Liquefied Natural Gas as a Marine Fuel in the USA:

The Commercial Realities

FC Business Intelligence

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INTRODUCTION

The US shipping industry is facing a period of upheaval. As tighter environmental restrictions come in to force over the next decade, ship owners, fuel refiners, bunkering providers and other stakeholders must adjust accordingly. Substantial investment will be unavoidable during this period; however deciding when and in which capabilities to invest presents a challenge. On the one hand, ship owners/operators must be sure of the infrastructure to support their new fuelling choices prior to investing in conversions or placing new orders. On the other hand, refiners and bunkering providers are stymied by uncertainty as to the nature and scale of future demand.

Operational, logistical and safety concerns will likely have some influence, but mostly, the popularity of future marine fuels will rest upon commercial considerations i.e. the comparative costs of different solutions. However, even this apparently straightforward methodology brings immense difficulties, not least the impossibility of accurately forecasting energy prices.

The challenge of going green comes as the US shipping industry continues to navigate commercial difficulties. Many shipping firms have been forced to find innovative ways to preserve or recover margins eroded by lower shipping rates and higher overall costs. Given the high capital costs involved with switching to greener fuels, substantial additional financing will be required in the years ahead, an additional hurdle that must be overcome.

The state of play

The catalyst for change in the marine fuel market is environmental regulation, enacted by the International Maritime Organization (IMO). The designation of Emissions Control Areas (ECAs) represents the first step in the introduction of these rules. In the USA, ECAs are enforced by the Environmental Protection Agency (EPA) and the US Coast Guard (USCG).

There are two ECAs in USA waters; one of which came in to full effect on 1 August 2012 and the other scheduled to take full effect as of 1 January 2014.

Table 1: Emissions Control Areas in the USA	Entry in to Force
North America	1 August 2012
US Caribbean Sea	1 January 2014

These ECAs place restrictions on sulfur oxide SOx (SOx), nitrogen oxide NOx (NOx) and particulate matter (PM) emissions pursuant to the International Maritime Organization's (IMO) International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI.

The North American ECA covers waters within 200 nautical miles of the coast, as shown in Figure 1.

Also designated under MARPOL is the United States Caribbean Sea ECA, which covers waters around Puerto Rico and the United States Virgin Islands. This is scheduled to take full effect on 1st January 2014. The area regulated under the United States Caribbean Sea ECA can be seen in Figures 1 and 2.

Figure 1: North American ECA

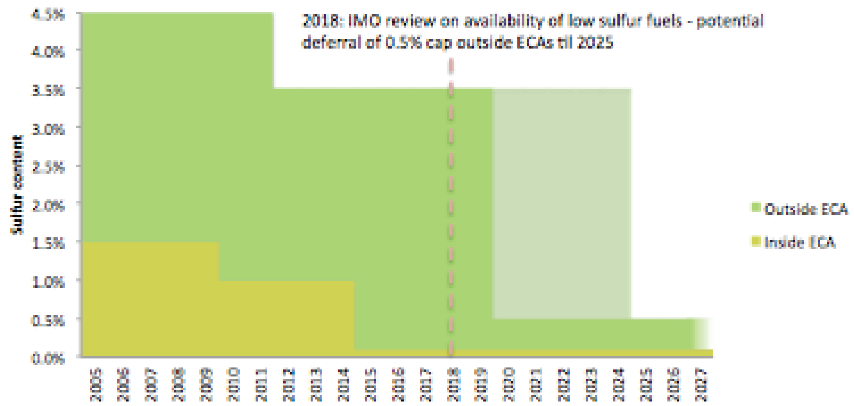
Figure 2: Caribbean Sea ECA

Sulfur emissions limits

Ships traveling within ECAs must comply with sulfur emission limits set by the International Maritime Organization under the revised MARPOL Annex VI. Within ECAs, marine fuels used must have a sulfur content of no more than 1% m/m, falling to 0.10% m/m on 1 January 2015.

Outside of ECAs, the limit for bunker fuel sulfur content is 3.5% m/m, falling to 0.5% m/m on 1 January 2020 (though this date could be deferred to 1 January 2025 depending on the findings from a feasibility review to be completed by 2018). Some industry figures have called for the date of this review to be brought forward, in order to mitigate uncertainty. For example, if a refiner invests to deliver more marine diesel by 2020, a negative outcome of the IMO review could leave the refiner stranded with oversupply of product. The review hence creates a degree of insecurity.

Figure 3: MARPOL Annex VI - sulfur content of marine fuels



Nitrogen oxides

IMO rules also subject vessels to emissions standards for nitrogen oxides (NOx). These apply to diesel engines and vary depending on the engine size and maximum operating speed. Tiers one and two demarcate global limits while tier three, active as of 2016, applies within ECAs.

Table 2: MARPOL Annex VI NOx Emission Limits

Tier	Date	NOx Limit, g/kWh		
		n < 130	130 ≤ n < 2000	n ≥ 2000
Tier I	2000	17	45 · n-0.2	9.8
Tier II	2011	14.4	44 · n-0.23	7.7
Tier III	2016†	3.4	9 · n-0.2	1.96

† In NOx Emission Control Areas (Tier II standards apply outside ECAs).

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Particulate Matter (PM)

Particulate matter is partially burned hydrocarbon material that emanates from the ship's exhaust in the form of smoke or soot. It contains free radicals linked to cancer and respiratory problems. PM also causes corrosion onboard ships. One of the great benefits of LNG-fuelled vessels is the elimination of this hazardous pollutant. The IMO does not explicitly define PM limits, because PM emission will inevitably fall in line with reduced SOx emission.

Alternative to changing fuels

As an alternative to adopting compliant fuel, ship operators can choose to fit exhaust gas cleaning systems or undertake other approved methods to cut SOx emissions. Such systems must reduce total SOx emissions to 6.0g SOx /kWh when within the ECA.

EEDI & SEEMP

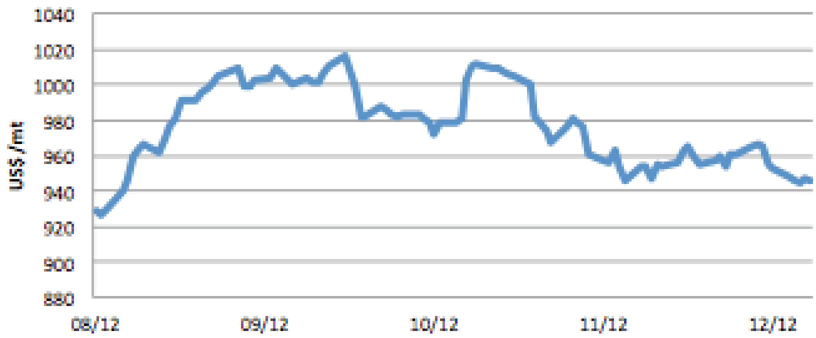
Other key regulatory requirements instated by the IMO include the Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships. The EEDI will require all ships built from 1 January 2013 onwards to meet a minimum energy efficiency level per capacity mile. Reference levels will vary depending on ship type and size segment, and will be tightened every five years. The SEEMP is a mandatory tool from 2013 to continuously evaluate energy efficiency aboard vessels and implement improvements.

The rising cost of shipping

The adoption of MARPOL emissions regulations around USA waters caused increased prices for low sulfur fuels, ultimately pushing up the cost of shipping in the US in 2012. Prices vary considerably from port to port; data collected by the Transpacific Stabilization Agreement (TSA) shows that price differentials between standard bunker and premium low sulfur fuel at Los Angeles/Oakland, Seattle, Charleston and New York ranged from $87 to $260 per metric ton as of mid-August 2012.

These premiums were higher than anticipated. Prior to the institution of the North American ECA, total demand for 1% sulfur RMG 380 constituted approximately 15% to 20% of the 108m barrel per year US bunker fuel market. However, according to Platts, demand increased, 'rapidly beyond expectations' when the ECA came into effect, with some traders reporting between 40% and 50% of daily volume being taken up by low sulfur fuel. As a result, prices rose sharply, with the premium over high sulfur counterparts increasing from approximately US$100 per metric ton in June and July to as high as US$125 per metric ton on the east coast of America and US$280 per ton on the west coast by late August. In the gulf coast, refiners responded by producing more 1% RMG, whereas east coast suppliers imported more low sulfur oil for blending from Latin America or Europe.

Figure 4: Marine diesel oil average global bunker price



Following initial price spikes, the price of low sulfur fuels fell to more normal levels in the latter months of 2012, as illustrated on table four. However, even at present levels the cost of low sulfur fuel compared to marine heavy fuel oil inflates the cost of shipping within ECAs substantially, so that ship owners will continue to consider alternative options.

Looking ahead at the longer term, opinions vary as to how the industry will respond to new more stringent environmental regulations. One critical factor will be ensuring sufficient supply of compliant fuels: some question whether supply of low sulfur fuels will be able to keep pace with demand. Particularly as global demand for marine fuel is widely expected to increase in the medium and long term. Indeed, after slow growth in previous years the TSA reported an upward trend for cargo shipping in 2012, with full year growth in the 3% to 4% range.

By 2018, the IMO will carry out a study to determine whether or not introducing a global 0.5% sulfur emissions cap by 2020 is feasible i.e. whether or not enough compliant product can be supplied. Senior figures in the shipping industry have commented that as of 2012, the industry is not on track for this target to be reached. Speaking at this year's Singapore International Bunkering Conference (SIBCON), Adam Ritchie, Shell trading's general manager of oil market analysis argued that unless the industry picks one alternative now and invests in it collectively, the industry would not be able to make the switch to lower sulfur fuels in 2020.

What are the options?

Spikes in the price of lower sulfur fuel oil in mid-2012, caused by the introduction of the North American ECA, could be a harbinger for future shortages. Sulfur emissions limits are set to drop further, initially within ECAs, followed by global restrictions. Refiners and bunkering providers have a substantial task on their hands to deliver the low sulfur fuel capacity that will be needed over the next decade. How this task will be approached depends to a large extent on how ship owners choose to comply with emissions regulations.

Much discussion has already formed around the best ways to comply with new regulations. One potential response to more stringent restrictions in ECAs is to avoid these areas altogether. The widely held belief is that ship owners are unlikely to take this route. The cost of traveling to nearby ports and arranging alternative transport for cargo would likely outweigh the cost of any compliance solutions. In addition, the pending global emissions limits under MARPOL Annex VI mean this solution would only be a relatively short-term fix.

Three routes forward stand out as realistic options: the first is to continue burning traditional heavy fuel oil but to fit emissions abatement technologies. The second is to burn lower sulfur marine fuels i.e. marine diesel oil or marine gas oil. The third option is to shift fuel-type to run on LNG.

A number of consultants have investigated the comparative benefits of these different solutions. There is some consensus that LNG fuel is anticipated to be more cost-effective than using alternative low sulfur distillate fuels such as marine diesel. However, it is unclear which of abatement technologies or LNG is most cost effective. As an aside, it is important to note that while cost considerations are a major part of this decision, they are not the only factors at play.

The three options are outlined in Table 3. There may be overlap between these solutions: particularly because of the uncertainty clouding the future of marine fuel, some ship owners and shipbuilders are opting for a dual fuel solution, such as marine diesel and LNG, in order to hedge against the possibility of shortages.

Table 3: Options for ship owners

1) Burning lower sulfur fuels such as marine diesel oil or marine gas oil
2) Fitting abatement technologies i.e. exhaust gas scrubbers
3) Converting to LNG or ordering new LNG-fuelled ships

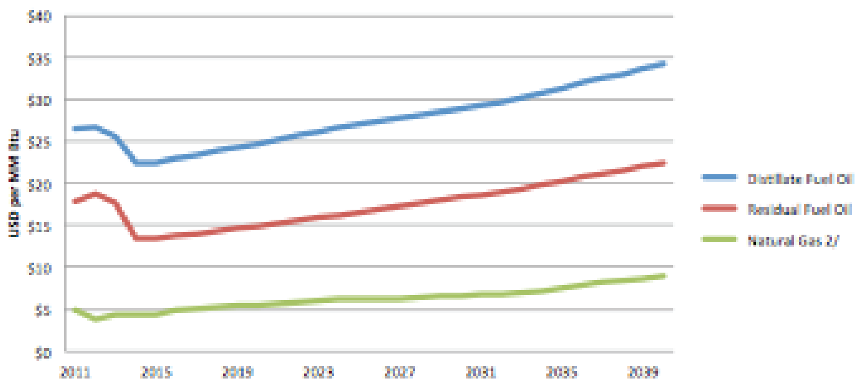
LNG – a viable solution

Two important drivers make Liquefied Natural Gas (LNG) an attractive alternative marine fuel. Firstly, the use of LNG reduces sulfur oxide (SOx) emissions by between 90% and 95%. This brings emissions within limits mandated by the Emission Control Areas designated by the IMO. LNG also has a lower carbon content than traditional bunker fuels, giving off up to 25% less CO2 emissions. Secondly, it is anticipated that the cost of LNG will be less than marine gas oil (MGO) or marine diesel oil (MDO).

Much of the debate surrounding future marine fuels focuses on pricing considerations. At present prices, utilizing LNG would yield significant cost savings for ship owners and operators. In the US, LNG costs about half as much as fuel oil , and with all considerations taken in to account, it is anticipated that fuelling vessels with LNG as opposed to marine diesel could yield savings of c.30%.

Looking ahead to the long-term, the most common consensus is that LNG is likely to be remain chepaer than alternatives, such as marine diesel oil. Data from the US Energy Information Administration Outlook supports this: natural gas is projected to retain a significant price advantage, even as its price increases at a faster rate than distillate fuel oil (used here as a proxy for marine diesel) and residual fuel oil (proxy for heavy fuel oil). When the cost of liquefaction and transportation are included in the price of natural gas, the economic case for LNG-fuelled vessels is still compelling.

Figure 5: EIA Fuel Price Projections

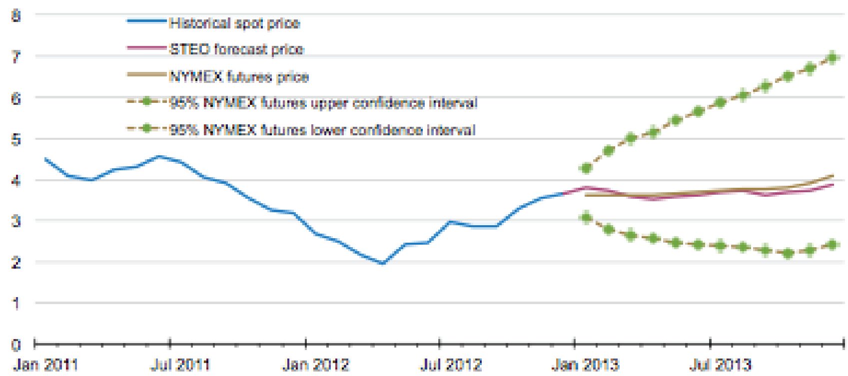


source: Annual Energy Outlook 2013 Early Release

Unfortunately, energy price forecasting is notoriously uncertain. While North America's natural gas reserves are reportedly close to 8 trillion cubic meters; analysts disagree over the future direction of prices. Some argue that the cost of natural gas is likely to increase, as diminishing marginal returns gradually reduce the cost-efficiencies enjoyed by contemporary fracking operations. Furthermore, demand for LNG is expected to increase, driven by exports to Asia and Europe. Others argue oppositely that the cost of extracting natural gas in the US will decrease as fracking technologies develop. Protesting too that the abundance of natural gas in Asia will mean greater exploitation of these resources. This could be facilitated by Asian businesses purchasing US firms and utilizing learned technologies on home soil.

Ultimately, the best-supported position is that natural gas in the US will retain a significant price advantage compared to other compliant marine fuels. Some convergence is correctly anticipated with distillate fuels, though this is not expected to erode the price competitiveness of LNG in the long term. Nevertheless, the uncertainty of energy prices looms over the industry, as illustrated by figure five, which shows projections for the Henry Hub price.

Figure 6: Henry Hub Natural Gas Price
dollars per million btu



Note: Confidence interval derived from options market information for the 5 trading days ending December 6, 2012. Intervals not calculated for months with sparse trading in near-the-money options contracts.

Source: Short-Term Energy Outlook, December 2012

Environmental benefits

Successfully using LNG as a marine fuel would mean compliance with long-term MARPOL requirements. Table 3 outlines the extent of the environmental benefits in comparison to the other compliance options under consideration. Not only is using LNG the most effective in reducing sulfur emissions, it also reduces NOx, CO2 and Particulate Matter (PM) emissions more effectively than other methods. LNG use also contributes towards EEDI compliance (see below).

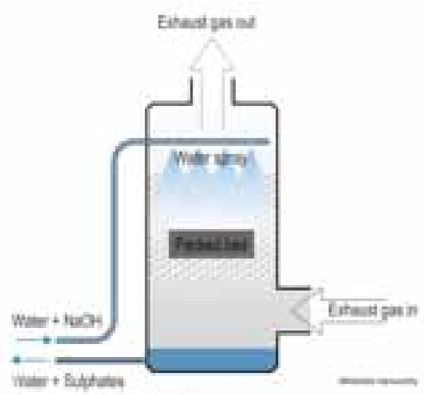
Table 3: Environmental benefits of main compliance options

Option	HFO	MDO/MGO	LNG
CO_2 removal	Abatement technologies	No	10-20%
SO_x removal		MDO: <2% MGO: 0.01-1%	100%
NO_x removal		Abatement technologies	Up to 80-90%
Particulate Matter			98-100%

Source: LNG fuelled deep sea shipping, Lloyds Register, August 2012

Abatement technologies

Exhaust gas scrubber (EGS) technology is being considered as a viable method for removing sulfur and particulate matter from exhaust gas emissions. In order to remove NOx in addition to SOx, EGS must be operated in conjunction with Selective Catalytic Reduction (SCR). Such systems work through treating exhaust gases to remove harmful pollutants. While they have proved relatively popular, there are concerns over the long-term costs of these systems.



Source: Wärtsilä

The cost of installing EGS systems is estimated to be up to US$4m. In addition, scrubbers may have high operating costs in the long-term. One study placed the annual cost for operating a scrubber globally at close to US$2m per year by 2020 . Perhaps because of these high long-term operating costs as global MARPOL restrictions come in to effect, ship owners see them as a only a medium term solution. Another implication is the load space taken up by the EGS. Finally, abatement technologies have an impact on the overall energy efficiency of vessels, increasing fuel consumption by approximately 3%.

Not smooth sailing

The route to LNG becoming widely used in shipping is peppered with obstacles. The main issues concern the cost of initial investment, the availability of bunkering infrastructure and the cost efficiencies of LNG compared to other compliance solutions.

Cost

A primary issue is the cost of building an LNG-fuelled vessel, or converting an existing vessel for LNG. Adopting LNG requires a purpose built engine or modifications to an existing one, as well as a significant investment in an LNG tank system. In addition, converting a heavy fuel oil ship to LNG or building an LNG ship means sacrificing TEU slots in comparison with traditionally fuelled carriers. Lost capacity is mainly a concern when retrofitting ships and cannot be considered in isolation, but is just one of the factors ship owners will consider when deciding on which fuelling system to adopt in the future. Overall, the estimated cost for an LNG fuelled ship compared to an equivalent vessel is between 20% and 25% higher.

Developing bunkering infrastructure

Delivering LNG bunkering on a global scale will require substantial investment from bunker service providers. While some European ports have plans to develop LNG bunkering infrastructure, LNG bunkering at North American ports has a long way to go. None of New York, Houston or Vancouver has plans to develop LNG infrastructure and were they to adopt plans in the near future, the investment would be expected to come from private companies operating within the port. This lack of infrastructure is however to be expected given the novelty of LNG as a shipping fuel in the US. Regulations for bunkering are still yet to be established, highlighting the scope of the challenges ahead.

Supply of LNG

Whether enough LNG can be supplied in order to meet demand has been raised as a concern. However, given the abundance of reserves and current pricing levels, it seems evident that demand in the US can be met. Some firms are moving early in order to position themselves for the opportunities. Royal Dutch Shell Plc for example, is planning to increase LNG for transport capacity to in excess of 5 million tonnes a year, half of which will be made available as marine fuel in the Great Lakes, Gulf of Mexico and Baltic Sea. The CEO of Shell is well aware of the LNG opportunity in the US, noting that 'the current gas equivalent price per kilometer is double-digit percentage lower than for diesel in the US.' At these prices, natural gas producers like shell generate profits even after liquefaction costs.

Methane slip

Methane slip occurs when any LNG gas that is not combusted is released. This is particularly a risk during bunkering. Given that the objective of fuelling ships with LNG is to reduce emissions, any slippage of methane during the bunkering process is highly undesirable. Ship builders and bunkering operators are aware of the risks of methane slip and it should be avoidable.

Payback times for LNG

Germanischer Lloyd & Man recently conducted a study projecting the costs of LNG fuelled cargo ship operation in comparison to using abatement technology. They looked at five container vessel sizes between 2,500 and 18,000 TEU. The study found that payback times for an LNG system are attractive compared to scrubber systems, concluding, 'when standard assumptions are used, LNG systems offer shorter payback times than scrubber systems.' However, the study also found that at price parity of HFO and LNG, based on energy content, payback time for the larger vessels is longer than 60 months. Under these conditions the LNG system would breakeven only with 2020 IMO sulfur emissions

regulations in effect. This finding perhaps supports opinion among ship owners that LNG is a long-term solution.
However, different studies reveal different findings. The Danish Maritime Authority found payback times of around two years for LNG compliance strategies, rising to four years with higher LNG prices. They found that Burning HFO and using a scrubber has a shorter payback time than any LNG options, and payback times for dual fuel solutions are between 2-4 years.

The contrasting findings serve to highlight the uncertainty facing the marine fuel market. Proponents of LNG must demonstrate unequivocally the benefits of LNG systems over HFO and scrubber systems in order to attract more adopters. This argument will be fundamental to the penetration of LNG-fuelled shipping over the next decade as ship owners consider options for replacing or upgrading their vessels.

Popularity of LNG vessels growing in Europe

At present there are 34 liquefied natural gas ships in operation, with 31 confirmed orders for delivery in 2013-14. The majority of these are in Europe, due to the Baltic Sea and North Sea ECAs coming in to force in the region in 2005 and 2006. The Danish Maritime Authority recently conducted a study concluding that LNG fuelled vessels in Northern Europe could be consuming up to 4m tonnes per annum (mta) by 2020. Hypothetically this would require at least 11 LNG bunkering facilities around the Baltic and North Sea. One of the factors enabling ship-owners to make the decision to switch to LNG is the availability of LNG at European ports, something that will need to be addressed if LNG-fuelled shipping is to take hold in the US.

Converted: Bit Viking
This 25,000 dwt product tanker underwent a conversion from heavy fuel oil to LNG. Delivered in October 2011, the vessel qualified for support under the Norwegian NOx fund, which was created to encourage sustainable shipping. In September 2011 Bit Viking became the first LNG vessel to conduct a successful bunkering from a shore facility. She operates a duel fuel system, with the option to switch to marine gas oil.

Newly built: MT Argonon
The MT Argonon was the world's first new-build LNG-fuelled tanker. Delivered in Rotterdam at the end of 2011, she is a 6,100-dwt dual-fuelled chemical tanker designed to burn an 80/20 mix of diesel and natural gas. LNG is stored on deck.

Under construction: Viking Grace
This €240m, 57,000 gross tonnage car ferry currently in construction is set to become the largest LNG fuelled passenger ship in operation. Due for commissioning in 2013, the ferry will operate between Finland and Stock-holm on the Baltic Sea. She will use dual fuel technology, allowing her to sail on HFO, diesel or LNG. Bunker tanks are located on the stern. The ship will bunker in Stockholm, at the Stadsgården facility, with LNG sourced from the AGA LNG terminal in Nynäshamn.

Conclusions

IMO regulations have stimulated action among various stakeholders in US shipping, now seeking the most cost-effective ways to comply with emissions standards. From an environmental as well as a cost perspective, the benefits of LNG are clear. Given the ageing state of many US ships, and news that low viscosity alternative fuels are causing erosion to engines designed for heavy fuel, appetite for LNG could increase faster in future. However, forecasts for penetration of LNG-fuelled shipping in the US will always be vague.

Nevertheless, the abundance of natural gas, and its low price in the US make a very strong case. Initially, the greatest opportunities will be focused around those vessels operating within the North American and Caribbean Sea ECAs. This includes passenger ferries, offshore support vessels and some cargo carriers. There is already evidence of this trend. At the end of 2012, Canadian operator Société des traversiers du Québec (STQ), ordered the first North American LNG fuelled ferry. Built by Wärtsilä in Italy, it will be used on routes crossing the St Lawrence River (where ECA regulations are extended). The vessel will be 130 meters long and carry up to 800 passengers and 180 cars.

Demand for LNG fuel among deep-sea vessels is expected to follow, depending heavily upon natural gas maintaining its price advantage over alternatives. One popular solution in Europe has been duel-fuelled ships, it is likely that the same will be true in the US, as ship operators seek to hedge against possible shortages during this period of transition.

How to build an LNG fuel market for the Marine Sector

If you are looking to incorporate gas into your future marine fuel strategy in 2013 and beyond, then the LNG for Marine Transportation Conference (Houston, 11-12 June 2013) is tailor made for you. To find out more about the event all the key topics being discussed, who you can meet and how to register then go to **www.lngmarineevent.com**.

At the event we will be covering:

- Market Development: Create consistent and reliable access to LNG by building effective partnerships throughout the supply chain
- Infrastructure: Finance and deliver the bunkering infrastructure you need to capitalize on the US marine market's potential
- Logistics: Develop an ironclad logistical framework that gets LNG to marine customers at the lowest cost
- Regulation: Get up to speed on the regulatory framework for ship design, emissions control, training and health & safety so you can be part of a seamless transition to LNG fuel
- Customer Focus: Meet with key marine stakeholders and overcome the challenges of engine conversion, vessel construction and risk assessment

Join us in Houston to find out more about this crucial new industry making waves in the USA