)

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

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. In general, the threshold for reporting is 25,000 metric tons or more of carbon dioxide (CO2) equivalent per year. Reporting is at the facility level, except for certain suppliers of fossil fuels and industrial greenhouse gases. Those industry segments in which GHG emission reporting is required include:

- Offshore petroleum and natural gas production
- Onshore petroleum and natural gas production
- Onshore Natural gas processing facilities
- Onshore Natural gas transmission compression
- Underground natural gas storage
- Liquefied natural gas (LNG) storage
- LNG import and export equipment
- Natural gas distribution

Should the decision be made to pursue an LNG facility around the Great Lakes, a more detailed analysis will have to be conducted to ascertain whether the emission levels meet the reporting requirements. Further, there may be a requirement to conduct an Environmental Impact Statement (EIS) for an LNG storage facility or liquefaction plant. If it is determined that federal permitting action is required then the requirements of the National Environmental Protection Act will apply. The applicable federal agency would then conduct an EIS or an Environmental Assessment, as appropriate.

The Coast Guard exercises regulatory authority over LNG facilities that affect the safety and security of port areas and navigable waterways under Executive Order 10173; the Magnuson Act (50 United States Code (USC) section 191); the Ports and Waterways Safety Act of 1972, as amended (33 USC section 1221, et seq.); and the Maritime Transportation Security Act of 2002 (46 USC section 701). 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 apply to facilities that handle large quantities of LNG. Similarly, Coast Guard Navigation and Vessel Inspection Circular 01-2011 (Guidance Related to Waterfront LNG Facilities) and Commandant Instruction (COMDTINST 16010.3 Risk Based Decision-Making Guidelines) only apply to LNG facilities and tank ships that transport LNG as cargo. The Coast Guard is working on policy that will apply to the transfer from a facility to the vessel.

The States of Wisconsin and Michigan require permits to build a facility (storage tanks or liquefaction plants) and approval from appropriate agencies prior to construction. At the local level, the cities of Ludington and Manitowoc also require permits and approval from the applicable city government agency. Fire departments from both cities require compliance with the National Fire Protection Association Code (NFPA 59A: Standard for the Production, Storage, and Handling of Liquefied Natural Gas). The fire chiefs will require facilities (both fixed and mobile) to submit standard operating procedures, and that fire fighters, facility personnel and shipboard personnel are properly trained to fight LNG fires. While facility safety requirements vary between federal, state and local government agencies, fixed facilities will need to comply with applicable security requirements in the Maritime Transportation Security Act and the accompanying regulations in 33 CFR Part 105 (Maritime Security: Facilities). Compliance with these requirements will be to the satisfaction of the cognizant Coast Guard Captain of the Port.

Mobile Facility Requirements (Tanks Trucks)

There are several federal agencies that have jurisdiction over tank trucks transporting LNG. The Federal hazardous materials transportation law (Federal hazmat law), 49 U.S.C. § 5101 et seq., is the basic statute regulating hazardous materials intrastate, interstate, and foreign commerce transportation in the United States. The Federal Motor Carrier Safety Administration has authority over the transportation or shipment of hazardous materials by highway. FMCSA also enforces the Federal Motor Carrier Safety Regulations (49 CFR Parts 350-399), issued under various motor carrier safety acts codified in 49 U.S. Code. FMCA requires carriers to be registered, trucks need DOT and MC numbers, and drivers need to be qualified to transfer LNG. The Pipeline and Hazardous Material Safety Administration (PHMSA) is responsible for regulating and ensuring the safe and secure movement of hazardous materials to industry and consumers by all modes of transportation, including pipelines. PMHSA has responsibility for issuing rules and regulations governing the safe transportation of hazardous materials. Those regulations are detailed in Title 49 Code of Federal Regulations Parts 100-185 and 190-199. The Office of Pipeline Safety ensures safety in the design, construction, operation and maintenance, and spill response planning of natural gas and hazardous liquid transportation pipelines. The Office of Hazardous Materials Safety develops regulations and standards for the classifying, handling and packaging of hazardous materials within the United States.

The Coast Guard does not currently have regulations that apply to LNG transfers from mobile facilities. The transfer regulations found in 33 CFR Parts 154, 155 and 156 apply to oil and

hazardous material transfers. The Coast Guard is in the process of developing a policy that addresses LNG transfers between tank trucks and vessels (ships and barges). The states of Michigan and Wisconsin also do not have regulations that apply to the transfer of LNG from a tank truck to a vessel, however all tank trucks must comply with state requirements for transporting LNG over the roads of the respective states. Similarly, the cities of Ludington and Manitowoc do not have regulations that require permits or local government approval however tank truck companies and vessels must submit standard operating procedures (which include transfer procedures, hours of operation, fire fighting plans and training, etc) to the fire chiefs of both cities for approval. Further, the companies must demonstrate compliance with the applicable standards of NFPA to the satisfaction of both fire departments.

Vessels (Ships or Barges)

Most of the federal, state and local agencies defer vessel inspection requirements/responsibilities to the Coast Guard. The Environmental Protection Agency is the only other federal agency that has regulations that cover vessels with marine engines powered by natural gas. In April 2010, EPA published rules on engines installed on U.S. commercial vessels as well as marine diesel fuels produced and distributed in the United States. The regulations also include a program to implement Annex VI to MARPOL in the United States, including engine and fuel sulfur limits, and extends the Emission Control Area (ECA) engine and fuel requirements to U.S. internal waters. Regulations in Title 40 CFR Part 1042 detail emission requirements for replacement engines with engine power levels over 250Kw and replacement fuel systems. Further, there are two new tiers of engine standards for marine engines: Tier 2 standards that began in 2011 and Tier 3 standards that will begin in 2016.

Great Lakes Steamship Repower Incentive Program

The EPA added a provision to the marine diesel engine program to encourage owners of Great Lakes steamships to repower those steamships with cleaner Tier 2 or later marine diesel engines. Currently, due to safety and other considerations, these steamships are exempt from the fuel sulfur requirements that began on the Great Lakes in August 2012. This provision will provide an automatic, limited fuel waiver for qualifying repowered Great Lakes steamships that will allow the owner to use higher sulfur residual fuel in the repowered diesel engine for a specified period of time. The replacement engine must be a Tier 2 or cleaner marine diesel engine. The automatic Great Lakes steamship repower fuel waiver is valid through December 31, 2025.

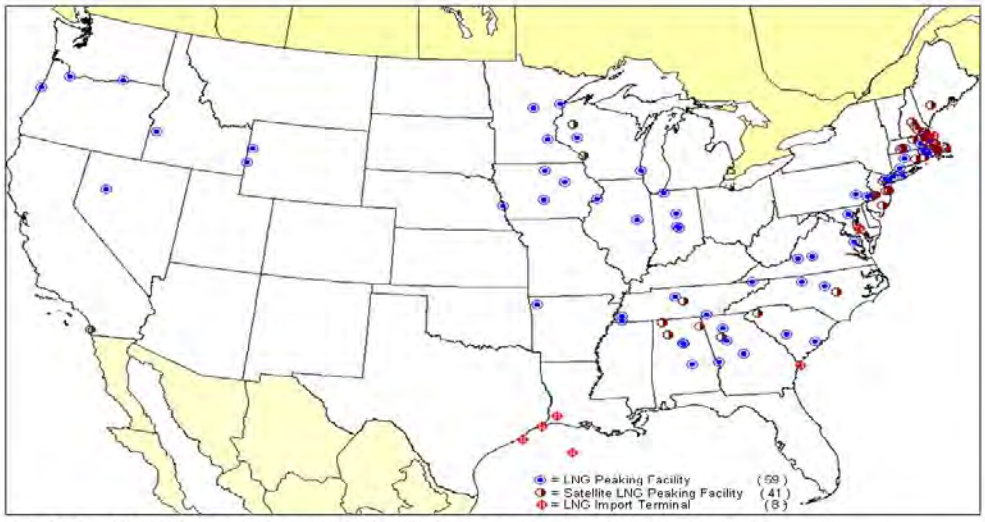
As previously stated, the U.S. Coast Guard currently has regulations that cover the transport of LNG (as cargo) and the ships that use LNG boil off in their propulsion. There are no regulations in place that address LNG main propulsion engines. The most recent policy letter (CG 521 Policy Letter (01-12), signed in April 2012 entitled: Equivalency Determination – Design Criteria for Natural Gas Fuel Systems states the Coast Guard has adopted the International Maritime Organization Resolution MSC 285(86) (Interim Guidelines for Gas-Fuelled Engines on Ships) as the primary standard. In addition to the IMO guidelines, they have also included additional requirements that address ship arrangements and system design, fire safety, electrical systems, control, monitoring and safety systems, compressors and gas engines, testing, and operational and training requirements.

The Coast Guard has also been working on policies that address training requirements for LNG bunkering, and the Merchant Marine Personnel Advisory Committee (MERPAC) recently formed a working group to advise the Coast Guard on Standards of Training Certification and Watchkeeping (STCW) qualifications and licensing requirements. Similar to facilities, vessels need to comply with MTSA and the accompanying regulations in 33 CFR 104 (Maritime Security: Vessels). Compliance with these requirements will be to the satisfaction of the cognizant Coast Guard Captain of the Port.

Supply Chain in the Great Lakes

There is no doubt that the Midwest has a plentiful supply of natural gas. The question is whether there is enough existing infrastructure and/or interest from LNG supply companies to support the potential conversion of the SS *Badger* from coal to LNG. In order to answer that question, GLMRI hosted an LNG Supply Chain conference in June 2012, and a number of companies from the trucking industry detailed the conversion of their fleet to Compressed Natural Gas (CNG). There were also presenters who explained that a number of gasoline stations around Minnesota and Wisconsin have included CNG.

A closer look at the region's LNG supply chain revealed several LNG Peak Shaving facilities in close proximity to the SS *Badger's* ports of call. One facility is in Wisconsin and the other in Indiana (See Figure 1). However, there are no other LNG facilities that were identified in this study that are in close proximity to the SS *Badger;* although a number of companies have expressed an interest in developing the LNG infrastructure around the Great Lakes. If the engineering studies show that the SS *Badger* could be fueled by tank truck, these facilities may be a source of fuel.



Note: Satellite LNG facilities have no liquefaction facilities. All supplies are transported to the site via tanker truck.
Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division Gas, Gas Transportation Information System, December 2008.

Figure 1: U.S. LNG Peaking Shaving Import Facilities, 2008

LNG as Maritime Fuel In Norway

Since the use LNG as maritime fuel is new in the United States, it was important to learn from countries that have successfully implemented this technology. Over the past decade, Norway has built natural gas powered ferries and are currently building additional natural gas powered vessels to support the North Sea oil and gas industry. This initiative was undertaken in part because of the strict emission standards in Europe and the establishment of Emission Control Areas. Further, The European Union (EU) has embarked on an approximately $14 million study on converting vessels operating in the Baltic and other Emission Control Areas to using natural gas as a primary fuel.

While the supply chain infrastructure for LNG is a concern to the Norwegians, it has grown substantially over the past decade. The maturity of the supply chain infrastructure along with an abundant source of natural gas positions them well to expand this technology.

The primary government agency that has jurisdiction over commercial shipping is the Norwegian Maritime Authority (NMA). NMA has similar authorities to the U.S. Coast Guard in that they are responsible for ensuring Norwegian vessels meet the highest level of safety and environmental standards, that mariners are properly qualified (licensing), and that foreign ships that enter Norwegian ports and territories meet applicable international rules.

Norway adopted IMO Resolution MSC 285(86), Interim Guidelines For Gas-Fuelled Engine on Ships and all Norwegian flagged ships must comply with those standards. Specifically, regulation No.1218 of 9 September 2005 addresses construction and operation of gas-fueled passenger ships (more than 12 passengers) and Regulation No. 644 of 17 June 2002 addresses cargo ships with natural gas fueled combustion engines. For other ships (entitled Unclassified ships), gas related matters not regulated by NMA are to comply with Det Norske Veritas (DNV) rules currently in force for gas-fueled engine installations.

Facilities

The agency responsible for LNG facilities (storage tanks and liquefaction plants) as well as the bunkering process from shore to ship (or barge) is the Directorate for Civil Protection and Emergency Planning (DSB). Recognizing that two government agencies that have jurisdiction over the bunkering process, there has been significant coordination between NMA and the DSB to standardize the requirements for LNG bunkering since both agencies have regulatory jurisdiction. Both agencies are looking at developing a standardized risk assessment process and implementing a safety work permit (similar to the Coast Guard Declaration of Inspection for transfer operations).

Bunkering Operation on the Fjord 1 Passenger Ferry Raunefjord

An important part of learning about the Norwegian efforts implementing LNG as a marine fuel was observing the operation and bunkering operations of the Fjord 1 passenger ferry Raunefjord. GLMRI team members had the privilege of observing the LNG bunkering process, witness the ferry's Rolls-Royce LNG engine in operation and ride the ferry on the assigned route. The ferry is 129.8 meters in length, 4856 gross tons, travels 21 kts and carries 589 passengers and 212 vehicles. Upon arrival, the team witnessed a LNG tank truck refueling the land-side storage tanks used to supply the passenger ferry. The location of the storage tanks were across the parking lot from the ferry's embarkation area. The two LNG storage tanks, 500 cubic meters

each (which was about four full ferry loads) were surrounded by a combination of a chain linked fence with a locking device and a cement fence along the perimeter. (Figures 2, 3 and 4)

Figure 2 LNG Storage Tanks

Figure 3 Tank Truck Refilling LNG Tanks

Figure 4 LNG Tank Gauges and Valves

Additionally, there were access restriction signs as well as natural gas information signs posted on the chain linked perimeter fencing. (Figures 5 and 6) No additional physical security requirements (guards/cameras/etc) were in place, nor required.

Figure 5 LNG Storage Tank Fencing and Warning Signs

Figure 6: LNG Storage Tank Signs

The team then observed the off-loading and loading of vehicles, trucks and passengers which was extremely quick and smooth. (Figures 7, 8)

Figure 7 Ferry RAUNEFJORD Offloading Vehicles and People

Figure 8 Ferry RAUNEFJORD Loading Vehicles

There is no prohibition of type of vehicle and cargo that were allowed to go onboard. In fact, a LNG tank truck was on the ferry during the transit. (Figure 9) GLMRI team members rode the ferry on its 1.5 hour round trip transit during which we observed the operation of the vessel.

Figure 9: LNG Tank Truck On-Board RAUNEFJORD

Upon completion of the final transit, the ferry shifted to another berth to complete LNG bunkering operations (adjacent to the ferry loading/unloading terminal). LNG bunkering operations are restricted to times when there are no loading or off-loading operations taking place.

The facility was comprised of a fixed piping and manifold system that was used to transport LNG from the storage tanks, underneath the parking lot to the vessel. (Figures 10, 11, 12 and 13) The vessel uses a flexible hose connected from the dock-side manifold to the vessel piping. Prior to conducting transfer operations, the pipes were purged with nitrogen for 3 minutes; upon completion of the nitrogen purge, the piping was purged with LNG for 4 minutes in order to remove the remaining nitrogen before initiating LNG bunkering operations. All officers and crew members have been trained in LNG bunkering procedures.

Figure 10 LNG Refueling Facility

Figure 11 LNG Refueling Location Adjacent to Walkway

Figure 12 LNG Fixed Manifold and Piping

Figure 13 LNG Facility Cargo Control Area

The Chief Engineer used an extensive check list that was developed by the company to ensure each part of the process was completed in the proper order and within the prescribed time period. He could open and close all valves remotely from the control room located on the vessel. During the bunkering process, the Chief Engineer was in the control room, another engineer was on the dock (at the manifold) and the Master and another officer were on the bridge in case the vessel

needed to get underway in short order. These individuals remained at their locations during the entire bunkering process which took about 4.5 hours.

Nitrogen Oxides (NOx) Fund

Norway has been very successful in encouraging the maritime industry to invest in NOx reducing technology. The main driver for the this initiative is the environmental requirements mandated by MARPOL as well as the Baltic/North Sea limitations on nitrogen oxide emissions. Starting in August 2012, the Baltic Sea and North Sea as well as North American coasts are regulated as Emission Control Areas (ECA), limiting the amount of nitrogen oxide emissions. MARPOL Annex VI requires NOx reduction to meet Tier II requirements (20% reduction) by 2011 and Tier III requirements (80% reduction) by 2016.

Because of these standards, Norway established a federal tax on NOx emissions. As an option, they also approved the establishment of a private NOx fund that companies can voluntarily contribute monies (through a tax); if companies sign up and contribute, then 85 percent of differential costs between the LNG and non-LNG engine plants can be recouped from the fund by companies who upgrade their technology with NOx reducing equipment This program applies to Norwegian flag vessels that transit strictly on Norwegian territorial waters. The NOx fund has been extremely successful and has contributed in furthering LNG fueled ships initiative.

Roadblocks to Success

This study has identified some potential roadblocks that could hinder the development of LNG fueled vessel technology and supply chain on the Great Lakes. The roadblocks listed below are not limited to regulatory challenges, but also include a broader context including stakeholder involvement and buy-in, the cost to implement this new technology and the current lack of LNG supply chain.

Stakeholder concern over LNG: the quickest way to have a project stopped in its tracks is to not include stakeholders in the process. This process must include an outreach and education effort on the properties of LNG as well as addressing any concerns over its handling and storage. LNG has been safely carried as cargo on ships and at production facilities around the world for many years, however, there may be some misconceptions regarding its safety. Those issues need to be addressed before the project can be successful.

Cost to implement: the cost to repower a vessel with either a replacement engine or refueling using LNG is expensive. Companies may not have the capital to invest unless there are federal grant programs that encourage investment in this technology. Norway's NOx fund is an excellent example of the government approving the establishment of a private fund that is used to reimburse a portion of the purchase of NOx reducing technology.

Delays in completing Federal, State and Local regulatory requirements: if the decision is to pursue fixed facilities (storage tanks or liquefaction plants), there are numerous federal, state and local government permits required prior to construction. Depending on the speed of that process, there could be delays in beginning this effort.

Lack of LNG supply chain infrastructure: the availability of LNG as fuel is minimal due to the lack of needed infrastructure around the Great Lakes. However, the Lake Michigan Car

Ferry SS *Badger* does have the option of refueling using a tank truck. The two LNG Peak Shaving locations, one in Wisconsin and the other from Indiana could be a fuel source for the SS *Badger*. The supply chain availability for other Lakers will have to be more closely analyzed for potential fueling locations.

Recommendations

The future of LNG fueled vessels on the Great Lakes is extremely positive. The U.S regulatory and policy framework is being developed and the supply chain infrastructure is not well defined but there is interest in developing it. In order to move forward and make this technology a reality, the following recommendations are offered. They are divided into those involving outreach and others that address facility and vessel compliance, and supply chain requirements. Both areas are critical to make this effort successful.

Outreach

Outreach to all stakeholders, including but not limited to local citizens, environmental groups, federal, state and local agencies and is critical in any project that may be controversial. The use of LNG in the Great Lakes is bound to raise interest on both sides of the issue. Therefore, it is recommended that key individuals with this project:

- Work closely with federal, state and local officials in planning and implementation (i.e., fueling procedures, fire fighting training, transfer requirements, licensing qualifications, etc). Specifically, SS *Badger* representatives and other companies intending to implement LNG fueled technology need to reach out to Coast Guard Sector Lake Michigan, States of Michigan and Wisconsin, and the Cities of Manitowoc and Ludington in complying with transfer operation requirements (regulatory and NFPA) for fixed and/or mobile facilities.
- Develop an outreach plan to obtain buy-in and support from local and regional stakeholders. This area is critical to success as noted in the previous section. Failure to obtain buy-in and support from this group could result in significant delays or possibly cancellation of the project. This effort needs to be started as soon as possible.

Facilities (Fixed and Mobile)

This is new technology in the U.S. and few federal, state and local government agencies have regulations that apply to the vessel and facility. With the forthcoming stricter emission standards, there is great interest by the maritime community to make the shift to LNG fueled engines. The Great Lakes are not unlike the other parts of the U.S. The technology is new and the infrastructure is not available to support this initiative. Therefore, the following is recommended that key individuals in this project:

- Initiate a phased-in approach by starting with LNG bunkering by tank truck. At the same time, develop plans and obtain approvals/permits from applicable federal, state and local agencies for LNG storage tanks or liquefaction plants, if desired. There appears to be sufficient space available in Ludington, MI to construct a LNG storage facility if it is approved by applicable government agencies.

- Continue to develop the LNG supply chain in Ludington, Manitowoc and around the Great Lakes.
- Further research is needed to analyze the supply chain availability, including potential fueling locations at U.S. and Canadian ports for the Lakers.

Figure 14 Ludington: Additional Parking/Open Space Adjacent to Badger Mooring

Vessels

- Work closely with the U.S. Coast Guard (Marine Safety Center and Sector Lake Michigan) to obtain plan approval for a LNG conversion on the SS *Badger* or other Laker. The requirements for obtaining plan approval are detailed in the Coast Guard policy letter CG 521 (01-12).
- Implement Coast Guard mandates for transfer procedure requirement, training and licensing, when applicable. The Coast Guard is currently developing policy for these areas and there is an opportunity, through MERPAC and other professional organizations to be involved in the process.

The future of LNG fueled vessels on the Great Lakes is extremely positive. The U.S. regulatory and policy framework is being developed, and there is an opportunity for the maritime industry to provide input in the development of governmental regulations and policy. There is an eagerness on all levels of government and industry to see this project succeed.

Disclaimers

The opinions expressed here are those of the author only and do not represent the opinions, conclusions, or plans of any of the companies or agencies that have provided assistance to this study.

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