

## LNG BUNKERS – COMING OF AGE

### Entering the Mainstream

LNG as a marine fuel can no longer be described as a Nordic curiosity. It is now firmly in the frame as a serious fuel of choice in trucks, mining and off-road, railroads and marine. Both the USA and Canada are establishing “green” corridors based along the most popular trucking routes. “Henry Hub” gas prices have been low, placing domestically produced LNG around \$12-15/MMBtu. With diesel prices at around \$25-30/MMBtu, the choice for efficient operations is clear. Ship operators are beginning to “see the light”.

The introduction of the North American Emissions Control Area (ECA) in August 2012 was a watershed. 2013 saw a surge of intentions, conversions and new building orders for vessels operating in North American ECA waters. This has brought a minor and welcome resurgence in USA shipbuilding. Europe is also making steady progress and we now expect to see the pattern followed globally.

### LNG - SHRINKING ITS WAY TO GREATNESS

Traditional LNG has been supplied in large quantities to meet domestic and industrial gas and power generation demand for nations. Budgets for projects to produce and deliver LNG against such demand can typically run around \$12 billion and project gestations can be around a decade. Core demand is contracted, often with a single customer on 20 year “take or pay” terms. Through this there is almost no financial risk – the production is effectively pre-sold, ensuring return on project investment. Transport LNG is different. Were LNG to wholly replace fuel oil in shipping, it would effectively double today’s 250 million MT global LNG demand. There simply is not the time and available single-source equity to meet the new demand offered by Transportation. The trajectory remains clear, but the timing, dependent on an array of sometimes independent factors, less so. Hence, the investment risk is exponentially greater. Or is it?

Transport LNG cannot be served by the same business models as conventional LNG. Early computer centres were constructed around the computers they housed. Today our smart phones in our pockets have more computing power than that which accompanied the first men to the moon. LNG is scaling down in the same way.

LNG, produced in small plants, can today be produced in dedicated quantities, in integrated units the size of shipping containers. They will undoubtedly continue to shrink their way into a wider range of prospective markets. Small scale LNG production today, is not dependent on large gas fields, being produced from domestic or industrial gas mains or from “previously uneconomic” stranded or shale gas.

*LNG Markets Perspective is a periodic paper looking at key issues and events.*

*Developments in the LNG market are discussed in more depth in our LNG Brief and quarterly LNG Markets Updates*

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## WHERE ARE WE HEADED?

There will be around 50 LNG fuelled vessels in service by the end of 2015 covering a range of sizes and duties. According to DNV GL, the number will double every two years thereafter for the next ten years. If simply projected forward, to 2024, this gives 1 million tonnes in 2016 and 5.5 million tonnes in 2024, equivalent only to Hong Kong's annual bunker sales volume and a fraction of the current global market for all bunkers, about 250 million tonnes a year. Given the limit of true sustainable choices, we project that the global market for LNG bunkers will be considerable in 10 years' time and in the range of 15-20 million tonnes per year, closer to LR's 2012 prediction of 24 million tonnes by 2025.

## RUDOLPH DIESEL OR NIKOLAUS OTTO?



Wärtsilä's 50DF dual-fuel engine

All hydrocarbon powered 4-stroke reciprocating engines (used with fuel gas) conform to either the "Diesel" cycle or the "Otto" cycle.

The Diesel cycle, also known as a "compression – ignition" cycle, relies on the heat created by compression in the cylinder of a diesel fuel spray to raise the mix above the auto-ignition temperature of diesel. In dual fuel gas engines, a small injection of diesel self-ignites the gas. The explosive pressure rise pushes the piston downwards and "powers" the engine. Dual fuel engines can burn gas (+ igniter fuel), or diesel, or Heavy Fuel Oil (HFO).

In "Otto" cycle engines, pure gas is ignited by a spark plug, timed to flash just before maximum compression of the gas, immediately before the combustion (power) stroke. Diesel is not required. Dual-fuel capability enhances operational flexibility, but is marginally less fuel efficient.

The major global players in the dual-fuel (Diesel cycle) market are Finland's Wärtsilä and Germany/Denmark's MAN. For the pure gas (Otto cycle) it is Rolls-Royce subsidiary, Bergen, based in Norway, that leads the pack.



Rolls-Royce Bergen B35:40 gas engine



Wärtsilä's new X72 2-stroke LP gas injection dual fuel engine

In a new development, Wärtsilä has launched the world's first low-pressure gas injection 2-stroke engine. The problem for 2-stroke cycles and gas fuel has always been that containment of gas at the very high injection pressures required has led to "methane slip", whereby un-combusted gas passes through the engine from the exhaust system. Methane, the main component of LNG, is a virulent Greenhouse Gas (GHG), so the avoidable emission of such Volatile Organic Compounds (VOCs) is desirable at a minimum and may fall subject to future legislation under the International Maritime Legislation (IMO).

This is an important development, as 2-stroke cycles have traditionally offered higher levels of fuel efficiency than 4-stroke, making them suitable for long voyage vessels.

## FERRY TALES

The greatest adoption of LNG, both planned and delivered, in 2013, has been in the ferry sector. We previously reported the upcoming debut of the world's first LNG powered cruise ferry, "Viking Grace" on the Turku (Finland) to Stockholm (Sweden) route.



Source: Viking Line

### Viking Grace has been "a heaven for engine room personnel"

This vessel has now been operating for around a year with "zero fuel related operational or maintenance failures", according to the vessel's Project Manager. "With cleaner engines, clean exhaust boilers, no need to change lubricating oil due to low Total Base Number (TBN), cheaper lubricating oil, no soot on deck, no HFO smell in engine rooms or outer deck, longer service intervals, easy to keep engine rooms clean, no HFO spills, no need to use strong chemicals, it has been a heaven for engine room personnel".

And the accolades continue.



## THE AMERICAS

The introduction of the North American Emission Control Area (ECA), in conjunction with other ECAs, will see a drop in the maximum fuel sulphur level to 0.1% S from the beginning of 2015. This point is not lost, particularly on US and Canadian vessel operators. But 2013's glittering prizes go to a South American operator.

Australia's Incat built the 99 m LNG-fuelled fast catamaran ferry, "Francisco", carrying up to 1,000 passengers and 150 autos, serving the 3 hour River Plate transit from Montevideo (Uruguay) to Buenos Aires (Argentina) route. It set a world speed record last August when it sailed at 58.1 knots (67 mph or 108 km/h). This makes it competitive with the alternative air route. The operator, Argentina-based Buquebus has also won the inaugural "Black Diamond" award at World LNG Fuels 2014 in Houston.



Source: Buquebus

Buquebus's LNG-fuelled fast catamaran ferry, "Francisco" set the world speed record at 58.1 knots

## TRI-ZEN LNG PERSPECTIVE

Fellow winners included Incat, GE, supplier of the two turbines that drive Wärtsilä pumps to propel the ship, Chart Industries for the fuel-delivery systems and Galileo, for their “CRYOBOX” gas liquefaction unit.



### Galileo’s “CRYOBOX” produces a dedicated LNG supply to the Buquebus “Fransico” in Buenos Aires from a mains gas feed

With very low gas prices and tight regulations in the USA and Canada, it is perhaps not surprising that a large number of ship operators are abandoning oil in favour of gas as their preferred fuel. This includes conversions. Operators like New York’s Staten Island Ferry and Seattle’s Washington State Ferries have determined that they can save up to 60% on their fuel costs by converting to gas; a welcome saving in hard financial times. This message is not lost on the Canadians. The Société des traversiers du Québec (STQ) has ordered two gas burning, dual fuelled RO-PAX vessels which will operate on their Quebec routes, entering service in 2015.



### New York’s Staten Island Ferries, Seattle’s Washington State Ferries and Quebec’s STQ ferries have all opted for gas

And the US container vessel market is following suit, set to lead the world of container shipping. TOTE Marine will operate its Florida to Puerto Rico route with new gas fuelled vessels from 2015/6 and its CON-RO, Tacoma to Alaska route with converted vessels. Likewise, Jacksonville, Florida based Crowley has inked contract for two LNG fuelled CON-RO vessels to serve their USA – Puerto Rico routes from 2017. Matson Navigation Company has also ordered two 3,600 TEU dual fuel container vessels from Aker Philadelphia for delivery in 2018 for service on its US West Coast – Hawaii routes.



### US carriers TOTE and Crowley have inked conversions and new buildings for their CON-RO services and Matson for container services

Renewed oil operations in the Gulf of Mexico in 2012, following absolution of the industry of the 2010 Macondo disaster, combined with the introduction of the North American ECA, coincided with a lively resurgence in offshore activity and a dash for gas fuelled Offshore Support Vessels (OSVs).



Source: Harvey Gulf

Harvey Gulf has ordered 6 Dual Fuel Offshore Supply Vessels.

In January 2014, Mississippi based Gulf Coast Shipyard announced the launch of the first of six Harvey Gulf International Marine 302' x 64' (92m x 20m) Dual-fuel Offshore Supply Vessels.

Shell announced two marine LNG “corridor” projects. The first covers the Gulf region, including 3 of the abovementioned Harvey Gulf vessels, to become the first such domestic operators. The second, covering the Great Lakes and the St. Lawrence Seaway.

In its efforts to promote the benefits and use of LNG as a fuel in larger engines, Shell also announced a Joint Co-operation Agreement with Wärtsilä North America.



## EUROPE

The European Union (EU) implemented policies via the 2008 Climate and Energy Package to facilitate its own transition to a low carbon economy, arguably the most comprehensive regulatory framework globally. It comprises different policy measures designed to facilitate the transition and has come to inspire action by partner countries. Taking timely economy wide action remains a top priority of the EU in fighting climate change.

The EU initiative, funded via the TEN-T programme with over €1.2 million, includes a study, commissioned in 2012, aimed at identifying and addressing barriers to the construction and operation of LNG fuelled vessels. Specific aspects related to the manufacturing, conversion, certification and operation phases of a LNG fuelled vessels will be analysed in a partnership with stakeholders comprising of ship-owners, cargo owners, LNG suppliers, ports and marine equipment manufacturers. The project is set to be completed by the end of 2014. Subject to findings, the intention is that all large EU seaports will offer LNG bunkering facilities by 2020, with inland water ports following by 2025. Again, while the number of Offshore Support Vessels (OSVs) rises, ferries in Europe have been the growth leaders.

Backing the successful introduction of the “Viking Grace” service has been the rapid conversion of a former ferry to a dedicated LNG bunker barge for Linde subsidiary, AGA.

To its credit, and with a little help from international friends, the Swedish Transport Agency rapidly developed and implemented a technical and operational regulatory framework that enables gas refuelling operations in Stockholm with vehicle movements and passengers on board, the latter being a much debated issue. This service is now in operation on a daily basis.



Source: Viking Line

Viking Grace is refuelled daily in Stockholm by a dedicated bunker barge “AGA SeaGas”



Source: AG EMS

1985 built ms Ostfriesland is to be retrofitted with Wartsila dual fuel technology

Following a different refuelling approach, Germany’s AG Ems has struck a deal with Bomin Linde LNG to supply gas at newly constructed LNG bunker terminals in Hamburg and Bremerhaven. The 1985 built ferry “MS Ostfriesland” will be retrofitted with Wärtsilä dual fuel technology and re-delivered mid-2014. This makes it the oldest ship to be retrofitted for LNG. According to the vessels owners, “The Ostfriesland sails through an ecologically sensitive part of the North Sea and the switch to LNG bunkers is designed to reduce its environmental impact”.

Buoyed by previous gas ferry experience, in 2013, Norwegian Fjord Lines commissioned two new cruise ferries from Gdansk, followed by Bergen Group Fosen for the fitting out. The first vessel, the 25,000 GRT “Stavangerfjord” completed her maiden voyage in July 2013 and was followed by her sister ship “Bergensfjord” a few months later.

The significance is that these are the largest vessels to date with pure gas fuelling for Rolls-Royce engines, based on the “Otto” combustion (spark ignition) cycle. Refuelling, supplied by Skangass in the port of Risavika, Norway becomes Europe’s first port where ships can bunker directly unload and load at the same place.



Source: Fjord Line

Fjord Line’s latest 2 ferries are pure LNG fuelled



Source: BALEARIA

Three of Balearia’s high speed ferries are being converted from diesel to pure gas fuel

In another Rolls-Royce deal, three of Spain’s Balearia.com high-speed ferries are to be retrofitted with pure gas burning engines in a conversion from diesel.

This is the first service to adopt LNG fuel in the Mediterranean.

The prime driver here is to mitigate the increasingly high costs of diesel and in anticipation of EU directive for very low sulphur fuel limits to be introduced in all European waters by 2020.

### THE WAY AHEAD

After a predictable chorus of objection by North Sea and Channel ferry operators at the tightening emissions legislation, Brittany Ferries has “grasped the nettle” and taken the first brave steps towards environmental compliance and safeguarding future operating costs. It is presumably only a matter of time before other such operators come to the same conclusions. It is to be hoped they do this quickly.

It has commissioned a 210 m RO-PAC, dual fuel vessel for delivery in the fourth quarter of 2016, for its England – Spain routes. It will also retrofit three other ships to run on LNG and install exhaust gas scrubbers on three further ships.



Source: Brittany Ferries

Brittany Ferries planned new 210 m RO-PAC vessel for the England – Spain routes

## THE CANAL ROUTE

Europe's shipping emissions initiatives have not ignored the extensive European inland waterways network. Whilst no binding legislation has been agreed, it is the intention that tight emissions controls will be backed by a comprehensive network of river ports by 2020. Rotterdam, Antwerp and Gothenburg have declared their intentions to serve the ocean marine market. Rotterdam has declared itself officially open for refuelling of inland waterway craft with truck loading facilities in Seinehaven and fixed facilities due in 2016. Since we last reported on the first Rhine barge conversion for diesel to dual fuel, of the Deen vessel "Arganon", we have learned that she enjoys trouble free operation. She has been joined by Greenstream, the first 100% LNG powered tank barge, built by Peters Shipyards and on long-term charter to Shell, with some irony, delivering oil products on the Rotterdam – Basel route.



Source: Shell

Shell chartered "Greenstream" LNG fuelled river barge



## ASIA

The biggest news from Asia comes from the Middle East. Dubai based United Arab Shipping Company (UASC) has ordered with Korea's Hyundai, five 18,000 teu and five 14,000 teu dual fuel "LNG ready" container ships for the Asia – Europe trade. When converted, these will become the largest LNG fuelled container ships in the world.



Source: UASC

When converted, UASC's 10 new container vessels will become the largest in the world to be fuelled by LNG

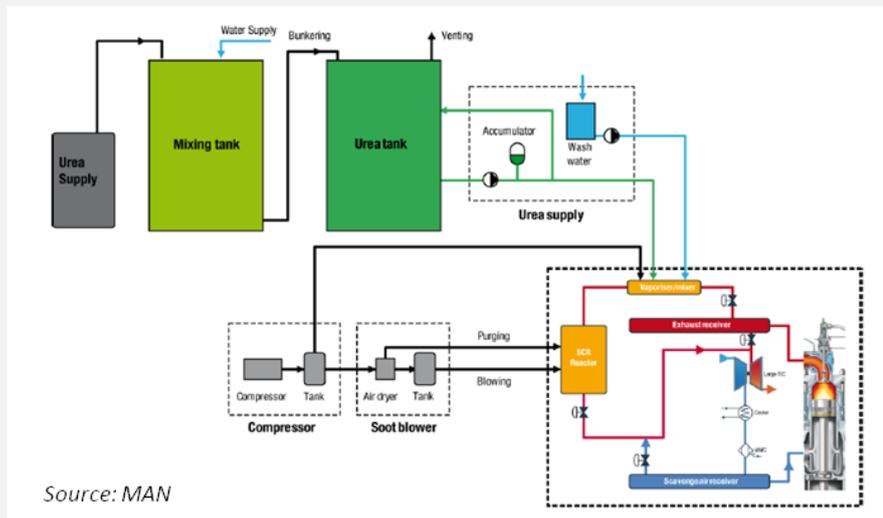
The cryogenic pumps, pipes and tanks and other LNG handling apparatus are not fitted initially, but the space is provisioned, making conversion quick and relatively easy. UASC are looking to establish LNG bunker locations on the inbound and outbound legs.

Korea's KOGAS has started truck supplied LNG bunkering in Incheon and Japan has commissioned its first dual fuelled tug.

## WHAT ABOUT THE ALTERNATIVE TECHNOLOGIES?

Leonardo da Vinci is quoted as having said "Simplicity is the ultimate sophistication". At a shipping emissions conference in the Mediterranean last year, a collage of clever technologies was portrayed along the catwalk by vendors. They had reason to be proud. Tackling any kind of emissions control in an effective, sustainable and economic manner, whether from static or mobile plants is not easy.

## SO<sub>x</sub> MITIGATION



Source: MAN

Open loop Exhaust Gas Scrubber circuit

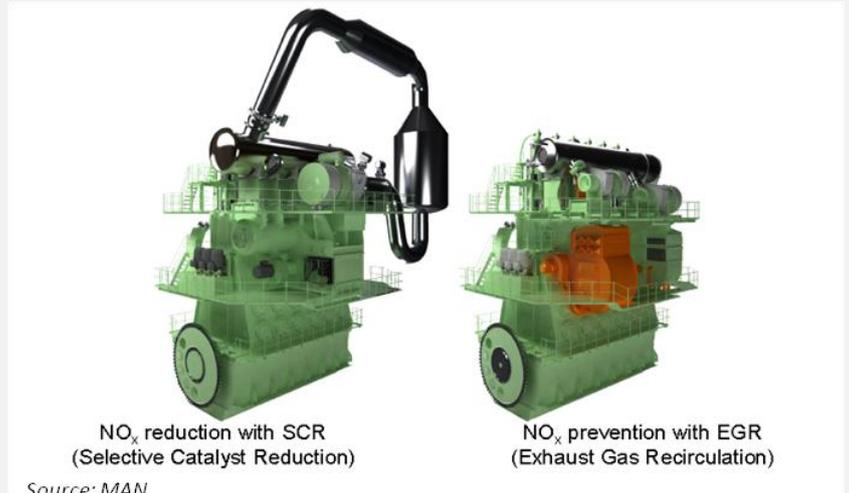
Sulphur level reductions remain on course, 0.1% in ECAs in 2015 and 0.5% by 2020. And Exhaust Gas Scrubbers (EGS) remain the preferred solution to post treat sulphur emissions from non-compliant fuels. But all the old problems remain in place:

- Space, cost and extra electrical power for reactors, pumps and tanks
- Added running costs of urea
- Raised fuel consumption
- Ocean acidification
- Toxic sludge discharge
- Long-term reliability
- Emissions compliance monitoring

## NO<sub>x</sub> MITIGATION

Even the burning of sulphur-compliant fuels produces nitrous oxides (NO<sub>x</sub>). Ironically, the more efficient the combustion process in the engine, the more NO<sub>x</sub> are produced. NO<sub>x</sub> is either mitigated by the addition of a Selective Catalytic Reduction (SCR) reactor that reacts the hot exhaust gases with urea in the presence of a catalyst.

Alternatively, new technology has been developed to re-circulate the exhaust gas through the combustion process. This reduces combustion efficiency, but can virtually eliminate NO<sub>x</sub>. Many of the problems associated with EGS remain however.



NO<sub>x</sub> mitigation is achieved by Selective Catalytic Reduction (SCR), or Exhaust Gas Recirculation (EGR)

## PM MITIGATION



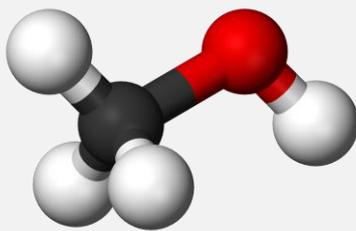
Particulates (PM) are associated with cancer and ice melt

Further recent research has identified Particulate Matter (PM), or black soot, as being far more harmful to the earth's climate than previously considered. Marine diesel engines, especially those burning heavy fuel oil (HFO), are the most prolific generators of PM on the planet.

The International Maritime Organization (IMO) continues to seek accord on limiting the output of PM, but has yet to reach success in this. Let us hope, for all our sakes, they do so quickly.

EGS will reduce PM, but this adds to operational complexity and the sludge burden.

## METHANOL



Methanol (CH<sub>3</sub>OH) has been cited as a potential alternative and emissions compliant fuel for shipping. Methanol is the simplest alcohol and is a light, volatile, colourless, flammable liquid. Modern methanol is produced via a catalytic industrial process directly from carbon monoxide, carbon dioxide and hydrogen. It can be produced using coal or natural gas. It burns in air to produce carbon dioxide and water. Some formaldehyde formation is also possible under certain conditions. In many ways it sounds like the ideal fuel and has already been adopted for use on some vessels.

But there is a dark side, making methanol a less obvious choice.

- Methanol is very hygroscopic – it readily absorbs moisture, promoting rust and corrosion in pipes and tanks, reducing lubrication efficacy, suppressing ignition and reducing energy density
- It is susceptible to abuse. If ingested in large quantities it is metabolised to formic acid or formate salts, which are poisonous to the central nervous system and may cause blindness, coma, and death
- It has a Flash Point of around 11°C, not a problem under the IGF codes, but, unlike Natural Gas, being a liquid it can accumulate to present a risk of asphyxiation or fire

## ALTERNATIVE TECHNOLOGY CONCLUSIONS

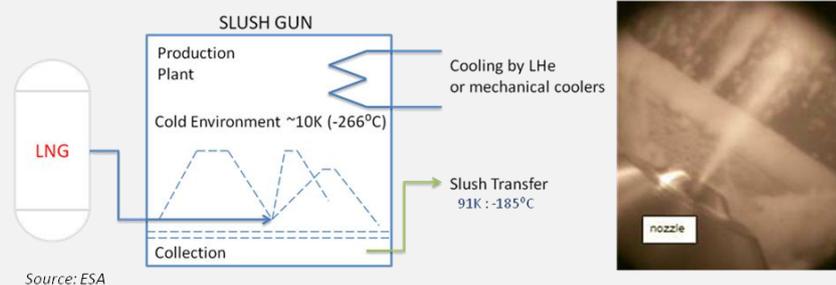
All the previous technology solutions are feasible and achievable. But they are not necessarily sustainable. Continuous exhaust gas emissions monitoring is not easy or cheap. Exhaust gas treatment systems can be bypassed or disengaged and their scope for falling into disrepair, especially with less qualified, less competent or even less scrupulous personnel, is great, potentially defeating the whole objective of emissions reduction.

Over past years we have predicted that LNG would become the preferred choice of marine fuel, replacing oil, even though most existing tonnage is unsuitable for conversion and will have to be replaced. We stand by that prediction. Today, only LNG meets in full, da Vinci's requirements for true "Sophistication" i.e., simplicity.

## THE "SUPER COOLED" SOLUTION

When LNG forms ice crystals, it contracts by around 13.4%. This is important. One of the few disadvantages with LNG is that it takes up more space than diesel to deliver the same energy content. Depending on the gas source you need 1.6 – 1.7 times the volume to go the same distance compared with diesel. Probably the greater advantage is that Super Cooled LNG substantially reduces the burden of dealing with unwanted Boil Off Gas (BOG). A "slush gun" has been developed and tested in a European pilot plant. The LNG slush exits the gun at 91K or -185°C, leaving 22.5°C before the flash point of LNG and the commencement of BOG generation.

Another potential role for the LNG slush is in the cooling of electric motors and cables to create electrical "super conduction", thus enabling more efficient power generation. As a general principle, LNG can also be used for a range of cooling processes aboard ship, from cargo chilling to air conditioning system to engine air intake pre-chilling to improve combustion efficiency.



LNG "Slush Gun" schematic

The currently piloted "Slush Gun" process works by injecting LNG through spray nozzles into a cold chamber, chilled by liquid helium, or a mechanical process to around 10K or -266°C. The chilled LNG forms crystals, densifying in the process. Slush, a mix of solid and liquid LNG exits the chamber at around 91K or -185°C. Early days, but technology to watch.

## A GROWING AND DIVERSIFYING SUPPLY CHAIN

While the LNG bunker supply chain advanced on point to point services, backed by the featured development of small scale LNG production, 2013 was a relatively slow year for large scale infrastructure. In Europe, Rotterdam is the most advanced with plans laid for Gothenburg and Hamburg. Germany set up a small truck fed terminal at Brunsbüttel on the River Elbe. Belgium's Zeebrugge Terminal has also carried out a number of reloads. And in Belgium Exmar brings its experience to the fore, joining the Port of Antwerp to offer LNG Bunkering in future. It is expected that the EU directive, matched by TEN-T project funding with start to make a big difference in Europe in 2014.

In the USA, 2 new terminals are due. Harvey Gulf's Port Fourchon, Louisiana facility has started construction and is due to open in 2016. It will serve customers from the US Gulf offshore support vessels sector. The USA's first ocean going vessels LNG terminal is planned to be built in Jacksonville, Florida by a US-Canadian consortium, Eagle LNG.



Harvey Gulf's planned terminal in Port Fourchon



In a recent development, Crowley Maritime has announced the commissioning of the first of a fleet of LNG Bunker Barges to serve the dual purposes of moving LNG from LNG America's Louisiana supply source to coastal-based storage and distribution terminals and in directly bunkering large ships. The first barges, to be operated for Houston-based LNG America, will have a planned capacity for 3,000 m<sup>3</sup> of LNG. The first barges are for delivery late 2015.

**Crowley Maritime will build a fleet of 3,000 m<sup>3</sup> LNG bunker barges for 2015**

### TIME FOR THE TALKING TO END – TIME TO JOIN UP THE DOTS

Though we may not see it immediately, things have moved on a long way for LNG as a marine fuel in the past year. No longer a purely Norwegian and small vessels play. Big ships are, or soon will, be operating on both sides of the Atlantic and burning gas. The latest large cruise ferries burn gas. The fastest ship in the world burns gas.

The world of LNG bunkers today, is a “mish mash” of ideas, intentions, some decisions and some project implementations. Cargill has partnered with Shell to provide LNG for its global routes and Maersk has declared its future in LNG fuel. Welcome news, but for most the current status is, at best, confusing for ship-owners. Shippers need the assurance that if they make the investment in cleaner, more efficient and more cost effective tonnage (good for all of us), that their vision is matched with the counter-assurance that they can refuel wherever they ply their trade. We need to see a global LNG bunkering network emerge fast. Time to join up the dots.



**Key bunker locations, most in need of LNG capability: Time to join up the dots**

In marine infrastructure, Asia, with exception of China's Yangtze River craft, has disappointed – all talk, but little action. Asia continues to study and procrastinate. With a global fuel sulphur maximum of 0.5% in place, Asia will become the engine of change for the transition to gas as the globally preferred marine fuel. Asian GDP growth may slow, but we predict a shift away from current export to domestic led growth, stimulating wider wealth distribution, demand for goods and hence, global trade. The switch away from fuel oil is now inevitable. For shippers now, the decision is not if they need to change away from oil, but how and when. A few will experiment with alternative technologies, but this will continue to be a minority. The rise of small scale LNG has seen the supply options multiply exponentially. So, questions raised include:

- Do you, or can you, bunker from a shore side terminal, or via a LNG bunker barge, if there is one?
- Do you go for fuel tanks based on IMO Type C pressurised bullets, or choose from new offerings, such as Type B, Prismatic, or the new small Membrane containment.
- In the engine room, do you opt for 4-stroke Otto Cycle (spark ignition), or Diesel Cycle (dual-fuel compression ignition), or DF 2-stroke engines, direct or electric propulsion?
- Is there mileage in Super Cooled LNG Slush?

There is an array of choices to make and nobody has a monopoly on experience here. The individual choice will be dependent on the desired service and operating logistics.

But one thing is for sure, LNG as a marine fuel has come out of the cold and has entered the mainstream – it is coming of age.

## TRI-ZEN

We are energy consultants. Over the past ten years we've built a client base that includes global and national energy firms, global professional services businesses and investment banks. We provide the clear analysis and strategic input required by business leaders needing to make decisions, whether these relate to acquiring reserves, building liquefaction capacity or LNG receiving terminals, making purchase decisions or entering markets. TRI-ZEN brings industry knowledge and a range and depth of industry and management experience that is unique. We combine a broad functional focus with deep expertise in the energy industry. Our senior gas consultants have worked for leading companies in the business such as Shell, Mobil, BP and BG and collectively have more than 200 years of hands-on LNG knowledge and experience, with some at the most senior levels.

The range of services we offer includes:

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- Asset optimisation
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- Market studies
- Forecasting
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