Feasibility Study on LNG Fuelled Short Sea and Coastal Shipping in the Wider Caribbean Region

This report presents the results of the study in caption and has been reviewed and updated following a workshop arranged by RAC-REMEPEITC Caribe in Trinidad & Tobago, 5-7 November 2012.
SUMMARY

In August 2012 the North American ECA came into force, in January 2014 the US Caribbean ECA will take effect, and in the future the ECAs in the WCR are anticipated to expand further. There are a few different technical and operational options available to comply with the ECA requirements and the transition from HFO to LNG fuel is considered an interesting option. IMO therefore contracted SSPA Sweden AB and White Smoke AB to investigate the feasibility of introducing LNG as a ship fuel for short sea and coastal shipping in the WCR.

The report addresses the following main issues and topics:

- Identification of shipping activities in the WCR
- Identification of key trends of shipping activities in the WCR
- Estimation of the potential for LNG as ship fuel in the WCR
- Appraisal of existing LNG infrastructure and future plans
- Identification of key barriers for adopting LNG as ship fuel
- Identification of key enablers for adopting LNG as ship fuel

The following sources were reviewed for information of ship traffic data:

- RAC-REMPEITC Caribe GIS database for maritime traffic in the WCR
- Recorded AIS statistics and
- Statistics from the Panama Canal Authority and other organisations

The shipping segments addressed in the study are categorised as follows:

- Tanker
- General cargo
- Tug and supply
- Bulk
- Passenger
- Other

Ship traffic in the WCR is intensive with more than 100,000 registered port calls per annum. General cargo traffic dominates in the WCR but tanker and passenger traffic are also frequent. Today about 37% of the registered port calls are within the present North American ECA but the US Caribbean ECA will contribute another 9% in 2014.

Today LNG is loaded or unloaded in terminals along the US Gulf Coast, in Trinidad & Tobago and in the mid Caribbean islands of the Dominican Republic and Puerto Rico but a number of new terminals are projected in various places.
in the WCR. If existing and new LNG terminals are complemented with facilities for truck loading, for loading of bunker vessels or bunkering of LNG fuelled vessels, a basic infrastructure network for distribution and supply of LNG fuel can be established and ensure an attractive LNG FOB bunker price.

In addition to the physical infrastructure for LNG fuel distribution, barriers related to regulative gaps and the lack of technical standards also needs to be addressed. Training and education requirements are another important issue where international cooperation and careful control are needed to minimize the specific hazards associated with the handling of LNG as ship fuel. Public consultation and awareness processes as well as possible economic incentive schemes also represent important enablers that may facilitate and speed up the introduction of LNG as ship fuel in the WCR.

A number of the identified short sea and coastal shipping segments are considered suitable for introduction of LNG as fuel but not only typical short sea and coastal segments may become early adopters.

Platform support vessels and some specific tug segments are considered suitable for LNG introduction and may become early adopters. New buildings in the cruising segment and container feeder vessels in the WCR are also categories considered suitable with respect to additional cost for LNG supply infrastructure. Another WCR ship segment, which is in contrast to the ones above, not associated with very high conversion costs for introduction of LNG fuel is the tanker segment. The specific ferry service between Trinidad and Tobago islands is also considered a particularly interesting potential pilot route for introduction of LNG as ship fuel.

The introduction of LNG as fuel in these segments is not necessarily to be seen as an ECA compliance strategy for application within ECAs only, but full time LNG operation may also be found economically attractive and environmentally beneficial compared with HFO-MGO swapping strategies. Future possible expansion of the WCR ECAs will provide further incentive for LNG introduction and speed up the adoption rate.

Quantitative examples of possible future LNG demand and costs for required LNG bunker distribution infrastructure, bunker vessels etc. are presented, indicating that introduction of LNG as ship fuel in the WCR is feasible and that there are good prospects for LNG to become an attractive fuel option for specific ship segments operating in the WCR.

The presented examples together with the general suitability and trend analyses provide a good overview of the possibilities and limitations for introduction of LNG as ship fuel for short sea and coastal shipping in the WCR and the feasibility for establishment of an LNG bunkering infrastructure.
# Abbreviations and Definitions

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Explanation</th>
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<tbody>
<tr>
<td>CNG</td>
<td>Compressed Natural Gas</td>
</tr>
<tr>
<td>dwt</td>
<td>Dead Weight Tonnage (total weight of a ship's cargo, fuel, etc.)</td>
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<tr>
<td>ECA</td>
<td>Emission Control Area</td>
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<tr>
<td>ESD</td>
<td>Emergency Shut Down</td>
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<tr>
<td>FEED</td>
<td>Front End Engineering Design</td>
</tr>
<tr>
<td>FLRSU</td>
<td>Floating Liquefaction, Regasification and Storage Unit</td>
</tr>
<tr>
<td>FLSO</td>
<td>The Floating Liquefaction Storage Offloading vessel</td>
</tr>
<tr>
<td>FOB</td>
<td>Free On Board (with regard to bunker prices)</td>
</tr>
<tr>
<td>FOC</td>
<td>Fuel Oil Consumption</td>
</tr>
<tr>
<td>FSRU</td>
<td>Floating Storage and Regasification Unit</td>
</tr>
<tr>
<td>GT</td>
<td>Gross Tonnage (an index of ship's overall internal volume)</td>
</tr>
<tr>
<td>HFO</td>
<td>Heavy Fuel Oil</td>
</tr>
<tr>
<td>IGC Code</td>
<td>International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. A new version of the code is under development by IMO.</td>
</tr>
<tr>
<td>IGF Code</td>
<td>The International Code for Gas Fuelled vessels, which is under development by IMO.</td>
</tr>
<tr>
<td>IMO</td>
<td>International Maritime Organization (<a href="http://www.imo.org">www.imo.org</a>)</td>
</tr>
<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
</tr>
<tr>
<td>LFL</td>
<td>Lower Flammability Level</td>
</tr>
<tr>
<td>LNG</td>
<td>Liquefied Natural Gas</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Explanation</td>
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<tr>
<td>MGO</td>
<td>Marine Gas Oil</td>
</tr>
<tr>
<td>MMBtu</td>
<td>Million British Thermal Unit, 1 MMBtu = 293 kWh = 1.055 MJ</td>
</tr>
<tr>
<td>OSV</td>
<td>Offshore Supply Vessel (often used in the US instead of PSV)</td>
</tr>
<tr>
<td>PSV</td>
<td>Platform Supply Vessel</td>
</tr>
<tr>
<td>SIGTTO</td>
<td>Society of International Gas Tanker and Terminal Operators</td>
</tr>
<tr>
<td>RAC REMPEITC</td>
<td>Regional Activity Center, Regional Marine Pollution Emergency Information and Training Center</td>
</tr>
<tr>
<td>TPS</td>
<td>Bunkering from storage Tank via Pipeline to Ship</td>
</tr>
<tr>
<td>STS</td>
<td>Ship To Ship (LNG bunkering concept)</td>
</tr>
<tr>
<td>TTS</td>
<td>Truck To Ship (LNG bunkering concept)</td>
</tr>
<tr>
<td>UFL</td>
<td>Upper Flammability Level</td>
</tr>
<tr>
<td><strong>Term</strong></td>
<td><strong>Definition</strong></td>
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<td>-------------------------------</td>
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<tr>
<td>AIS</td>
<td>Automatic Identification System is a very high frequency (VHF) radio-based system, which enables the identification of the name, position, course, speed, draught and cargo of ships.</td>
</tr>
<tr>
<td>WCR</td>
<td>The Wider Caribbean Region, referring to the area covered by the RAC/REMPEITC-Caribe, is the Cartagena Convention area, which represents the marine environment of the Gulf of Mexico, the Caribbean Sea and the areas of the Atlantic Ocean adjacent thereto, south of 30 degrees north latitude and within 200 nautical miles of the Atlantic coasts of the States referred to in Article 25 of the Convention. Countries include: Antigua and Barbuda, Bahamas, Barbados, Belize, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, France, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Kingdom of the Netherlands, Nicaragua, Panama, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago, United Kingdom, United States of America and Venezuela.</td>
</tr>
<tr>
<td>International shipping</td>
<td>Shipping between ports of different countries, as opposed to domestic shipping. International shipping excludes military and fishing vessels. By this definition, the same ship may frequently be engaged in both international and domestic shipping operations [IPCC 2006 Guidelines]</td>
</tr>
<tr>
<td>Domestic shipping</td>
<td>Shipping between ports within one country.</td>
</tr>
<tr>
<td>Coastwise shipping</td>
<td>Coastwise shipping is freight movements and other shipping activities that are predominantly along coastlines or regionally bound (e.g., passenger vessels, ferries, offshore vessels) as opposed to ocean-going shipping. The distinction is made for the purpose of scenario modelling and is based on ship types, i.e. a ship is either a coastwise or an ocean-going ship</td>
</tr>
<tr>
<td>Short Sea shipping (Shortsea shipping in project ToR)</td>
<td>Short sea shipping includes domestic and international maritime transport, including feeder services, along the coast and to and from the islands, rivers and lakes. Short sea shipping includes domestic and international maritime transport, including feeder services, along the coast and to and from the islands, rivers and lakes. Typical short sea ship size ranges from 1 000 – 15 000 dwt.</td>
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SSPA Sweden AB and White Smoke AB acknowledge the Regional Activity Center, Regional Marine Pollution Emergency Information and Training Center (RAC-REMPEITC) for access to GIS-based database for maritime traffic in the WCR. Traffic pattern diagrams from the web map application have been derived and are excerpted as figures in the report.
1 INTRODUCTION

1.1 Background

The International Maritime Organization (IMO) has a special responsibility for the regulation of international shipping, safety at sea, and the prevention of marine pollution.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main international convention covering prevention of operational or accidental pollution of the marine environment by ships. MARPOL Annex VI, specifically addressing air pollution from ships entered into force in 2005. The Baltic Sea Sulphur Emission Control Areas (SECA) has been in force since 2005, and the North Sea and English Channel SECA came into force in 2007. In August 2012 the North American ECA covering the US coasts and Hawaii came into force and from 2016 the area will encompass NOx emission control requirements. In January 2014 the US Caribbean ECA covering Puerto Rico and the US Virgin Islands is due to take effect.

Within ECAs, the maximum allowed sulphur content of fuel oil is 1.0 % and after 1 January 2015 the maximum allowed sulphur is 0.1%. Outside ECA 3.5% is allowed until 1 January 2020 (or possibly until 2025\(^1\)) and thereafter 0.5%.

More areas within the Wider Caribbean Region (WCR) will possibly become a future Emission Control Area (ECA) under MARPOL Annex VI. In addition to the decided designations of ECAs some additional areas are also discussed as indicated by the map below.

To prepare for this possible regulatory development, the use of different fuels with less environmental impact needs to be further studied.

There are a few different technical and operational options to comply with the ECA requirements and the transition from HFO to LNG fuel for operation of ships within the ECA is considered an interesting option.

IMO has therefore given SSPA Sweden AB and White Smoke AB the task to further explore the feasibility of LNG as a potential fuel source for short sea and coastal shipping in the WCR.

\(^1\) Depending on the outcome of a review to be completed by 2018
1.2 Scope and methodology

The scope of this feasibility study of LNG as potential ship fuel in the WCR includes six main components as listed below.

Table 1. Components of the feasibility study according to the assignment.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1 Identification of shipping activities</td>
<td>The present shipping activities within the WCR will be identified, looking at ship types, main routes, intensity of traffic, etc.</td>
</tr>
<tr>
<td>2 Identification of key trends</td>
<td>The key trends in demand for shipping services in the WCR will be identified and the likelihood and impact of possible future development scenarios will be estimated, one possible scenario being the introduction of ECA in the region.</td>
</tr>
<tr>
<td>3 Estimation of potential for LNG</td>
<td>Based on the shipping activities and the key trends identified, the potential ship types and routes in the region for which LNG has significant potential will be identified.</td>
</tr>
<tr>
<td>4 Appraisal of LNG Infrastructure</td>
<td>Current and planned infrastructure for LNG in the region will be appraised, giving special focus to availability and costs of the infrastructure needed for LNG introduction.</td>
</tr>
<tr>
<td>5 Identification of key barriers to adopting LNG</td>
<td>There are several barriers to the adoption of LNG as fuel for shipping. The key barriers in the WCR will be identified and discussed.</td>
</tr>
<tr>
<td>6 Identification of key enablers to adopting LNG</td>
<td>The key enablers to aid adopting LNG and synergies with other developments in the region will be identified.</td>
</tr>
</tbody>
</table>
1.2.1 Geographic coverage

The study covers the Wider Caribbean Region (WCR) comprising the insular and coastal states and territories with coasts on the Caribbean Sea and Gulf of Mexico as well as waters of the Atlantic Ocean adjacent to these states and territories and includes 28 island and continental countries. The figure below shows the area as defined by RAC-REMPEITC Caribe. This definition is consistent with the coverage of the REMPEITC WCR ship movement database, which is used in this report for characterisation of the WCR ship traffic.

It may be noted that in MARPOL Annex V (Garbage), the WCR special area does not include Suriname and French Guyana and its border in the Atlantic ocean are given by the coordinates: Coast of Florida at 30 N; 30N 77 30'W; 20N 59W; 7 20'N 50W; Coast of Guyana.

![Figure 2. The Wider Caribbean Region, WCR as defined by RAC-REMPEITC Caribe.](image)

1.2.2 Short sea and coastal shipping

The focus of this study is on short sea and coastal shipping. The term short sea shipping has no established precise definition but the term clearly excludes trans ocean shipping, and inland waterway shipping is traditionally not included in short sea shipping. In Europe Short Sea Shipping means the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports and ports situated in non-European countries having a coastline on the enclosed seas bordering Europe. Short sea shipping includes domestic and international maritime transport, including feeder services, along the coast and to and from the islands, rivers and lakes. Short sea shipping includes domestic and international maritime
transport, including feeder services, along the coast and to and from the islands, rivers and lakes.

Typical short sea ship size ranges from 1 000 – 15 000 dwt but some are small enough to travel and be engaged on inland waterways. Short sea shipping includes the movements of wet and dry bulk cargoes, containers and passengers.

The distances in the WCR between ports in Texas in the north and in Trinidad & Tobago in the south are comparable to those between European ports in Finland and Italy. With a broad definition of the WCR short sea shipping, it includes movement of cargo and passengers by sea between ports situated in the WCR, coastal shipping along the mainland coasts, along the large islands and between the small islands. In this report the term “internal WCR ship traffic” is also used to denote this traffic and to separate it from ship traffic entering or leaving WCR ports from ports outside the WCR, denoted “WCR external traffic”.

2 SHIPPING IN THE WIDER CARIBBEAN REGION

2.1 Basic shipping characteristics in the WCR

The WCR is a busy shipping area representing a wide range of different shipping segments, different commodities and ship sizes engaged in inter-ocean routes as well as regional short sea, coastal and inter-island traffic. Extensive offshore operations and cruising activities contribute to making the shipping situation very complex.

A number of major global shipping routes primarily pass through the WCR area. These routes, primarily running in an east-west direction, are related to traffic passing through the Panama Canal. Some of the vessels trading in these routes are calling ports within the WCR but most of them only transit through the area without any stop over.

Another major route is the north-south trade route related mainly to the energy trade between North and South America. This route is related to the oil and gas resources available in the Northern part of South America feeding primarily the US market with energy.

In addition to the oil and gas sources in the southern part of the WCR there are also significant oil and gas resources in the Mexican gulf. Both these areas generate a lot of ship traffic related to the exploration, production and transportation of oil and gas and in addition to the necessary tanker operations there are also a lot of PSV, anchor handlers, construction vessels, seismic exploration vessels, etc. operating within these areas.

Traditionally the backbone of the intra-regional ship transport system in the WCR have been supplied by small scale artisanal vessels, shipping all kinds of cargo such as passengers, agricultural products, consumer goods, energy, chemicals, wood products, machinery, construction material etc. This kind of shipping is gradually replaced by bigger ships, handling of containerised cargo, etc.

Another significant shipping segment is the cruise industry. According to Florida-Caribbean Cruise Association (FCCA 2012) almost 40% of all global cruise capacity operates in the Bahamas/Caribbean region but the cruise activity is also significant in other part of the WCR.

With regard to possible future extended ECA requirements in the WCR and the potential for LNG as ship fuel, the WCR internal traffic is more interesting than the transit traffic through WCR and other external WCR traffic only spending part of its operation time in the WCR. Ship operators whose vessels basically are operating outside ECAs are assumed to be less prone to change to LNG fuel.

The portion of the WCR traffic that is specifically serving and calling US ports are subject to the Merchant Marine Act from 1920. This act, known as the
Jones Act, has a significant impact on the shipping in the WCR basically stating that any vessel trading between two US ports have to fulfil a number of criteria such as:

- Being built in the US
- Being owned by a US company/US citizens
- Being crewed by US citizens
- Flying the US flag

From a commercial perspective the Act has created a closed market for vessels only trading between US ports. The cost levels for these vessels are significantly higher than for equal vessels in international trade. Provided the act remains unchanged the market for these vessels is more predictable and less competitive than for the international markets.

2.2 Available data on ship traffic statistics and route pattern

A number of various sources have been reviewed in order to find information on the ship traffic pattern, the main routes, ports and traffic intensity in the WCR. The sources considered most useful were the following ones:

- RAC-REMPEITC Caribe GIS-based database for maritime traffic in the WCR
- Recorded AIS statistics
- Statistics from the Panama Canal Authority and other regional and port agencies

Detailed information on the RAC-REMPEITC Caribe GIS-based database in the WCR can be found at the web site http://cep.unep.org/racrempeitc/maritime-traffic.

2.2.1 Main shipping segments

In this report the traffic within the WCR is sub-divided into and analysed for the following six main traffic segments:

- Tanker
- General cargo
- Tug and supply
- Bulk
- Passenger
- Other
The division in these six segments is made in accordance with the categorisation applied in the RAC-REMPEITC Caribe GIS database for maritime traffic in the WCR.

2.3 Analysis of ship traffic data in the WCR

Ship movements registered with both departure and destination ports within the WCR (WCR internal ship traffic) are considered of primary interest with regard to potential future transition to LNG fuel. Ship movements with both or either destination or departure outside the WCR (WCR external ship traffic) are not considered as short sea coastal traffic and thus outside the main focus of this study. Some examples of WCR external traffic are, however, presented for comparative purposes in this analysis.

The REMPEITC database comprise a very large number of registered ship movements on different routes and as this study is aiming at a first rough estimation on the feasibility of LNG as fuel, it is considered accurate enough to carry out indicative analyses and estimations based on a selection of the major routes and ports.

In order to be able to estimate potential future LNG fuel demand, today's total fuel consumption by the total number of registered ship movements within the WCR would provide a relevant reference figure. There are, however, no statistics on the bunker volumes supplied in the WCR ports today and neither any detailed data on the travelled distances nor time spent for each vessel in the registered WCR routes. Therefore it is difficult to do any general estimations of the fuel consumption within the WCR. In chapter 6 some examples are presented for specific segments and routes identified as possible LNG fuelled services to provide some insights in the quantitative calculation of LNG demand.

The figure below represents the total number of ship movement registrations in the period 2007–2008. The total number of registered movements are 207,226 or an average of 108,118 annually. Each movement is registered with one port of departure and one port of destination and for specified ports; the number of ship arrivals and ship departures can be displayed separately. The red circles represent the ports and the size of the circle is proportional to the number of registered arrivals and departures from the port. The seven blue route end markings in the Atlantic Ocean and the one at the mouth of the Panama Canal represent entry/exit points of movements from/to outside the WCR.

It should be noted that the presented ship traffic statistics represent the situation about five years ago and that the present traffic intensity generally is

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2 The REMPEITC database includes data for 23 months from January 2007 to November 2008.
3 The estimated annual figures are calculated by multiplying the REMPEITC figures by a factor 12/23.
higher than it was in 2007/2008. The increase rate has been somewhat
different for different segments and in different regions but as a general
average figure, the increase from 2008–2012 may be estimated to about
15-20%. The Panama Canal traffic statistics indicate about 17% increase in
number of transits during this five year period, see chapter 3.1.1.

The figures presented in the report are not recalculated to include this
15-20% increase and are representing the 2007/2008 situation.

Figure 3. Overview of the total WCR ship traffic based on more than 200 000 movement registrations in the REMPEITC database.

When all WCR external movements are excluded, still 73% of the movements
remain with a number of 78 597 estimated annual WCR internal movements.

These movements are distributed over the six main ship type segments
according to the figure below, showing that 43% of the movements are
referred to general cargo vessels.
2.3.1 Largest ports

There are about 335 ports in total in the REMPEITC database with registered ship movements. Many of the ports are small and represent only a minor portion of the total number of movements. In order to provide a basis for rough estimations and an overview of the main traffic pattern a ranking of the ports in terms of number of registered movements was derived.

The table below includes the “top-twenty” ports for each of the six main ship type segments. The number of registered movements (registered departures) are presented as estimated annual figures for each port. The table columns also include the sum and the percentage fraction of the total number of registered movements represented by the listed “top-twenty”.

Many of the large WCR ports offer bunker supply services for HFO and MGO today but it is not necessarily today’s’ main bunker ports that will be the first to offer LNG bunker supply services in the WCR. None of the WCR ports is ranked among the world top 10 of major bunker ports today.

From the table below it can be noted that typical high frequency ferry ports, i.e. Port of Spain, Trinidad are not listed. This may indicate that some of the regular ferry services between the islands in the WCR are underreported in the utilised statistics.
Table 2 Top-twenty ports in 2007-2008 - Estimated annual number of movements (excluding external WCR movements) based on registered departure movements

<table>
<thead>
<tr>
<th>Rank</th>
<th>Tanker</th>
<th>No of dep.</th>
<th>General cargo</th>
<th>No of dep</th>
<th>Tug and supply</th>
<th>No of dep</th>
<th>Bulk</th>
<th>No of dep</th>
<th>Passenger</th>
<th>No of dep</th>
<th>Other</th>
<th>No of dep</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:</td>
<td>Houston</td>
<td>2420</td>
<td>Port_Everglades</td>
<td>1915</td>
<td>St._Thomas</td>
<td>563</td>
<td>New_Orleans</td>
<td>532</td>
<td>Port_Everglades</td>
<td>1121</td>
<td>Freeport(BHS)</td>
<td>251</td>
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<tr>
<td>2:</td>
<td>Texas_City</td>
<td>894</td>
<td>Miami</td>
<td>1386</td>
<td>San_Juan(PRI)</td>
<td>327</td>
<td>Houston</td>
<td>468</td>
<td>Nassau</td>
<td>1024</td>
<td>Palm_Beach</td>
<td>220</td>
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<tr>
<td>3:</td>
<td>Coatzacoalcos</td>
<td>789</td>
<td>Houston</td>
<td>1349</td>
<td>Christiansted</td>
<td>313</td>
<td>Mobile</td>
<td>242</td>
<td>Cozumel</td>
<td>937</td>
<td>Dominica</td>
<td>118</td>
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<td>Puerto_Limon</td>
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<td>Veracruz</td>
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<td>Tampa</td>
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<td>Santa_Marta</td>
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<td>Port_of_Spain</td>
<td>95</td>
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<td>Kingston(JAM)</td>
<td>1173</td>
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<td>St._Thomas</td>
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<td>86</td>
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<td>Pointe_a_Pierre</td>
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<td>1132</td>
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<td>220</td>
<td>Altamira</td>
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<td>101</td>
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<td>409</td>
<td>St._George's(GRD)</td>
<td>58</td>
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<td>Port_of_Spain</td>
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<td>Corpus_Christi</td>
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<td>Tortola</td>
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<td>Anguilla</td>
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<td>79</td>
<td>St._John’s</td>
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<td>St._John’s</td>
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<td>Pointe_a_Pitre</td>
<td>226</td>
<td>Tortola</td>
<td>29</td>
</tr>
</tbody>
</table>

| Sum of listed top-20 | 11494 | Sum of listed top-20 | 19967 | Sum of listed top-20 | 3461 | Sum of listed top-20 | 2978 | Sum of listed top-20 | 10409 | Sum of listed top-20 | 1569 |

61% of the total     18816     60% of the total     33854     71% of the total     4877     61% of the total     4915     75% of the total     13895     70% of the total     2239
2.3.2 Ship size distribution

The ship size of the registered movements in the REMPEITC database is included in terms of deadweight tonnage (dwt) and gross tonnage (GT) and is an important parameter for characterisation of the fleet composition and possible LNG fuel demand. A histogram for each segment is presented in the following text and most segments show a peak in the number of movements in the ship size range 5 000 – 15 000 dwt representing the typical short sea tonnage.

In the REMPEITC map GIS application, the ship size intervals are separated and presented in fixed intervals according to the colour scale in the figure below. The figure shows that the highest number of movements is made by general cargo vessels in the 10 – 50 000 dwt range and that small cargo vessels and passenger vessels < 10 000 dwt also represent a large share of the total number of the registered movements.

Figure 5. Estimated number of annual internal WCR movements per ship type segment and dwt class

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4 The relative distribution in dwt classes is based on traffic including external WCR. Also note that distribution in dwt classes is less relevant for the tug & supply and passenger segments.
2.4 The tanker traffic characteristics

Most types of tankers are operated within the WCR ranging from small product and chemical tankers up to large crude oil tankers. In general tankers are trading all over the WCR. This is also clearly illustrated by the GIS map below showing a number of tanker movements (48 788 per 23 months incl. WCR external) in the area and the overall traffic pattern including oil terminals\(^5\).

![GIS map of tanker movements](image)

*Figure 6. All tanker movements including WCR external 2007-2008 and tanker terminals*

The figure below with tanker ship size distribution histogram displays peaks in the typical coastal tanker size interval up to 10 000 dwt and 20 000 dwt, but also in the medium range (MR) size 30 – 50 000 dwt. The peak from 90 – 120 000 dwt includes Aframax crude carriers and the registrations around 300 000 dwt represent a few rare events with very large crude carriers (VLCC).

\(^5\) US tanker terminals are not marked in the map
Each of the peaks identified in the histogram above corresponds to the specific tanker size segments described below.

2.4.1 Crude oil tankers

In contrast to most crude oil trades in the world, the backbone vessel type of crude oil transportation within the WCR is not the VLCC. Instead most crude trade is done with Aframax tankers. The main reason for this is that few ports within the WCR and particularly in the US are able to accommodate VLCCs.
The main route for these Aframax tankers is between a number of large Venezuelan crude export ports and the major US crude import ports along the US Gulf Coast. This trade is clearly visible in the figure below.

![Figure 9 All tanker movements, Jan 2007 – Nov 2008 with tankers in the size interval 100 – 150 000 dwt.](image)

### 2.4.2 Coastal tankers

Within the WCR coastal tankers are used for regional distribution of energy and other liquid commodities. They trade all over the WCR and are usually not operated on fixed schedules between fixed ports.

Main loading ports for this segment are the large industrial ports with refineries and chemical plants etc. such as US and Mexican Ports along the Mexican Gulf coast as well as ports along the northern coast of South America. The single most visited port areas are the various ports of Trinidad and Tobago.

![Figure 10. Typical coastal tanker (Photo Courtesy FKAB Marine Design).](image)
Areas with high-density traffic are found between the Leeward and Windward islands and in particular between Granada and Trinidad & Tobago in the southern part of the area.

In the figure below ports and movements for tankers up to 10 000 dwt (about 6 900) are displayed.

![Figure 11. All tanker movements, Jan 2007–Nov 2008 with tankers in the size interval up to 10 000 tonnes.](image)

2.4.3 Medium range tankers

The medium range tankers (MR) operated within the WCR are primarily used for oil products and chemicals. Many MR tanker movements are registered in the US Gulf Coast ports, but their basic trade pattern also include WCR external routes northward along the US east coast. These tankers are seldom operated on WCR internal routes and will not be further discussed.

2.5 General Cargo traffic characteristics

In the REMPEITC database the general cargo segment is divided into the following three sub-segments:

- Container
- Vehicle
- Other general cargo
The figure below, displaying a representative relative distribution from 2008, shows that about half of the segment represents container traffic and the other half is referred to as other general cargo. The sub-category vehicle carrier represents only a minor fraction and is therefore not specifically addressed in the analysis below.

![General cargo vessel movements incl WCR external per vessel sub-category - Nov 2008](image)

*Figure 12. Relative distribution per vessel sub-category of cargo vessel movements including WCR external, represented by registered data from November 2008.*

### 2.5.1 Container traffic

Container shipping is the fastest growing ship segment within the WCR. The graph in the figure below shows the development between handled tonnes of cargo and handled number of TEUs in a number of WCR countries. Even if the selection of countries is not complete the development is considered representative for the entire WCR.

![Growth rate comparison for a selection of WCR countries (Source ECLAC)](image)

*Figure 13. Growth rate comparison for a selection of WCR countries (Source ECLAC).*
2.5.2 Large container vessels

Larger container vessels with a TEU capacity of above 3 000 corresponding to a GT of approximately 30 000 only transit through the WCR heading to or from the Panama Canal. The main route of these vessels is from the area between Florida and the Bahamas though the Windward passages and down to the entrance of the Panama Canal. If these vessels do stop overs in the WCR, they normally call the main ports in the Bahamas/Miami region, in Jamaica or in Panama.

The only other main route for these vessels within the WCR is for vessels calling ports in the Houston area entering the WCR via the area between Florida and the Bahamas.

2.5.3 Container feeders

Most WCR internal trades are done with container vessels with a GT of less than 20 000, which correspond to vessels with a TEU capacity of up to approximately 2 000. These vessels called Container feeders are the workhorses of the intra-regional container trades and service most developed ports in the region.

A typical trading pattern for a container feeder is a scheduled route between a number of fixed ports where at least one of them may be considered as a transhipment port connecting the route to the global container flows.

*Figure 14. The 974 TEU container feeder vessel K Breeze (Photo courtesy Crowley).*
The histogram in the figure below displays a peak in the size interval 5 - 15 000 dwt. This interval accommodates typical container feeder vessels.

![Histogram of WCR internal container vessel movements 2007-2008](image)

*Figure 15. Size distribution of WCR internal container vessel movements 2007–2008.*

Selecting November 2008 as a representative month for the display of registered container vessel traffic in the size interval 0 – 50 000 dwt, a complex grid incorporating a large number of ports is displayed, shown in the figure below.

![Trading pattern for General cargo container carriers 0–50 000 dwt](image)

*Figure 16. Trading pattern for General cargo container carriers 0 – 50 000 dwt.*
The figure shows that container feeders are operated all over the WCR visiting most developed ports in the area.

2.5.4 Other general cargo

By tradition small general cargo carriers have been a very important part of the sea based transportation system within the WCR. Their on board cargo handling equipment, cranes, etc. allow them to call less developed ports all over the area. Yet flexible and cheap the cargo handling efficiency is low compared to modern container feeders but since they require significantly less port investments, they still have their markets in the WCR.

From the map in the figure below it is clear that these vessels are operated all over the WCR.

Figure 17. Typical small geared general cargo carrier calling Pointe-a-Pitre on Guadeloupe. (Photo: Urs Steiner)

Figure 18. Trading pattern for General cargo carriers below 10 000 dwt.
As displayed in the histogram below these vessels are usually small with the main sizes below 10 000 dwt.

![Histogram showing the size distribution of WCR internal cargo vessel movements 2007-2008.](image1)

**Figure 19. Size distribution of WCR internal cargo vessel movements 2007-2008.**

### 2.6 Tug and supply vessel traffic characteristics

For the segment of tug and supply vessels a total of 9 640 movements are registered (over the total 23-month period of the REMPEITC database).

The geographical distribution indicates that there is a concentration of tug and supply vessel traffic in two areas – in the US Gulf Coast area and around the Virgin islands – which can be seen in the figure below.

![Map showing tug and supply vessel traffic in the WCR.](image2)

**Figure 20. Tug and supply vessel traffic in the WCR.**
2.6.1 Harbour tugs

Three dominant sub segments are included in the tug and supply segment. For tugs there are two main applications within the WCR. The first one, commonly used in all ports within the WCR, is the harbour tug assisting vessels entering or leaving ports.

Figure 21. Typical harbour tug.

2.6.2 ITB/ATB

The second main tug application is ITB/ATB/push barge solution where both normal tugs and tailor made tugs are used for moving one or several barges with all kinds of commodities between ports. There are two high-density areas for this kind of operation.

The first one is along the US coast where a lot of these combined units are operated. The other area is around the northern Leeward Island where these units distribute all kind of commodities including water, energy, and general cargo, etc. between the different islands.

Figure 22. An oil ATB outside Key West (Photo courtesy Crowley).
2.6.3 Platform supply vessels

Supply vessels of all kinds are commonly used for the offshore oil and gas industry along the US Gulf Coast operated out of different base ports primarily in the Houston area. The figure below show this traffic but also include all traffic with tugs/ATBs and ITBs in the area.

![Figure 23 Tug and supply vessel traffic in the US Gulf area represented by April 2008.](image)

Since 2008 when the main data used for this report was retrieved the activities of platform supply vessels (PSVs) in the waters along the north coast of South America have increased significantly due to the increased interest in the exploration of the offshore oil and gas resources in that area.

2.7 Dry bulk shipping characteristics

The dry bulk segment within the WCR consists of two typical segments. The main segments is dry bulk shipping related to import and export of typical dry bulk commodities such as coal, grain, ore etc. from the US Gulf coast ports (USACE NDC 2012). Most of this shipping is on behalf of ports outside the WCR. The main trading routes for this segment is from the US Gulf Coast ports to the inlet of the Panama Canal or south of Florida and then towards the North American east coast or Europe. Therefore it will not be further evaluated in this study.

The other type of dry bulk shipping is a more small-scale artisanal intra-regional dry bulk shipping, which is very similar to the small general cargo segment and therefore difficult to distinguish. In terms of trading patterns and other characteristics it looks relatively similar to the general cargo segment.
2.7.1 Size distribution

The size distribution for registered WCR internal movements with dry bulk carriers is presented in the figure below.

![Dry-bulk carrier size distribution](image)

*Figure 24. The size distribution for registered WCR internal movements with dry bulk carriers.*

2.8 Passenger vessel traffic characteristics

In principle, there are two types of passenger traffic within the WCR, regular passenger traffic and cruise.

Regular passenger traffic between the Caribbean Islands and elsewhere in the WCR is basically conducted by vessels ranging from 100 up to 10 000 GT. Passenger vessels ranging from 10 000 – 150 000 GT are assumed to represent cruise ships.
2.8.1 Regular passenger vessels

There are a large variety of passenger vessels operated in the area ranging from small ferries operated in short distances between small and sheltered island communities up to large vessels operated between the main islands in the Caribbean and elsewhere. There are also high speed craft (HSC) ferry services operated in many places of the WCR.

The REMPEITC map below clearly displays that the main area for this traffic is between the different Caribbean islands. Note that the ferry traffic between islands Trinidad and Tobago is not reflected in the map.
2.8.2 Cruise

The cruising industry within the WCR is huge and most of the services are operated from the main cruise ports in southern Florida. As displayed in the figure below, most of these vessels are trading the Bahamas, the Caribbean Islands as well as the waters of Mexico, Belize, Guatemala and Honduras. The cruising activities are operated year round with a peak season between October and March. A typical cruise trip runs for seven days.

![Figure 27. Trading pattern for passenger vessels above 10 000 GT within the WCR.](image)

2.9 Other ship traffic

The other vessel group is a relatively small segment with various types of vessels not typically characterised as short sea shipping. One group that, however, may be of future interest for LNG fuel adaptation is the fishing vessels.

![Figure 28. RCCL Monarch of the seas on a cruise within the WCR.](image)
There are about 1,000 fishing vessel 100 -10,000 GT movements registered with a concentration in the Lesser Antilles islands (Leeward Islands) and with Trinidad and Dominica as the largest ports. As seen in the figure below, 90% or about 900 are in the size range 100-500 GT.

Figure 29. Size distribution histogram of fishing vessels.

Figure 30. Trading pattern with fishing vessels in the size range 100 – 500 GT.
2.10 External traffic – Ships entering and departing the WCR

2.10.1 Panama Canal related traffic

For the WCR external traffic passing through the Panama Canal, there are detailed statistics available from Panama Canal Authority. The graph in the figure below shows the development over the past 10 years indicating a significant increase in the dry bulk segment compared to the years 2007 and 2008 used as references for the RAC-REMPEITC comparisons.

![Graph showing development of Panama Canal traffic over 10 years.](image)

*Figure 31. Segment divided transhipments in long tons (Panama Canal Authority).*

The three segments containers, dry bulk and tankers dominate the transhipment through the Panama Canal. The division between ship types in 2011 is displayed in the figure below, showing that the three major segments represent 68% of the number of ship passages.

![Graph showing distribution of transits between ship types 2011.](image)

*Figure 32. Distribution of Transits between ship types 2011 (Panama Canal Authorities 2012)*

If the comparison is presented in terms of cargo quantities the three major segments represent 90% of the total transported cargo weight.

In order to display the pattern of departures and destinations within and outside the WCR, all registered movements (January 2007 – November 2008)
are shown in the figure below. A total of 24 301 (12 679 annual) ship movements, all segments, were registered in the Panama Canal. This figure corresponds to 12% of all the ship movements registered in the REMPEITC database.

![Figure 33. All ship types passing the Panama Canal (Arc 10116) January 2007 – November 2008.](image)

Except for Manzanillo in Panama, Houston (1 327 movements) and New Orleans (1 176 movements) are the main WCR ports for the Panama Canal traffic (see figure above). Of the total 24 301 passages (12 679 annual) through the canal 9 491 (4 952 annual), or 39% of the traffic is bound for or arriving from the Atlantic Ocean without calling at any WCR ports.

**2.10.2 The Atlantic Ocean – WCR arrivals from and departures to the Atlantic**

Registered in routes entering from or exiting to the Atlantic Ocean were 55 379 ship movements from all segments. This figure corresponds to 12% of all the ship movements registered in the REMPEITC database. The one most frequently used (marked with green in the below figure) shows 12 589 registrations with Houston (1 632 movements [of which 760 by tankers]) as the main port within the WCR.

![Figure 34. WCR arrivals from and departures to the Atlantic.](image)
3 KEY TRENDS AND FUTURE SCENARIOS

3.1 General Key Trends

3.1.1 Panama Canal Expansion

Since the opening of the Panama Canal in 1914 it has been a major global shipping route and for years the limitations set by the locks in the canal was decisive for how ships in various segments were designed. During the late twentieth centuries this changed and a significantly larger share of the newly built ships were designed without considering the Panama Canal limitations. This development has reduced the relative importance of the canal in a global perspective.

In 2006 it was decided to expand the canal. The main reason was to secure its position as one of the major global shipping routes for the future as well as regain some lost market shares. Some segments are more influenced than others by this development. The on-going expansion is due to be completed by 2014 and will allow more and larger ships to pass.

The general cargo segment, and especially the container shipping, is probably the segment that will be most affected by the expansion plans. Vessels that are too large to pass the present canal do most of the intercontinental container trades today. The new dimensions will once again make it possible for the large inter-continental container flows to pass through the Panama Canal and the most plausible development is that the growth in TEU or tonnes shipped through the canal will grow faster than the global shipping growth.

For other main segments such as dry bulk and tankers the result of the new canal size is more ambiguous and a plausible development is that the flows tonne wise will increase in line with the global shipping growth but that the number of passages will be less, as vessels passing the canal will grow in size.

Figure 35. Development of Panama Canal transits (Panama Canal Authority).
In a long-term perspective with continued increasing maritime traffic and if the capacity of the expanded Panama Canal will become insufficient, the feasibility of another canal project may be subject for renewed considerations.

3.1.2 Environmental requirements

Shipping as such has been a business with rather limited environmental requirements of either commercial or regulatory character. During the last decade this situation has changed drastically. Today shipping is under heavy pressure from authorities, clients and the general public to improve the environmental performance of shipping both in a local, regional and global perspective.

This development is forcing the shipping community to invest in new vessels and technologies, change to alternative fuel, develop the general operational performance as well as increase the level of education of the professionals involved in shipping. This development has a significant influence also on shipping in the WCR.

Recent designations of the North American ECA and the US Caribbean ECA within the WCR will further enhance the development of the environmental performance of the fleet operating in the WCR.

3.2 Additional segment related key trends

3.2.1 Tankers

The tanker shipping within the WCR is relatively stable and it will probably develop without any dramatic short-term changes. Some minor trends may, however, be identified and mentioned.

The increasing interest in using LNG as the main source of energy in some of the island communities in the WCR, will likely contribute to an increasing demand for and construction of small and medium-size LNG carriers.

In recent years some of the main refineries in the WCR have been closed because of poor profitability. A typical example is the Hovensa refinery at the island of St Croix, US Virgin Islands. Such development will have significant local impact on the tanker shipping segment but seen in a regional perspective the impact is considered limited.

3.2.2 General Cargo

A very clear trend in the WCR is that local and regional small-scale shipping operation is outrivaled by ship operations more integrated with the passing large-scale shipping operation. This is also connected to port development and efficiency.
Segments that are most affected by this development is the General Cargo segment where cargo is moving from small general cargo into containers, which then is handled in the growing container flows (Sánchez and Wilmsmeier 2009). For the WCR communities this implies reduced shipping costs also for internal WCR cargo transportation as long as the ports are connected to the container infrastructure systems either by feeder or a transhipment port.

The losers of this development are everybody involved in the traditional artisanal shipping systems that used to be the backbone of the WCR internal distribution such as:

- Small and less developed ports
- Societies and private companies relying on these ports
- Owners and operators of small general cargo and bulk carriers

From the society's point of view, it is of great importance to be included in container feeder networks. In order to keep up competitiveness it may be necessary to invest and develop key ports to become attractive for the cargo owners and shipping companies to use.

As identified in the previous section, the expansion of the Panama Canal will have a significant impact on the general cargo segment and a plausible development is that the number of large container carriers passing through the WCR will grow.

As described in the previous section the number of large transhipment ports for containers is limited especially in the central part of the WCR. Several of the large regional ports in the area, such as the Kingston Container Terminal of Jamaica, are investing heavily to be able to attract the global large-scale container routes to include stopover in the WCR on its way to or from the Panama Canal. If one or several of these ports are successful, it may create new trading patterns for container feeders, reducing the demand for small general cargo even more.

### 3.2.3 Dry bulk

The main dry bulk segments are considered relatively stable but influenced by the general trends identified in section 3.1. For the smaller segment there is a similar trend as for the general cargo segment described in section 3.2.2. Based on the high efficiency that usually characterises the container flow, some of the typical bulk commodities may be containerised leading to a reduced demand for small bulk vessels.

### 3.2.4 Supply and tug

For the tug segment, it is difficult to identify any clear trends except the general trends stated in section 3.1. Concerning the supply segments there is a
possibility for a significant increase in the supply vessel operations along the northern coast of South America since there are several unexploited offshore oil and gas reserves in that area.

3.2.5 Passenger

The passenger segment differs from route to route and it is difficult to identify any general trends concerning the future development of the passenger within the WCR. It should, however, be noted that passenger traffic and in particular the cruising segment often is influenced by external requirements for improved environmental performance and public perception and that environmental performance may gain increasing importance as a competitive market factor.

3.2.6 Other ship types

Other ship types cover a wide scope of vessel types operating in different areas and no clear-cut general development trend has been identified for this segment within the WCR.

3.3 Baseline scenario with regard to emission control

It is well known that the shipping industry represents a significant contribution to global airborne pollution and that the three worldwide-established MARPOL Annex VI-designated ECAs are effective measures for improvement of air quality and reduction of health risks. The measures taken to reduce current ship emission levels to the ECA standard are a most cost-effective way to achieve air quality improvement in the area. In the proposal to IMO for the US Caribbean ECA, US EPA estimated emission reductions of 10 000 tonnes of NO\textsubscript{x}, 3 000 tonnes of particles PM2.5, and 28 000 tonnes of SO\textsubscript{x} (US EPA 2011).

The ECAs in the Baltic Sea area, the North Sea area and the recent North American ECA that came into effect 1 August 2012, all cover sea areas with dense sea traffic and environmentally sensitive surrounding coastal zones and islands. The US Caribbean ECA that will come into effect in 2014 also represents sensitive sea and coastal areas located in an area of the WCR with dense ship traffic and a wide range of ship types. The ECA designation will influence the operational costs of shipping in the area but the cost increase is expected to have marginal impact for end consumers. US EPA has estimated that a five-day cruise from the US mainland to Puerto Rico will increase less than 1% and the cost increase for transportation per TEU container will also stay below 1% (US EPA 2011). Other stakeholders claim that costs will be more significantly influenced.

For ship operations within NO\textsubscript{x} ECAs, ships constructed from 2011 must comply with the “Tier II” standard for marine diesel engines of Reg. 13 of MARPOL
Annex VI. Ships constructed from 2016 will be required to comply with the more stringent Tier III NO\textsubscript{x} emission standard.

### 3.3.1 North American ECA

The North American ECA extends to about 200 nautical miles off the coast except in the narrow areas between Florida, Cuba and Bahamas.

For the internal WCR registered movements, 28% of all ship movements were movements in the ports within the North American ECA.

![Figure 36. North American ECA (US EPA 2010)](image)

### 3.3.2 US Caribbean ECA

For the internal WCR registered movements, 9% of all ship movements in the REMPEITC database (counted by departure movements) are referred to ports within the US Caribbean ECA.

The US Caribbean ECA will basically affect ships calling at San Juan and other ports in Puerto Rico and St. Thomas, Hovensa and Tortola in the US Virgin Islands. The Mona strait between Hispaniola and Puerto Rico is about 70 nautical miles wide and has a dense traffic including Panama Canal – Atlantic Ocean transits. The ECA stretches only about 15 nautical miles in the Mona strait, about 40 miles off the north coast of Puerto Rico and 50 miles off the south coast.
3.3.3 WCR ports outside the ECAs

For the internal WCR registered movements, 63% of all ship movements in the REMPEITC database (counted by departure movements) are referred to WCR ports located outside the designated ECAs. Assuming that only ships calling ports within the two presently designated ECAs will operate with sulphur emissions in compliance with the ECA requirements; this indicates that a majority of the WCR internal ship movements still will be with vessels without any measures taken for reduction of SOx emissions.

The figure below indicates that the introduction of the North American ECA (NA ECA) will have a significant impact on the tanker segment in which 44% of the ship movements have to be carried out by ships compliant to the NA ECA requirements but only another 3% more need to adapt when the US Caribbean ECA come into force. For the general cargo segment a major part or 71% of the internal WCR ship movements will still be calls to ports outside the designated ECAs.
It should, however, also be noted that if a ship has been designed or retrofitted for operation with LNG fuel in order to comply with ECA regulations, it is likely that LNG, because of lower price and operational cost, may be found to be a preferable fuel also for operation outside the ECAs.

In the table below with the top-twenty list of ports for internal WCR calls in the period from January 2007 to November 2008, ports within the North American ECA and the US Caribbean ECA respectively have been marked with different colour shadings to illustrate where the designated ECAs will have an impact.
<table>
<thead>
<tr>
<th>Rank</th>
<th>Tanker</th>
<th>No of dep.</th>
<th>General cargo</th>
<th>No of dep</th>
<th>Tug and supply</th>
<th>No of dep</th>
<th>Bulk</th>
<th>No of dep</th>
<th>Passenger</th>
<th>No of dep</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Houston</td>
<td>2420</td>
<td>Port_Everglades</td>
<td>1915</td>
<td>St._Thomas</td>
<td>563</td>
<td>New_Orleans</td>
<td>532</td>
<td>Port_Everglades</td>
<td>1121</td>
<td>Freeport(BHS)</td>
</tr>
<tr>
<td>2</td>
<td>Texas_City</td>
<td>894</td>
<td>Miami</td>
<td>1386</td>
<td>San_Juan(PRI)</td>
<td>327</td>
<td>Houston</td>
<td>468</td>
<td>Nassau</td>
<td>1024</td>
<td>Palm_Beach</td>
</tr>
<tr>
<td>3</td>
<td>Coatzacoalcos</td>
<td>789</td>
<td>Houston</td>
<td>1349</td>
<td>Christiansted</td>
<td>313</td>
<td>Mobile</td>
<td>242</td>
<td>Cozumel</td>
<td>937</td>
<td>Dominica</td>
</tr>
<tr>
<td>4</td>
<td>Port_Arthur</td>
<td>787</td>
<td>Puerto_Limon</td>
<td>1310</td>
<td>Phillipsburg</td>
<td>292</td>
<td>Veracruz</td>
<td>217</td>
<td>Miami</td>
<td>728</td>
<td>San_Juan(PRI)</td>
</tr>
<tr>
<td>5</td>
<td>Corpus_Christi</td>
<td>687</td>
<td>Puerto_Cortes</td>
<td>1286</td>
<td>Tampa</td>
<td>248</td>
<td>Santa_Marta</td>
<td>152</td>
<td>Freeport(BHS)</td>
<td>672</td>
<td>Port_of_Spain</td>
</tr>
<tr>
<td>6</td>
<td>Cayo_Arcas_Term.</td>
<td>587</td>
<td>Kingston(JAM)</td>
<td>1173</td>
<td>Marigot</td>
<td>242</td>
<td>Tampa</td>
<td>138</td>
<td>St._Thomas</td>
<td>642</td>
<td>Tampa</td>
</tr>
<tr>
<td>7</td>
<td>Pointe_a_Pierre</td>
<td>491</td>
<td>Manzanillo(PAN)</td>
<td>1132</td>
<td>Houston</td>
<td>220</td>
<td>Altamira</td>
<td>128</td>
<td>George_Town(CYM)</td>
<td>631</td>
<td>Port_Everglades</td>
</tr>
<tr>
<td>8</td>
<td>Lake_Charles</td>
<td>484</td>
<td>Cartagena(COL)</td>
<td>1119</td>
<td>Oranjestad</td>
<td>205</td>
<td>Tampico</td>
<td>121</td>
<td>Philipsburg</td>
<td>532</td>
<td>St._Thomas</td>
</tr>
<tr>
<td>9</td>
<td>Freeport(Texas)</td>
<td>477</td>
<td>Santo_Tomas_de.Castilla</td>
<td>1089</td>
<td>Corpus_Christi</td>
<td>136</td>
<td>Coatzacoalcos</td>
<td>110</td>
<td>St._Lucia</td>
<td>518</td>
<td>Philipsburg</td>
</tr>
<tr>
<td>10</td>
<td>Hovensa</td>
<td>473</td>
<td>Rio_Haina</td>
<td>1085</td>
<td>St_.Kitts</td>
<td>125</td>
<td>Freeport(BHS)</td>
<td>103</td>
<td>Bridgetown</td>
<td>493</td>
<td>Pascagoula</td>
</tr>
<tr>
<td>11</td>
<td>New_Orleans</td>
<td>437</td>
<td>San_Juan(PRI)</td>
<td>968</td>
<td>Port_Everglades</td>
<td>124</td>
<td>Point_Lisas</td>
<td>101</td>
<td>San_Juan(PRI)</td>
<td>409</td>
<td>St._George's(GRD)</td>
</tr>
<tr>
<td>12</td>
<td>Puerto_Jose</td>
<td>415</td>
<td>Port_of_Spain</td>
<td>860</td>
<td>Montserrat</td>
<td>86</td>
<td>Corpus_Christi</td>
<td>81</td>
<td>Tortola</td>
<td>380</td>
<td>Jacksonville</td>
</tr>
<tr>
<td>13</td>
<td>Altamira</td>
<td>378</td>
<td>Veracruz</td>
<td>819</td>
<td>Tortola</td>
<td>84</td>
<td>Rio_Haina</td>
<td>79</td>
<td>Port_Canaveral</td>
<td>371</td>
<td>Pointe_a_Pitre</td>
</tr>
<tr>
<td>14</td>
<td>Tuxpan</td>
<td>344</td>
<td>Altamira</td>
<td>751</td>
<td>Anguilla</td>
<td>83</td>
<td>Galveston</td>
<td>79</td>
<td>St._John's</td>
<td>351</td>
<td>St._John's</td>
</tr>
<tr>
<td>15</td>
<td>Port_Everglades</td>
<td>338</td>
<td>Bridgetown</td>
<td>686</td>
<td>Freeport(BHS)</td>
<td>83</td>
<td>Lake_Charles</td>
<td>75</td>
<td>Key_West</td>
<td>336</td>
<td>Bridgetown</td>
</tr>
<tr>
<td>16</td>
<td>Point_Lisas</td>
<td>299</td>
<td>Puerto_Cabello</td>
<td>645</td>
<td>Port_Arthur</td>
<td>71</td>
<td>Puerto_Cortes</td>
<td>74</td>
<td>Belize_City</td>
<td>278</td>
<td>Houston</td>
</tr>
<tr>
<td>17</td>
<td>Curacao</td>
<td>281</td>
<td>Freeport(BHS)</td>
<td>611</td>
<td>St_.John's</td>
<td>69</td>
<td>Puerto_Cabello</td>
<td>71</td>
<td>Fort_de_France</td>
<td>277</td>
<td>Guayanilla</td>
</tr>
<tr>
<td>18</td>
<td>Rio_Haina</td>
<td>247</td>
<td>Cristobal</td>
<td>607</td>
<td>Texas_City</td>
<td>65</td>
<td>Davant</td>
<td>70</td>
<td>Ocho_Rios</td>
<td>249</td>
<td>Cristobal</td>
</tr>
<tr>
<td>19</td>
<td>Tampa</td>
<td>242</td>
<td>Philipsburg</td>
<td>604</td>
<td>Galveston</td>
<td>65</td>
<td>Brownsville</td>
<td>70</td>
<td>St._George's(GRD)</td>
<td>234</td>
<td>Montserrat</td>
</tr>
<tr>
<td>20</td>
<td>Tampico</td>
<td>424</td>
<td>Port-au Prince</td>
<td>572</td>
<td>Guayanilla</td>
<td>60</td>
<td>Port-au_Prince</td>
<td>67</td>
<td>Pointe_a_Pitre</td>
<td>226</td>
<td>Tortola</td>
</tr>
</tbody>
</table>

| Sum of listed top-20 | 11494 | Sum of listed top-20 | 19967 | Sum of listed top-20 | 3461 | Sum of listed top-20 | 2978 | Sum of listed top-20 | 10409 | Sum of listed top-20 | 1569 |

61% of the total 18816 60% of the total 33854 71% of the total 4877 61% of the total 4915 75% of the total 13895 70% of the total 2239
3.4 Future scenario with extended emission control

During the preparations of the application for the North American ECA, the US Environmental Protection Agency discussed (with the Mexico National Institute of Ecology, INE) a possible joint application with Mexico with the aim to include also the Mexican Gulf Coast in the ECA. Such an expansion, as indicated in Figure 1, is considered as one plausible step of further expansion of the ECA in the WCR area.

In order to be eligible to submit an application to IMO for ECA designation of waters within the national economic zone, a country must be party to the MARPOL Annex VI. The list below indicates the present (August 2012) status of WCR countries that have ratified the Annex VI and thus are eligible to apply for ECA designations.

<table>
<thead>
<tr>
<th>WCR Country</th>
<th>Ratified Annex VI</th>
<th>WCR Country</th>
<th>Ratified Annex VI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigua &amp; Barbuda</td>
<td>✓</td>
<td>Jamaica</td>
<td>✓</td>
</tr>
<tr>
<td>Bahamas</td>
<td>✓</td>
<td>Mexico</td>
<td></td>
</tr>
<tr>
<td>Barbados</td>
<td>✓</td>
<td>Netherlands</td>
<td>✓</td>
</tr>
<tr>
<td>Belize</td>
<td>✓</td>
<td>Nicaragua</td>
<td></td>
</tr>
<tr>
<td>Colombia</td>
<td></td>
<td>Panama</td>
<td>✓</td>
</tr>
<tr>
<td>Costa Rica</td>
<td></td>
<td>Saint Kitts and Nevis</td>
<td>✓</td>
</tr>
<tr>
<td>Cuba</td>
<td></td>
<td>Saint Lucia</td>
<td></td>
</tr>
<tr>
<td>Dominica</td>
<td></td>
<td>St. Vincent &amp; Grenadines</td>
<td>✓</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td></td>
<td>Suriname</td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>✓</td>
<td>Trinidad &amp; Tobago</td>
<td>✓</td>
</tr>
<tr>
<td>Grenada</td>
<td></td>
<td>United Kingdom</td>
<td>✓</td>
</tr>
<tr>
<td>Guyana</td>
<td></td>
<td>United States</td>
<td>✓</td>
</tr>
<tr>
<td>Haiti</td>
<td></td>
<td>Venezuela</td>
<td></td>
</tr>
<tr>
<td>Honduras</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the list above and possible cooperation between geographically neighbouring countries it is possible that Bahamas would support an expansion of the North American ECA. If Mexico continues their preparation for ratification Belize would also possibly join a future application from Mexico for an expansion of the North American ECA.

Panama, Jamaica and Trinidad and Tobago are three key parties of the Annex VI and their roles in possible further expansion of the WCR ECA are important. It can be noted that Trinidad and Tobago’s neighbours, Barbados and St. Vincent and Grenadines, also are parties to Annex VI.
Close to the decided US Caribbean ECA covering Puerto Rico and the US Virgin Islands are the Annex VI parties Saint Kitts and Nevis and Antigua and Barbuda as well as the British Virgin Islands and British overseas territories like Anguilla and French and Dutch Territories, such as Saint Martin. Cooperation and possible joint application for ECA designation in this region may also be a possible scenario that would enable implementation of a relatively large and continuous Caribbean ECA.

In order to achieve a full ECA designation for the entire WCR it is, however, necessary that also the large island nations like Cuba, Dominican Republic and Haiti also actively support an ECA designation. Such a full WCR ECA would include large sea areas in the Caribbean Sea and the Gulf of Mexico and it would be larger and include more countries than the existing continuous Baltic Sea and the North Sea and English Channel SECAs.

The possible expansion options described above may be considered as plausible steps in a long-term development towards stricter global emission regulations for the shipping industry. In such a time frame it is also most likely that a number of new ECAs also will be implemented in other parts of the world and the global world fleet will have to adapt to the strict emission regulations and designed or modified for compliance.

### 3.5 Technically feasible compliance strategies and options

Heavy Fuel Oil, HFO is the dominating fuel type used for ship propulsion in the maritime industry. It is a residual fuel produced from refining of crude oil and generally has a sulphur content of about 3.5% by weight. This is 35 times more than the maximum allowed in the SECA in 2015. Marine Gas Oil, MGO, offers a fuel option for diesel-powered ships with sulphur content compliant to the SECA requirements. The price of MGO is, however, significantly higher than of HFO.

There are three main different compliance strategies identified and they are either based on a change of fuel type or the use of devices that purifies the exhaust emission after the combustion in engine.

- Change of fuel from HFO to LNG
- Change of fuel from HFO to MGO
- Continued use of HFO and installation of sulphur abatement technique/scrubber

Under MARPOL Annex VI, vessels may comply with the more stringent sulphur oxide (SO\textsubscript{x}) and particulate matter (PM) emission regulations by using fuel oil with sulphur content below the prescribed limit of 1.0% and later 0.1% or by utilising a “fitting, material, appliance or apparatus” such as exhaust gas cleaning technology. “Other procedures, alternative fuel oils or compliance
methods” such as the on board blending of fuel or the use of dual fuel (gas/liquid) may also be used, but such methods are subject to the approval of the vessel’s Flag Administration and must be “at least as effective in terms of emission reductions as that required by this Annex”.

Some basic aspects for comparison of the three main compliance strategies are listed in the table below with a ranking of pros and cons with regard to environmental performance and economic viability.

Table 5. Comparing the alternatives; LNG, MGO and HFO.

<table>
<thead>
<tr>
<th>Alternative</th>
<th>SO₂</th>
<th>NOₓ</th>
<th>PM</th>
<th>CO₂</th>
<th>Cargo capacity</th>
<th>Capital Investments</th>
<th>Operating costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>LNG</td>
<td>++</td>
<td>++</td>
<td>++</td>
<td>+</td>
<td>Restricted</td>
<td>Very high</td>
<td>Low</td>
</tr>
<tr>
<td>MGO</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not restricted</td>
<td>Low</td>
<td>Very high</td>
</tr>
<tr>
<td>HFO/Scrubber</td>
<td>+</td>
<td>--</td>
<td>+</td>
<td>-</td>
<td>Slightly restricted</td>
<td>High</td>
<td>Medium*</td>
</tr>
</tbody>
</table>

++ very good, + good, – bad, -- very bad

a) Fuel costs remain basically unchanged, a small increase (1 – 2%) can be expected. Cost for scrubber maintenance and waste handling are yet unknown but may add to the total operating costs.

3.5.1 Gas engine options

There are basically two different concepts for using LNG as fuel in ship engines. Dual fuel engines are able to run either on liquid fuel oil or gaseous fuel and can be designed either as four stroke engines or as two stroke engines. Single gas fuel engines are specifically designed for operation with gaseous fuel only.

Four stroke Otto-cycle Dual fuel engines

Dual fuel engines were developed for and are used in LNG carriers in order to utilize the boil off gas. LNG can be used as fuel when the ship is operating in a SECA and ordinary fuel oil can be used outside SECA and in regions where gaseous fuel is not available. The working principle for LNG operation is based on the Otto cycle and the Diesel cycle is the basis for operation on fuel oils. The ignition source during LNG operation is a small amount of fuel oil, which is injected and ignited by the compression heat and the burning oil ignites the gas injected at low pressure.

Two stroke dual fuel diesel engines

The two-stroke dual fuel technology applies high-pressure gas injection (about 300 bar) together with pilot diesel oil. The fuel oil ignites first and the gas is ignited by the burning fuel oil. This engine can run on fuel oil only or on a mixture of gas and fuel oil.
**Single fuel gas engines**
The Otto/Miller cycle is the basis for single fuel gas engines. Lean burn technology is applied in a spark ignition cycle. Instead of a pilot fuel, a rich gas/air mix in a pre-combustion chamber is ignited, which forms a strong ignition source for the very lean mixture in the cylinder. This technology ensures high efficiency and low emissions but does not allow the flexibility to also run on fuel oil.

**3.5.2 Liquefied Natural Gas, LNG as fuel on board**
LNG is expected to be available at competitive cost. It is a clean and non-sulphurous fuel. The gas engines have been proven to be reliable. Exhaust emissions such as SO\textsubscript{X} and PM are negligible. NO\textsubscript{X} can be reduced by approximately 80–90% for Otto cycle processes, and 10–20% for Diesel cycle processes. LNG contains less carbon than fuel oils, reducing the CO\textsubscript{2} emissions in a “from tank to propeller” perspective.

Methane is an aggressive greenhouse gas and an environmental drawback for Otto cycle process operation is the methane slip in the dual fuel engine. Technical development is progressing in this area and engine manufacturers claim that the methane slip issue will be reduced significantly in the future. If including the CO\textsubscript{2} and the methane emissions, LNG can still potentially give a reduction in greenhouse gases emissions compared to fuel oils (Danish EPA 2010). Methane slip is however not a problem for engines operating on gas in the Diesel cycle.

LNG is natural gas stored as liquid at -162°C. The predominant component is methane with some ethane and small amounts of heavy hydrocarbons. Natural gas is a fossil fuel but it can be mixed with or replaced entirely by biogas, which also consists mainly of methane. Due to the low temperature, LNG has to be stored in cryogenic tanks. LNG has a high auto ignition temperature and therefore needs an additional ignition source, i.e. a pilot fuel, to ignite in combustion engines. Natural gas is lighter than air and has a narrow flammability interval.

LNG storage tanks require more space than traditional fuel oil tanks. This may reduce the cargo capacity, depending on type of vessel, type of fuel tank and potential of adequate location of the LNG tanks on-board.

The reduction of cargo space was examined within a GL study of the retrofit from HFO to LNG of the CV Neptun 1 200 design. Due to the LNG tank dimensions the container capacity of 1 284 TEU would be reduced by 48 TEU to 1 236 TEU\textsuperscript{6}.

Another example is shown by the first retrofit worldwide of a seagoing vessel, the tanker Bit Viking. The two LNG fuel tanks with a capacity of each 500m\textsuperscript{3} LNG are located on deck with no actual reduction of the cargo capacity. Due to

\textsuperscript{6} GL Scholz & Plump
the properties of LNG and gaseous natural gas, special requirements for the tanks and the fuel supply system need to be fulfilled.

3.5.3 Marine Gas Oil, MGO - Low sulphur diesel oil

Heavy Fuel Oil (HFO) or residual fuel oil is the heaviest marine fuel with respect to viscosity and sulphur content. Distillate fuels can be further divided into two categories, Marine Gas Oil (MGO) and Marine Diesel Oil (MDO). When residual fuel oil is blended with distillates, the blend is called Intermediate Fuel Oil (IFO).

It is theoretically possible to desulphurize HFO and produce HFO with 0.1% sulphur but in practice the most viable solution is to use MGO when a new fuel oil quality is chosen for compliance to SECA regulations. If the refineries will get a surplus of HFO it is likely that it will be refined by cracking processes, etc. to MGO.

MGO with 0.1% sulphur or less is readily available and has similar properties as diesel fuel used for high-speed diesel engines. The viscosity of MGO is lower than for MDO or HFO and for operation in two stroke marine diesel engines the fuel may need to be cooled to stay at specified engine design viscosity levels to prevent fuel pump wear, etc. Swapping from heated HFO to cooled MGO when entering a SECA needs to be done with due care to the actual fuel viscosity in particular for conventional engines without common rail systems. For long-term shift of fuel, it may also be necessary to exchange the lubrication oil for another quality.

In addition to reduced SO\textsubscript{x} emissions, particulate matter in exhaust gases is also reduced. NO\textsubscript{X} and greenhouse gases will remain at the same level as when using HFO. In order to comply with NO\textsubscript{X} Tier III, SCR or EGR are needed when operating on MGO. MGO does not require extra volume for storage tanks, and retrofitting of the engine is not required and hence no or only minor investments are needed for a switch to MGO operation. The fuel price for MGO is, however, significantly higher than for HFO.

3.5.4 Other Alternatives

Beside low-sulphur fuel oils, exhaust gas cleaning and LNG there are other alternative fuels, which are considered within the current development of the IGF Code. These fuels are e.g. LPG, DME/methanol, ethanol and hydrogen and will be allowed after ratification of the IGF Code in 2014.

3.5.5 Exhaust Gas Scrubbers

Abatement technologies, or ‘end of pipe’ solutions, include primarily use of scrubbers for the SO\textsubscript{x} and PM removal in combination with either Selective Catalytic Reduction (SCR) or Exhaust Gas Recirculation (EGR) for NO\textsubscript{x} cleaning. This combination is considered to have good prospects to fulfil the
requirements in SECA 2015 and ECA Tier III. It is possible that Tier III NO\textsubscript{x} requirements may be fulfilled even without applying SCR technique.

The main advantage of the scrubber technology is that readily available high sulphur HFO can be used, thereby keeping the fuel costs down. The infrastructure, hence the availability, of HFO is also good and the ship owners do not need to retrofit or replace the engines. Scrubber tests show that the sulphur emissions are reduced to almost zero and a significant reduction of PM in the exhaust gases is also achieved.

In addition to the necessary capital investment in scrubber devices on board, the waste produced by operating the scrubber need to be handled and discharged in port. At present there is no infrastructure established in ports for reception and disposal of scrubber waste. Such infrastructure may be established in parallel with other established reception routines and facilities used for reception of ship generated sludge, garbage and sewage. A fee system for reception of scrubber waste must be designed not create disincentives for safe delivery ashore by undue delay or costs.

Different technical solutions are available for scrubber technique and cost, onboard space requirement, waste quantities produced, etc. vary. For the scrubber compliance strategy, high scrubber availability is important.

### 3.6 Economically viable compliance strategies

The strategy to switch from HFO to MGO operation will increase the operational costs significantly, essentially in proportion to the price difference between HFO and MGO but it is not associated with any major reconstruction efforts or investment costs on board. The existing bunker supply infrastructure generally offers both HFO and MGO to their ship clients and is not expected to undergo any dramatic modifications except for the relation between delivered HFO and MGO quantities.

Continued use of HFO and installation of scrubber is associated with significant investment costs for scrubber and related equipment but operational cost will only be marginally affected by slightly increased fuel consumption and by consumption of process chemicals. The investment costs will differ between retrofit installations and new build projects.

For LNG operation, ordinary diesel powered vessels will require major reconstruction works including engine and LNG tanks and new builds will also be associated with higher costs if equipped with duel fuel or LNG engines and LNG fuel tanks. A most important factor for economic viability of the LNG fuelled ship is the price of LNG bunker for the ship owner (FOB) and its relation to FOB price for conventional fuel oils.
3.6.1 **Investment cost for the different compliance strategies**

The investment cost differs for the different compliance strategies, for retrofit or new builds and is partly proportional to the size of the propulsion plant. The table below has been prepared by compilation of price information from different engine manufacturers and shipyards and a detailed version was presented in the DMA study, appendix 3 (DMA 2012).

*Table 6. Indicative investment costs for optional compliance strategies.*

<table>
<thead>
<tr>
<th>Compliance strategy</th>
<th>Retrofit</th>
<th>New builds</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGO – engine conversion, SCR and EGR</td>
<td>180 000 USD + 75 USD/kW</td>
<td>140 000 USD + 63 USD/kW</td>
</tr>
<tr>
<td>HFO and scrubber – scrubber and SCR</td>
<td>600 USD/kW</td>
<td>2 200 USD/kW*</td>
</tr>
<tr>
<td>LNG four stroke dual fuel – LNG tanks etc.</td>
<td>800 USD/kW</td>
<td>1 600 USD/kW*</td>
</tr>
<tr>
<td>LNG two stroke high pressure dual fuel – tanks etc.</td>
<td>700 USD/kW</td>
<td>1 500 USD/kW*</td>
</tr>
<tr>
<td>LNG four stroke spark ignition – LNG tanks etc.</td>
<td>800 USD/kW</td>
<td>1 600 USD/kW*</td>
</tr>
</tbody>
</table>

* including engine, generators, etc.

When a ship operator is going to choose compliance strategy it is essentially a matter of balancing high investment costs for retrofitting of new equipment or in new build projects versus long-term operational costs depending on the type of fuel selected. In addition to these basic calculations there may be other factors that also need to be considered, for example bunkering LNG may take longer than bunkering fuel oils, a need for extra education of the staff, requirements for special licences and certificates. Extra costs may arise due to loss of available cargo space due the need for extra space for LNG-tanks. This may be particularly relevant for container ships but less important for other ship types like tankers.

For the scrubber compliance strategy, high scrubber availability is important as well as a port infrastructure for efficient reception of scrubber waste.

MGO is considered to be an attractive “wait-and-see” strategy with low investment costs for actors who believe that LNG may have a breakthrough sometime in the mid-term future. However, if many actors use that strategy the MGO demand, and hence price, may increase further.

3.6.2 **Operational costs – fuel price and price predictions**

The energy content and densities vary between different fuel oil qualities and depends on the specific composition of the LNG. It is therefore important to take into account these differences when price comparisons are made for various fuel types and compliance strategy costs. For the price comparisons discussed below, the following figures in SI-units are considered representative.
and used as typical values for correction of comparisons.

Table 7: Representative physical and energy characteristics of optional ship fuels.

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Density kg/m³</th>
<th>Specific Energy GJ/tonne</th>
<th>Correction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGO</td>
<td>850</td>
<td>46</td>
<td>1.07</td>
</tr>
<tr>
<td>HFO</td>
<td>990</td>
<td>43</td>
<td>1</td>
</tr>
<tr>
<td>LNG</td>
<td>450</td>
<td>54</td>
<td>1.26</td>
</tr>
</tbody>
</table>

The price for HFO and MGO as well as the LNG price vary a lot and have traditionally been relatively well correlated to the crude oil market price. The price characteristics also differ from different areas in the world, for example the bunker fuel and LNG prices differ between Europe and the WCR. From the ship owners’ perspective it is the relative relation between the optional fuels (MGO or LNG) and the traditional HFO that is important. The figure below shows the relations LNG/HFO and MGO/HFO in Europe over a period of eight years. The curves are corrected to represent the price per unit of specific energy relation and show a magnitude of 50% higher price for MGO and about 40% lower price for LNG compared with HFO. In the US Gulf area, the LNG/HFO ratio is significantly lower.

![Energy price relations for MGO and LNG vs HFO](image_url)

Figure 39. MGO price relative to HFO and LNG price relative to HFO. Prices are at European import Hub and based on prices per GJ. Source: AF analysis, 2012 (DMA 2012).
Due to the expansion and shale gas production during recent years in the USA, today’s gas price in North America is significantly lower than in other parts of the world. The Henry Hub Index reflects the gas price in the US market and the figure below illustrates how the gas price differences have increased over the last year and how the JKM index representing the Japanese market increased significantly after the Fukushima power plant disaster in March 2011. The red NBP index is representative for the European market and is indicated at an order of 2–4 times higher than the Henry Hub figures.

The low Henry Hub gas price will of course also influence the market price for LNG as ship fuel (FOB) in the American Gulf ports and in the entire WCR when it is introduced as a fuel option. Compared with the European situation, where feasibility studies for introduction of LNG as ship fuel also have been conducted, this price relation clearly indicates that the attractiveness of swapping to LNG with respect to the operational cost is higher in the WCR than in Northern Europe.

If ships equipped with LNG dual fuel engines may choose between HFO or LNG operation outside SECAs, and the LNG/HFO energy based price relation is lower than 1, LNG will turn out to be the economically best option also when operating outside SECAs.

The production of shale gas is expected to increase in the USA and even if the export of gas will increase from the US it is anticipated that the gas price at the US market will stay at a low level. It is also considered likely that the future gas price will be less correlated to the crude oil price as it traditionally has been.

Figure 40 Time history plot of LNG price comparison (USD/MMBtu) between USA (Henry Hub), Europe (NBP) and Japan (JKM). Diagram excerpted from Medlock 2012 based on data from Platts, US EIA and Medlock.
4 INFRASTRUCTURE

In addition to USA there are five main natural gas-producing countries in the WCR but only one LNG producer. The natural gas production capacity has increased significantly in Trinidad and Tobago and in Mexico over the past decade. In Venezuela, the production has decreased while Colombia and Cuba show a moderate increase of their production capacity. The situation is illustrated graphically in the figure below.

![Dry natural gas production by WCR countries (excl US) and year](image)

*Figure 41. Development of dry natural gas production in the WCR countries (excluding USA) (BP 2012).*

The produced natural gas is traded between different WCR countries and exported as LNG from liquefaction plants and LNG tanker terminals to LNG import terminals with regasification plants and, in the future possibly to facilities for distribution of LNG to land based consumers and to ships. The figure below shows that Trinidad and Tobago is the main exporter and that USA the main importer of LNG, though it also has a minor export volume in 2011.
4.1 LNG Infrastructure in the Caribbean

The LNG market is expected to grow in the Caribbean region due to several factors that make it a more attractive energy fuel compared to oil-based fuels. Traditional oil-based fuels account for 95% of the Caribbean energy (Battistini, 2011). The current most widely used fuel product in the region is HFO.

The Caribbean countries are vulnerable to oil price volatility because of their high dependence of oil to generate most of their electricity in addition to vehicle fuel. Some islands are discussing a shift from oil to natural gas as a response to recent oil prices (Kitasei & Adkins, 2011). Reducing the dependence on oil is considered urgent to stimulate economic development, attract industries and improve life quality (Pereira, 2012). As long as the price differential between LNG and HFO remains large, USD 0.04/kWh (USD 12.10/MMBtu) for HFO and USD 0.02/kWh (USD 4.88/MMBtu) for natural gas (in 2010), it is likely that many Caribbean nations will try to replace oil by natural gas (Kitasei, 2011).

Currently there are on-going studies on the potential for development based around domestic renewable energy and energy efficiency resources in the Dominican Republic, Jamaica and Haiti (Kitasei & Adkins, 2011). LNG is a good alternative, even if it most likely would have to be imported. While LNG may be an appealing alternative, significant capital investment are required, both for construction of import terminals and infrastructure.

Natural gas consumption is increasing in the area, as is the interest in and potential of small-scale LNG projects in the region. Since LNG transports are no
longer restricted to large vessels, due to new technologies, small scale LNG is preferred over large-scale projects (Battistini, 2010).

Puerto Rico began importing LNG in 2000, and the Dominican Republic has a LNG regasification terminal supplying a gas-fired power plant (Andres). Jamaica currently has no LNG import facilities, but the government has shown interest in building one and has already reached an advanced stage in the development of an LNG project. Barbados, together with Jamaica, is also on the way to make a switch for natural gas as their premier fuel source. Barbados plans to start importing natural gas via pipeline from Trinidad and Tobago from 2015 (Caribbean360, 2012).

LNG in the Caribbean is likely to be supplied by imports from Trinidad and Tobago, the largest gas producer, and today also the only existing liquefaction LNG plant and export terminal in the Southern Caribbean region. It is the 11th largest natural gas exporting country in the world as well as the largest exporter of LNG to the US. In 2011, Trinidad and Tobago produced 40.7 billion m$^3$ of natural gas (BP 2012).

Several LNG liquefaction terminal projects and LNG regasification terminals have been proposed, or are under construction in the region for example in the Bahamas, Venezuela, El Salvador and Honduras (CEC, 2010). Around 30 floating regasification projects are planned worldwide; Asia and the Middle East account for 16 and South America six. Europe and Africa make up the majority of the remaining FSRU demand.
4.1.1 Overview of planned and existing LNG facilities in the WCR

The map below indicating the locations of existing and planned LNG facilities is compiled from various sources and more specific data referring to the indicated spots on the map is given for each country in the text sections below.

Figure 43. Overview of planned and existing LNG facilities in the WCR.

The table below summarises the available data of the facilities and plants indicated in the map above.
Table 8. Existing and planned LNG facilities and plants in the WCR.

<table>
<thead>
<tr>
<th>Country</th>
<th>Type of LNG plant or facility</th>
<th>Status</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aruba</td>
<td>FSRU</td>
<td>Planned</td>
<td>Send out capacity of 0.7 – 3.0 million m$^3$ gas per day</td>
</tr>
<tr>
<td>Bahamas</td>
<td>Import and regasification</td>
<td>Proposed</td>
<td>Import from Trinidad. Containerised import from USA</td>
</tr>
<tr>
<td>Barbados</td>
<td>Subsea gas import pipeline</td>
<td>Planned</td>
<td>300 km pipeline. 30 million m$^3$ natural gas per day.</td>
</tr>
<tr>
<td>Colombia</td>
<td>FLRSU (bi-directional plant)</td>
<td>Planned</td>
<td>Liquefaction capacity 500 000 tonnes of LNG per annum</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>Regasification plant</td>
<td>Proposed</td>
<td>Not specified</td>
</tr>
<tr>
<td>Cuba</td>
<td>Import and regasification</td>
<td>Planned</td>
<td>Import from Venezuela. 1 million tonnes LNG per year.</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>Andres import – regasification San Pedro import/regasification</td>
<td>Existing</td>
<td>0.9 billion m$^3$ of natural gas imported in 2011</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planned</td>
<td>Send out capacity of 7 – 20 million m$^3$ gas per day.</td>
</tr>
<tr>
<td>Guatemala</td>
<td>200 MW gas fired power plant</td>
<td>Proposed</td>
<td>Not specified</td>
</tr>
<tr>
<td>Honduras</td>
<td>LNG import for power plant</td>
<td>Proposed</td>
<td>Not specified</td>
</tr>
<tr>
<td>Jamaica</td>
<td>FSRU</td>
<td>Planned</td>
<td>Not specified</td>
</tr>
<tr>
<td>Martinique &amp; Guadeloupe</td>
<td>FSRU</td>
<td>Planned</td>
<td>Regasification of 400 000 tonnes of LNG per year</td>
</tr>
<tr>
<td>Mexico</td>
<td>Altamira, Import-regasification</td>
<td>Existing</td>
<td>Can be expanded to 10 billion m$^3$ of natural gas per annum</td>
</tr>
<tr>
<td>Panama</td>
<td>Import and regasification</td>
<td>Planned</td>
<td>Initial send out capacity 40 million m$^3$ natural gas per day</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Guayanilla Bay FSRU Aguirre Gas Port FSRU</td>
<td>Existing</td>
<td>Send out capacity of 1.200 million m$^3$ per annum</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planned</td>
<td>Send out capacity of 6 500 million m$^3$ per annum</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>Atlantic LNG liquefaction plant and export terminal</td>
<td>Existing</td>
<td>LNG export corresponds to 19 billion m$^3$ of natural gas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planned</td>
<td>A fifth liquefaction train is planned</td>
</tr>
<tr>
<td>USA</td>
<td>12 LNG import facilities 3 LNG export terminal in WCR</td>
<td>Existing</td>
<td>Import 11.6 billion m$^3$ natural gas in the form of LNG 2010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Approved</td>
<td>Export 3 million m$^3$ LNG (1.1 Bcf) per day in 2016</td>
</tr>
<tr>
<td>Venezuela</td>
<td>LNG liquefaction plants, 3 sites</td>
<td>Proposed</td>
<td>LNG production, 2 800 billion m$^3$ natural gas per year</td>
</tr>
</tbody>
</table>

4.1.2 Aruba

US Valero Energy and the government of Aruba are investigating possibilities with LNG with the intention of a joint venture between Valero, the Water & Energy Company WEB, and the Dutch Gasunie in which the refinery and WEB are to use gas instead of petroleum for their production while at the same time setting up a regasification terminal for supply (Amigoe, 2011b). An FSRU unit is considered the best solution in the short term, although an LNG import terminal is examined as an option. Due to possible offshore gas reserves, a temporary floating solution is a better option meanwhile (Meredith, R., 2012). In the long term a land-based LNG terminal or a gas pipeline from the South American coast (Venezuela) may be a replacement for the FSRU (Martin, 2010).
The send-out capacity of the FSRU will be 700,000 m³ natural gas (25 million cf) per day to solely supply the power plant. This could be increased to 3 million m³ natural gas (100 million cf) per day if the refinery stays in operation (Meredith, 2012c).

Two Dutch companies, Anthony Veder and Gasunie, are engaged in developing a business case for a small-scale FSRU, cost estimated and the best location, together with the government controlled Utilities Aruba. Gasunie will be responsible for the terminal infrastructure and Anthony Veder for LNG transports, should the government decide to go ahead with the project (Meredith, 2012c).

4.1.3 Bahamas

The Government of Bahamas is interested in introducing LNG and CNG as an alternative energy source (Smith, 2012). Three companies have long been interested in establishing LNG plants: AES Corporation, Tractebel and El Paso. Proposals to build LNG regasification terminals in the Bahamas have been investigated aiming to send natural gas imported from Trinidad to Florida via an undersea pipeline, diverting some of the gas to power plants in the Bahamas. The regasification terminals were proposed on either Ocean Cay (near Bimini) or Grand Bahama.

A Florida licensed firm has investigated the possibilities for export of smaller quantities of LNG to the Bahamas and other countries in the region in containers. The gas would be exported in special cryogenic tanks fitted inside 40-foot shipping containers (Smith, L., 2012).

4.1.4 Barbados

In Barbados plans have been presented for supply of natural gas from Trinidad and Tobago via construction of a pipeline. Originally the project was planned to start in 2013 to be completed by 2015. The pipeline project will involve a 300 km long pipeline running from the Cove Point Estate in Tobago to Barbados, supplying the Barbados Light and Power Company, the only electrical utility on the island, with 30 million m³ natural gas per day. US-based Beowulf Energy LLC and First Reserve Energy Infrastructure Fund will construct the pipeline (Caribbean360, 2012b).

4.1.5 Colombia

On the northern coast of Colombia, Exmar plans an export terminal together with Pacific Rubiales. Construction of a barge-based, bi-directional floating liquefaction, regasification and storage unit (FLRSU) has already started at a shipyard in China, the first of its kind. The South American operator Pacific Rubiales is expecting an environmental license for an 88 km long pipeline to transport gas from the onshore La Creciente field to planned location of the
FLRSU (Martin, 2012e). The project will have a 14 000 m$^3$ LNG onboard storage and a 140 000 m$^3$ LNG carrier will be moored alongside to be used as a floating storage unit. The project is set to be in operation by the end of 2014 (Meredith, 2012d). Exmar will build, operate and maintain the FLSRU. It will be fitted with type-C storage tanks and can be scaled up to 30 000 to 40 000 m$^3$. The whole floating terminal will be able to supply vessels of 150 000 to 160 000 m$^3$. Liquefaction capacity is approximated to around 500 000 tonnes of LNG per annum. Two small LNG carriers will be used to supply Caribbean customers that will use barge-based regasification for their imports (Hine, 2012d).

### 4.1.6 Costa Rica

Diesel fuelled power generation, public transports and freight are to be replaced with natural gas in Costa Rica and the results from an economic and technical feasibility study is awaited. In order to use natural gas a gasification plant is required. According to preliminary figures, a gasification plant would cost about USD 75 million and the funding remains to be defined (Centralamericadata, 2012c).

### 4.1.7 Cuba

Cuba is about to introduce LNG in the country’s energy mix. All natural gas production in the country is oil-associated. Approximately 1.2 million m$^3$ of associated natural gas is produced per year (2010). Associated natural gas production is being used as fuel for onsite power generating plants of 400 MW total capacity. An LNG re-gasification facility to receive Venezuelan-sourced LNG is currently being planned for the southern coast port city of Cienfuegos. Two regasification trains of 1 million tonnes have been planned for 2012 at a cost of over USD 400 million.

The Carlos Manuel de Cespedes electric power plant in Cienfuegos is in the middle of an upgrading process that allows the burning of natural gas. Natural gas will provide fuel to the refinery as well as hydrogen for the upgrading units scheduled to be completed by 2013. Natural gas will also be used as a feedstock for a planned USD 1.3 billion petrochemical (Piñón, 2010).

### 4.1.8 Dominican Republic

The Dominican Republic was the second island in the Caribbean to establish an LNG import terminal and a second terminal is now planned.

**Andres terminal**

The Andres terminal is a combined 319 MW gas-fired power plant and import terminal, built according to US standards. It was constructed in 2003 and is located 35 km east of the capital Santo Domingo. Storage capacity is 160 000 m$^3$ LNG (A Barrel Full, 2012).
The Andres import terminal is designed to receive LNG from ships with capacities ranging from 35 000 to 145 000 m$^3$. The regasification terminal is primarily supplied with LNG from Atlantic LNG’s train 4 (Meredith, 2012c). Since 2008 gas has been offered for industrial customers to be used instead of diesel in boilers and other factory processes. As a result many factories today get LNG delivered by truck from the terminal through distribution companies. In addition to industrial use, natural gas has also been used as transport fuel (Suvusari, S. 2011). LNG demand in the Dominican Republic has risen 40% between 2009 and 2012 (Meredith, 2011). Imports through the terminal are expected to continue to increase due to customers forecast consumption and contract negotiations, however, current infrastructure is assumed sufficient to supply the anticipated demand (LNG Unlimited, 2011).

**San Pedro de Macorís**

AES has been contemplating building another 160 000 m$^3$ regasification terminal to enable it to supply gas onwards to other parts of the Caribbean. Foster Wheeler’s subsidiary of its Global Engineering and Construction Group was awarded the basic design and front-end engineering design (FEED) contract by Complejo GNL del Este$^7$ for a new LNG receiving terminal and jetty. The terminal will be located in San Pedro de Macorís and is designed to handle a send-out capacity of 7 million m$^3$ natural gas per day (249 MMcfd), with future expansion possibilities up to 20 million m$^3$ per day (700 MMcfd). The FEED is expected to be completed in September 2012 (Hine, 2012).

San Pedro de Macorís is also the site of a floating terminal project, a result of a joint venture between BW Gas and InterEnergy Holdings, expected to be finished in 2014 (Dominican Today, 2012). The project is not affiliated with the land-based LNG terminal project. BW Gas has knowledge regarding business of transportation and storage of natural gas while InterEnergy has experience in the country’s energy sector (Dominican Republic Live, 2012).

BW Gas is considering three different solutions for a floating LNG import terminal and the technology for the job has yet to be determined.

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$^7$ Complejo GNL del Este is a consortium of Dominican and Colombian companies that participate in the energy sector of those countries.
4.1.9 Guatemala

Natural gas is not used in Guatemala but interest is growing for possibilities of its use in the country. Necessary infrastructure is needed to allow optimal storage tanks as well as pipelines. A tender is scheduled to be released in the last quarter of 2012 for the installation of a 200 MW power plant to generate electricity from natural gas. The start of operations could be in 2015. Studies have indicated Puerto Barrios as a suitable location for the installation of the natural gas power plant (Centralamericadata, 2012 and 2012b).

4.1.10 Honduras

A multi-disciplined marine investigation has been performed in the waters off Puerto Cortes in the Gulf of Honduras, including hydrographical, geophysical, oceanographic, meteorological and biological aspects. The aim of the investigation was to collect scientific data in support of the design of a proposed power plant, owned by AES Honduras, and marine terminal expansion on the west shore of the Cortes peninsula. The power plant will provide service to much of Honduras with transmission into El Salvador as well. The plant requires construction of cooling water intake and discharge pipelines, coastal protection structures, and a pier facility for offloading LNG that will be used to power the plant (Ocean Surveys, 2005).

4.1.11 Jamaica

Jamaica has been exploring the potential for importing LNG since 2001. In 2009 The Petroleum Corporation of Jamaica requested proposals for a FSRU and in 2010 a consortium led by Exmar was selected as a preferred bidder to
finance, build, own and operate the terminal. The project was however retendered (Meredith, 2011b). Part of the delay for the LNG project is a result from uncertainties over gas supplies (The Gleaner, 2012).

The FSRU terminal is currently set to supply three main customers. The Jamaican Public Service Company (JPS) is the country’s major power utility, demanding 360 MW. The second is Jamaica Energy Partners (JEP), an independent power producer requiring conversion of existing 125 MW Power Barges, and last, Jamalco, a bauxite mining and aluminium refining company.

The South Korean company Samsung was chosen as the preferred bidder in July 2012 to develop Jamaica’s first FSRU unit for LNG, including necessary infrastructure (The Gleaner, 2012b).

The Jamaica Gas Trust (JGT) was established to be the legal counterpart, a contractual focal point of the LNG and will act as a sole LNG purchaser for the project. It will be financed with USD 100 million and managed by the private sector (The Gleaner, 2012). Its objective is to execute the major commercial agreements, including LNG sales and purchase agreements, terminal and transportation agreements (MSTEM, 2012). The single stage RFP for an FSRU construction in the Port Esquivel area was announced in June 2012 and the target start date is approximated to 2014 (GoJ, 2012b).

4.1.12 Martinique and Guadeloupe

French EDF (Electricité de France) is investigating options to supply their power generation plants in Martinique and Guadeloupe with natural gas. A team building with Gasfin Development resulted in the launch of a project to supply 400,000 tonnes per annum to two Caribbean power plants. FEED studies as well as permitting of import infrastructure are on the way, including gas delivery infrastructure to support transportation, storage and regasification. A newly built mid-scale LNG carrier and two purpose-built floating storage and regasification units are to be developed for the project (Meredith, 2012d). LNG sourced from one of the regional LNG terminals will be delivered by the LNG carrier to the FSRUs moored in the vicinity of the power plants. The LNG will be stored and regasified on the FSRUs, and then sent to the respective power generation facilities via a short subsea pipeline (TGE Marine, 2011).

4.1.13 Mexico

Mexico has long relied on natural gas as a feedstock for its petrochemical manufacturing facilities. For home heating and cooking LPG is used. There are no LNG liquefaction plants in Mexico, and only one regasification terminal on the Gulf Coast, Terminal de LNG de Altamira (CEC, 2010c). Altamira could be expanded to 10 billion m³ per annum, with the addition of a third storage tank (Meredith, 2011c).
Several additional LNG regasification terminal projects are either under construction or are proposed.

4.1.14 Panama

Introduction of natural gas is negotiated between Repsol (Spain) and Panama’s CNG Clean Energy. First, construction of facilities for regasification of LNG and a storage vessel to be moored in Bahía de las Minas, on the Caribbean coast, is required. The location is very near the complex of power plants that have been operating in the area with petroleum and coal.

The regasification terminal is estimated to cost USD 250 million in the period 2011 to 2014 and operations are planned from the first quarter of 2014 providing an initial volume of 40 million m$^3$ natural gas per day (Centralamericadata, 2011).

4.1.15 Puerto Rico

Guayanilla Bay

An existing LNG import facility is located at Guayanilla Bay, Peñuelas. The facility began operations in 2000 and the gas powers a 461 Megawatt cogeneration plant, which sells electricity to Puerto Rico Electric Power Company (accounting for 20% of the generated electricity on the island). The facility consists of a marine terminal with a 550 meter pier for unloading LNG 160 000 m$^3$ LNG carriers and regasification plants with a send out capacity of 1200 Bm$^3$ natural gas (33,9Bcf) per year.

In addition to the FSRU there are plans to build pipelines. The Vía Verde natural gas pipelines would run in a south-north direction from the city of Peñuelas, existing LNG import terminal, to Arecibo, then east to San Juan, in total 145 km (Periera, 2012). The planned pipeline project will supply the north coast power plants. The Puerto Rico Government, however, are focusing on the south coast project because the FSRU is assumed to get a quicker federal approval and it could supply sufficient natural gas to partially supply the fuel needed to convert the power plants on the north coast.

The establishment of a “satellite” facility in San Juan to receive shipments of LNG from the south is an alternative. The FSRU would have enough excess capacity to satisfy the demand. It is possible to ship 2.5 million m$^3$ natural gas per day by barges, sufficient to supply units 5 and 6 of the San Juan power plant (Marino, 2012).

Aguirre GasPort

Development and permitting of an FSRU is in an executed agreement between US-based Excelerate Energy and PREPA, the Puerto Rico Electric Power Authority. The Aguirre GasPort terminal is planned 6.5 km off the southern
coast of Puerto Rico, near the towns of Salinas and Guayama, and will provide fuel to the existing Central Aguirre power plant. The power plant has already converted 600 MW of possible 1500 to utilize natural gas and will convert the total capacity once the FSRU project is completed.

Aguirre GasPort will offer year-round service and supply. It will be the seventh FSRU delivered by Excelerate Energy worldwide, thus using proven technology with facilities to receive, temporarily store, vaporize, and deliver up to 18 million m$^3$ natural gas per day. LNG will be delivered to the project via LNG carriers, unloaded and stored within a permanently docked FSRU unit and delivered directly to the Aguirre Plant by a subsea pipeline.

Construction of the 150 900 m$^3$ FSRU is expected to start in 2013 and planned to be in service in 2014 (A Barrel Full, 2011), however, authorisation is required from the FERC (Federal Energy Regulatory Commission) together with a full public environmental review and analysis under the National Environmental Policy Act. Capital costs for the floating terminal are in a range of USD173 million (Hine & Meredith, 2012). The Aguirre Offshore GasPort will consist of two main components: 1) an offshore marine LNG receiving facility consisting of an FSRU moored at an offshore berthing platform; and 2) a subsea pipeline connecting the offshore terminal to the Aguirre Plant.

The offshore terminal will be designed for long-term mooring of an FSRU and for receipt of LNG carriers ranging from 90 000 m$^3$ up to a Q-Flex2 size (216 000 m$^3$) LNG carriers.

LNG supply tenders for the FSRU are in progress. The required supply volumes have yet to be decided and depend on the supply contract (Hine & Meredith, 2012).

### 4.1.16 Trinidad and Tobago

Trinidad and Tobago holds the position of largest single LNG supplier to the US and sole provider of LNG to the only two Caribbean established markets, which are equipped to receive it – Puerto Rico and the Dominican Republic, although several nations are exploring FSRU as an option for import of LNG, (Renwick, 2011).

The Boston based company Cabot LNG initiated an LNG project in 1992, setting the ground for the Atlantic LNG project that exists today. Cabot was joined by Amoco, BG and the National Gas Company of Trinidad & Tobago (NGC) and, later on, by Repsol.

Sales contracts were signed with Cabot and with Enagas of Spain in 1995 for a total of 3 million tonnes per annum (mmtpa) of LNG. Construction started in 1996. The first cargo, bound for Boston, was loaded at the end of April 1999. Design work and sales negotiations for a two-train expansion were started in early 1999 and construction started in 2000.
In 2009 there were four active trains (Atlantic LNG, 2012), a rapid development by the standards of LNG projects and judged a success for all parties involved, compared to previous LNG projects (Shepard & Ball, 2004). It should be noted that Suez has recently announced the sale of their share in Train 1 to the China Investment Corporation (Algell).

![Figure 45. View of gas fields linked to Trinidad and Tobago.](image)

The Atlantic LNG plant in Point Fortin is the only current operating liquefaction facility in the Caribbean region. The plant, located on the southwest coast is supplied by different gas fields off the Trinidad and Tobago coast via dedicated pipelines.

The liquefaction plant uses two storage tanks (train 1), each with 105 000 m$^3$ LNG capacity and a 700 meter-long jetty, which are capable of accommodating LNG carriers with a capacity of up to 135 000 m$^3$. Trains 2 and 3 demanded an extra 160 000 m$^3$ storage tank and an extra loading arm to the jetty (Shepard & Ball, 2004). Train 4 began operations in December 2005 (MEEA, 2009). The total production capacity of the four trains is around 15 million tonnes of LNG per year (mmtpa); the capacity of Train 1 is 3 mmtpa and the capacity of each of Trains 2 and 3 is 3.3 mmtpa. Train 4 has a production capacity of 5.2 mmtpa. The total storage capacity of Atlantic LNG’s facility is 524 000 m$^3$.

A feasibility study for a fifth LNG train—Train X—was completed in 2008 but there has been no further progress to date largely due to concerns about gas reserve availability.

The Government is also reviewing several proposals for new LNG projects including one based on floating LNG technology and a second that proposes a mid-scale sized project targeting the Caribbean (Algell).
Most of the LNG now produced at the terminal is committed to specific markets in the US and elsewhere but there are excess cargos sold on a spot basis, which might be used in the Caribbean LNG trade (Renwick, 2011).

In 2011 the total natural gas export in form of LNG from Trinidad and Tobago was 18.88 billion m$^3$ of natural gas. Its distribution to receiving continents is illustrated in the figure below.

![Figure 46. Trinidad & Tobago LNG export destinations 2011 (Billion m$^3$ of natural gas) (BP statistics 2012)](image)

### 4.1.17 USA

Both the United States and Canada have used natural gas for over a hundred years, in application for industry as well as commercial, and to heat residential homes (CEE, 2004).

Natural gas production in the US has not met the demand for decades; most LNG terminals in the country are import terminals. Statistics have shown continued pipeline imports from Canada, deliveries of natural gas from Alaska and an increase of LNG imports. With recent years’ increasing shale gas extraction the situation has, however, changed and the need for import has decreased significantly.

Currently, there are many projects under consideration and re-evaluation for construction of onshore and offshore LNG receiving terminals in the US, some of which have received regulatory approval or are in the process of doing so. The majority, however, are awaiting regulatory approval or are about to enter the approval process. These processes control design, construction and eventual commercial viability of the new infrastructure.
Onshore facilities have been proposed in most coastal areas of the United States. However, the US Gulf Coast region is where most new onshore facilities have received approval from the Federal Energy Regulatory Commission (FERC), the responsible authority for onshore LNG import facilities. LNG import terminals have so far mostly been built on shore.

The option of developing offshore LNG import receiving and regasification capacity raises both opportunities and challenges. In some locations, an offshore receiving terminal may provide a better alternative due to the use of existing offshore facilities and pipelines, easier access for LNG tankers, and more flexibility to adapt to regulated exclusion zones. The drawbacks are distant access to natural gas distribution pipelines, lack of onshore services and in most instances, higher initial investments.

Along the US Gulf Coast, offshore LNG facilities can be developed to connect with available infrastructure, such as subsea pipeline networks, that are not used to their full capacity. The US Gulf Coast has a vast natural gas pipeline network that was built to serve shallow water exploration and production activity. Spare capacity is available in this infrastructure to carry natural gas to shore from offshore facilities. Offshore LNG facilities can also be placed to serve more than one market area and can provide convenient alternatives for LNG shipping (CEE, 2006).

Offshore LNG operations also face a different jurisdictional environment under the Deepwater Port Act (DWPA). The federal authority for the DWPA is the Maritime Administration (MARAD) with the US Coast Guard (USCG) (applicable for terminals in federal waters).

There are diverse approaches to offshore LNG receiving and regasification terminals. The LNG offshore import terminal design depends on many factors such as: the use of existing infrastructure (platforms, underwater pipelines); the constraints imposed by water depth (shallow versus deep); the need for local LNG storage facilities; and the opportunities for use of seawater to provide heat for the regasification process.

**LNG import facilities**

There are several operating LNG import terminals in the United States today: 12 U.S. facilities (and one facility in Puerto Rico) are capable of importing LNG of which eight are located within the WCR (CLNG, 2012):

- Elba Island, Georgia
- Lake Charles, Louisiana
- Gulf Gateway Energy Bridge, Gulf of Mexico
- Freeport, Texas
- Sabine, Louisiana
Imported LNG accounts for slightly more than 1% of natural gas used in the United States and are supplied via ocean tanker, the majority with LNG from Trinidad and Tobago, Qatar, and Algeria, with some shipments from Nigeria, Oman, Australia, Indonesia, and the United Arab Emirates.

According to the EIA (U.S. Energy Information Administration), USA imported 11.6 billion m$^3$ natural gas (0.41 Tcf) in the form of LNG in 2010. Due to increased domestic production, LNG imports are expected to decrease by an average annual rate of 4.1%, to levels of 4 billion m$^3$ natural gas (0.14 Tcf) by 2035 (NaturalGas.org, 2011). By 2016 the US is also expected to be a net exporter of LNG. Increase in LNG production is primarily a result of increased shale gas production due to new technologies. EIA expects the US to export around 3 million m$^3$ LNG (1.1 Bcf) per day, starting 2016. The EIA has also reported that offshore natural gas in the Gulf of Mexico stood at around 6.8 billion m$^3$ natural gas (2.4 Tcf) per year. Shale gas reserves in the US are estimated to 15.3 trillion m$^3$ (542 Tcf) (EIA, 2012).

**LNG export facilities**

Although outside the WCR, it is worth mentioning the only dedicated export facility in the US, located in Kenai, Alaska. Owned by ConocoPhillips/Marathon, the plant exports 1.3 million tonnes per annum. LNG is being exported to Japan, and further supplies to the Asian continent are under consideration (CEC, 2010b). Natural gas is exported here because without a pipeline or an LNG import terminal on the West Coast, it is impossible to bring the Alaskan natural gas to the lower 48 states for domestic consumption. Though the Kenai Peninsula facility is the only U.S. terminal currently exporting LNG, three of the existing LNG import facilities have been authorized to re-export delivered LNG and one has applied for authorization to do so. The three LNG import facilities authorized to re-export delivered LNG are located in: Freeport (TX), Sabine (LA), and Hackberry (LA).

There are also a number of potential sites for new LNG terminals, both export and import. (CLNG, 2012)

Existing terminal owners are also converting to LNG exports. Both Cheniere (Sabine Pass LNG) and Freeport LNG have announced plans to build liquefaction facilities to export gas from the US. The two companies built large LNG import terminals some years ago when the US was relying on gas imports and since the locations of the terminals on US Gulf of Mexico coast are very convenient for both Central America and the Caribbean, they are seen as very
good candidates for LNG supply to the region in addition to the current supply from Trinidad (Suvisari, 2011).

**New liquefaction trains**

At Sabine Pass, Louisiana, as much as seven million tonnes a year of LNG can be exported from the Cheniere Energy LNG terminal, and it will most certainly be a competitor for the Caribbean market. Terminal owner Cheniere has signed a non-binding agreement to sell 600 000 tonnes a year of LNG to the Dominican Republic starting 2015 (Cheniere Energy, 2011), motivating the decision to build four liquefaction trains for 18 mtpa in total. Several companies have already booked large quantities at the respective trains (BG Group, Gas Natural Fenosa of Spain, Gail in India) (Martin, 2012c). These negotiations contribute to an advanced position for a final investment decision as Cheniere will have roughly 89% of its capacity tied up on long-term agreements, adding a certainty to a long-term cash flow for the project (Martin, 2012d).

Freeport LNG plans a three-train liquefaction project. Permits to site, construction and operation of the facility will be received by September 2013, allowing request of permission right after. The first train is planned to be online in the last quarter of 2016. The overall construction schedule is set to take between 48 and 54 months and the terminal will include three 4.4 mtpa trains, pipe connections, a storage tank and a permanent construction dock (Meredith, 2012d).

Texas-based Excelerate is another company with interests in the LNG export market. The company has one project in the WCR, off the Texas coast in the Gulf of Mexico, outside Port Lavaca. It will be the first offshore liquefaction facility in the U.S. and it will be ready to export LNG worldwide by 2017, interconnected to the region’s existing pipeline system to receive natural gas and liquefy it on board the vessel. The Floating Liquefaction Storage Offloading vessel (FLSO) will get a production capacity of 3 million tonnes per annum (3 mtpa), a storage capacity of 250 000 m$^3$ LNG, and a fully integrated gas processing plant. The 338-meter long, 62-meter wide FLSO will be permanently moored and have multiple connections to the onshore natural gas grid in South Texas and can be adapted to most applications used near shore or offshore. The Port Lavaca location has previously received FERC approval as an LNG import facility (Marino, 2012b).

Other solutions for export of LNG is Seaboard’s, a US based corporation, proposal to export LNG on shipping containers to markets in the Caribbean and Latin America. Permissions to export 550 000 tonnes per annum, over 25 years to countries with a US free trade agreement are sought. Seaboard plans to ship out LNG on standardized containers that can be loaded on standard containerships. The project is targeted to start early 2014 (Martin, 2012b).
4.1.18 Venezuela

Venezuela had 5 trillion m$^3$ (179 Tcf) of proven natural gas reserves in 2011. PdVSA (Petróleos de Venezuela S.A.) produces the largest amount of natural gas in the country, and it is also the largest natural gas distributor, although a number of private companies also currently operate in Venezuela’s gas sector.

Venezuela is working to increase the production on gas (non-associated with oil) mostly through the development of its offshore reserves. Offshore exploration has yielded several successful finds (Shepard & Ball, 2004). In September 2008, Venezuela signed initial agreements to create three joint venture companies to pursue LNG projects along the northern coast of the country. Each project will consist of a separate liquefaction train with the capacity to export LNG corresponding to approximately 2,8 trillion m$^3$ (101.3 Tcf) of natural gas per year (EIA, 2011). The LNG export projects are currently frozen as a result of falling gas prices. Pricing issues have meant that PDVSA has struggled to attract investment from foreign companies with the right experience. This affects the offshore Mariscal Sucre project, estimated at 416 billion m$^3$ (14.7 Tcf). The Gran Mariscal de Ayacucho Industrial Complex (CIGMA) is an ambitious LNG project that has mostly been on hold for almost a decade (Wallis, 2011).
5 THE LNG POTENTIAL FOR TYPICAL WCR SHIP SEGMENTS

In Chapters 2, 3 and 4 the present and future shipping activities as well as the present and future LNG availability in the WCR are described. In this chapter some typical ship types and ship segments will be evaluated in term of its suitability as early adopters for LNG as marine fuel.

In principle any ship or ship type is suitable to use LNG as fuel if LNG is available in necessary quantities in suitable positions and at a competitive price. Since this ideal situation will not be present in either a global or a WCR context for many years to come, it is clear that some ships/ship types/shipping segments are more suitable than others.

5.1 Key aspects

Evaluating the suitability of different ship types, shipping segments and even a specific ship or operations with respect to early introduction of LNG as fuel, a number of technical, operational and commercial parameters have to be considered.

5.1.1 Range requirements

Since LNG has a lower energy/volume ratio than traditional FO, the space requirements for LNG are higher than for FO. In addition LNG tanks are much more complex and space consuming in relation to FO tanks since LNG have to be handled at low temperatures down to -163°C. This implies that a ship type with a significant range requirement needs relatively large tanks, which may have significant impact on cargo capacity and investment cost. A more optimised approach when it comes to range is necessary when using LNG as fuel.

A possible solution to keep LNG tank reasonably small is to use dual fuel (DF) engines as described in detail in chapter 3.

5.1.2 Suitable bunkering solutions

As per the traditional FO bunkering there are three main methods to do LNG bunkering. Each has its own characteristics and applicability.

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8 Approx. 2:1 LNG:FO
Today the most common LNG bunkering method is truck to ship and it is a feasible option as long as the volumes are reasonably small. A tank truck can carry up to approximately 25 tonnes of LNG depending on the capacity of the tank truck, the national transport and vehicle regulations, the road infrastructure and the standard of the roads to be used. If the receiving vessels require large quantities (>50 tonnes) other bunker methods are more suitable.
The main benefit of TTS operation is that the initial investment is limited and that the necessary investments are possible to use also for other purposes such as local energy distribution, etc. This makes TTS bunkering a very good start up solution or LNG bunkering.

On the negative side, the limited capacity is the most obvious limitation. Depending on what ship type to bunker TTS operation may also have a significant impact of the possibilities to parallel operation such as cargo and passenger handling since the bunker operation has to be carried out on the quay side of the vessel. Another obvious limitation is that the preferred bunkering position has to be connected by road to the source of LNG.

**Intermediate tank to ship (TPS)**

![Intermediate tank to ship (TPS)](image)

*Figure 49. Tank to ship bunkering (Photo courtesy Eidesvik).*

Another commonly used bunker solution is to bunker by pipeline directly from an intermediate LNG tank. Depending on the requirements and logistical options the size of such tanks could vary from as small as a few tonnes up to larger ones at 50,000 tonnes. The LNG supply to the intermediary tank could be done by truck or ship depending on the required volumes, availability, etc. In special situations it could also be possible to use an import or export terminal as direct source for TPS bunkering.

One limitation for this solution is that it is technically and operationally challenging to have long pipelines. This implies that the tank has to be situated in the close vicinity of the berth where the bunkering operation shall be performed. To do this is not always possible since the available space in combination with safety measures and other on-going activities in the port may...
be limited. The solutions also have limitations when it comes to flexibility since the bunkering position is fixed. The solution is most likely to be used for a port or berth with a stable and long-term demand for bunker delivery or when a local LNG bunker demand coincides with other consumers making it possible to co-use the necessary infrastructure.

**Ship to Ship (STS)**

![Ship to Ship (STS) Image](image)

*Figure 50. Proposal for 1 400 m³ LNG bunker vessel.*

Since both TTS and TPS has clear limitations when it comes to flexibility and/or capacity, a feasible option for bunkering of LNG in the future is by ship to ship operation similar to how FO is supplied to ships today. The solution is flexible both when it comes to capacity and location and an LNG bunker vessel can be used to bunker most kind of ship types. The main downside is that the initial investment in a bunker vessel is significant and it may be difficult to find alternative occupation in a situation when the LNG bunker demand is limited.

### 5.1.3 LNG availability and price

A key parameter when evaluating if a specific ship type/ship segment is suitable for LNG as fuel is availability and price.

According to both Ashworth (2012) as well as Moniz E.J. et al (2011) the most plausible development if comparing the global natural gas price with the global price of crude oil is that natural gas comes out as the favourable source of energy. The main reason for this is that the known resources of natural gas are significantly larger than crude oil and that new sources of natural gas are discovered in larger quantities than for crude.
In studying the natural gas prices over the last year there are significant regional differences with prices ranging from as low as below 3 USD/MMBtu in the US up to above 15 USD/MMBtu in Japan. The reason for this imbalance is a combination of new sources of natural gas discovered continuously especially in North America as well as peeks in demand especially in Japan related to the Fukushima nuclear accident and a capacity shortage of infrastructure for LNG production, distribution and import.

To achieve a stable and preferable low LNG price on a global level, significant infrastructure investments are necessary. At the same time LNG infrastructure is costly, which means that it is important that it is efficiently used. If not the additional infrastructural cost of LNG will be significant.

This fact is also very much relevant in a local or regional perspective and since the only price, which is of any interest to a ship-owner, or charterer is the FOB (Free On Board price). The additional cost for necessary infrastructure to be able to deliver LNG to ships in a regional and local perspective is of great importance for the attractiveness for LNG as marine fuel.

If shipping can co-use LNG infrastructure with other consumers such as power plants, refineries, local gas grids, etc., this is an enabler for a stable supply and reasonable price. Therefore, the location of existing or planned LNG infrastructure is of significant importance when evaluating a specific shipping segment in terms of its suitability as early adapters for LNG as marine fuel.

A similar situation occurs when it is possible to induce a relatively high LNG consumption from shipping in one single bunkering spot. Then the costs for the necessary infrastructural investments may be divided between many users resulting in an attractive LNG FOB price.

5.1.4 Present and future trade area

If a vessel is predesigned to be operated on the same route or in the same area for a significant part of its commercial and/or technical lifetime it is easier to be an early adopter of LNG as fuel since a local or regional reliable availability is sufficient to make such investment plausible. This make vessels such as ferries, RoRo:s, RoPax:s more suitable to become early adopters than for example tankers or bulk carriers that usually are operated more globally during its lifetime. This general conclusion is invalid if a vessel of any type is designed and built for a special trade such as between two refineries or between a mine and a mill, etc.

5.1.5 Typical design limitation

Different ship types have different characteristics making them more or less suitable for using LNG as marine fuel. Some of these characteristics are also contradictory. When the development of LNG fuelled ships started in Northern Europe the focus was very much vessels operation on fixed routes or areas.
over relatively short distances such as ferries, RoRo:s, PSVs, etc. The reason for this was that the LNG tanks were much more space consuming than FO tanks, and the availability of LNG distribution networks was limited. Vessels with regular trading patterns with short periods between potential bunker occasions seem like the way to go.

At the same time the first major conversion of an existing vessel from oil to LNG as main fuel was the 25 000 dwt product tanker M/T Bit Viking. This highlights the complexity of selecting which vessels are suitable to become frontrunners for the introduction of LNG as marine fuel and which are not.

![Image of M/T Bit Viking](Photo courtesy Germanicher Lloyd)

From a technical standpoint a tanker is among the easiest ship type to convert from oil propulsion to LNG propulsion. Tankers usually have available space for tank on top of the cargo area and are well suited to handle hazardous cargos/fuel. At the same time tankers usually aren’t operated on fixed routes visiting the same port on a regular basis. Therefore, a more general availability of LNG as marine fuel is necessary before the tanker segment as such is possible to use LNG as marine fuel. The reason why the Bit Viking project came through was that she got a long-term charter to be operated almost only on the Norwegian continental shelf.

The situation for container feeders is quite the opposite if compared with tankers. Container feeders are usually operated on fixed routes with regular visits to a limited number of ports. This implies that the demand for a well-developed LNG distribution system is limited and therefore makes container feeders suitable for LNG propulsion. On the other hand most container feeders have no suitable spots for the LNG tanks, which makes it more difficult to
convert a container feeder from oil to LNG propulsion without losing significant cargo capacity.

5.1.6 Demand for renewal

As discussed in previous sections there are several technical and commercial challenges when converting existing vessels from FO to LNG propulsion. Typical constrains when converting any existing vessel are weight and stability, space for tanks, space for ventilation and piping ducts, non-suitable engine room layouts as well as the suitability for conversion of existing main and auxiliary engines.

These types of constrains make it much more difficult to make a conversion of an existing vessel commercially viable compared to a new building. This fact implies that if a certain shipping segment has an underlying demand for renewal of the fleet that segment has a much better potential for the introduction of LNG as marine fuel than if not. When studying a shipping segment there are several aspects that govern the underlying demand for renewal. Age of the fleet is one aspect but also other aspects such as changing quality and capacity demands from cargo owners may have a significant impact on the underlying demand.

5.1.7 Environmental consideration

In addition to the existing, planned and discussed regulatory environmental demands as described in Chapter 3, the external non regulatory demand for environmental performance varies between different shipping segments and trade areas. In general shipping segments close to public awareness and use have more external environmental demands than more cargo related shipping segments.

For shipping segments with a clear high external environmental demand it may even be a commercial necessity to be in the forefront when attracting clients and communicating with various stakeholders. Another situation when the environmental performance may be of great commercial significance is when a reduced environmental impact from shipping may be used to compensate for other related businesses with a significant environmental impact.

5.2 Tankers

As described in Chapter 2, all types of tankers are operated in the WCR ranging from small product and chemical tankers up to large VLCCs (Very Large Crude Carrier). Two typical segments of interests have been selected for analysis in terms of suitability for LNG propulsion.
5.2.1 Coastal Tanker

Range requirements

Coastal tankers usually visit ports regularly and therefore have rather limited range requirements between bunkering in normal operation. But since they seldom are operated on fixed routes permanently they usually tend to be designed for flexibility and with rather large bunker capacity. Based on typical range requirements coastal tankers are not very suitable for the introduction of LNG as fuel. DF-engines in combination with optimised LNG capacity and large FO capacity may be a method to reduce the problem with the range requirements.

Suitable bunkering solutions

Typical bunker consumption for coastal tankers in the WCR is approximately between 5 and 20 tonnes of LNG per day. If four days of operation between bunkering is considered as an absolute minimum for operational reasons, the smallest tankers may use TTS but for most vessels STS is the bunkering solution to use. In special cases also TPS may come in use especially if it is possible to do TPS from existing LNG infrastructure during normal operation.

LNG availability and price

Based on the typical trading patterns of coastal tankers in the WCR and the availability of existing and planned infrastructure an interesting source of LNG as fuel for this segment is the existing liquefaction plant in Port Fortin, Trinidad & Tobago. Based on a rather simple additional supply infrastructure it would be possible to deliver LNG to vessels in that area to a very attractive FOB price.

Present and future trade areas

There are few special demands on coastal tankers operated in the WCR, which means that any of these tankers may be moved to most other parts of the world if it is commercially viable. This makes it necessary to use fuels that are available globally. Therefore coastal tankers are considered less suitable for a general introduction of LNG as long as LNG is not globally available as marine fuel.

DF-engines in combination with optimised LNG capacity and large FO capacity may be a method to reduce this issue.

Typical design limitation

There are few design limitations for coastal tankers and they are among the most suitable ship types to convert from FO propulsion to LNG propulsion.

Demand for renewal

Of commercial reasons the tanker segment as such has a high renewal rate since most clients have clear age limitation both for short and long-term charters. A sample of tankers trading in the Texas City area indicated that most
tankers within WCR are built after the year 2000 indicating that the fleet is rather young.

**Environmental considerations**

Since coastal tankers usually are operated in the coastal areas as well as visiting ports of various kinds, they are possibly more exposed to external environmental concern and requirements than other tanker types. This is extra valid for vessels that primarily are operated close to populated areas or areas with a significant tourist industry. Examples of such areas with the WCR where this could be valid are between the Leeward and Windward Islands, South of Florida and the Houston area.

**Conclusion**

Coastal tanker as such are not considered as suitable early adopters of LNG as marine fuel. The main reason for this is their typical trading pattern both in a short- and long-term perspective, which requires a globally available fuel. There are, however, also several parameters, which make coastal tankers very suitable for LNG propulsion. This implies that it may be very suitable to use LNG as marine fuel for coastal tankers in specific trades and for specific vessels.

A typical example of such vessel/trade could be a product tanker on a long-term charter delivering refined products from the refineries in Pointe a Pierre to the Leeward and Windward Islands. Some key points that make such vessels suitable are:

- Availability to LNG in Port Fortin
- Mainly trading in an area with clear external environmental demands
- Suitable vessel type to use LNG as fuel in a technical and operational perspective
- Clients with high safety and quality standard

**5.2.2 Aframax tankers**

In contrast to most crude oil trades in the world the backbone of crude oil transportation within the WCR is not the VLCC. Instead most crude trade is done with Aframax tankers. The main reason for this is that few ports within the WCR and the especially in the US are able to handle VLCCs.

The main route for these vessels is between a number of large Venezuelan crude export ports and US crude import ports along the Mexican gulf.

**Range requirements**

An Aframax tanker is traded on medium to long-range hauls. Typical ranges between port of calls are 2 000 up to 10 000 nautical miles and they are usually designed with significant bunker capacity. A typical daily bunker consumption
for an Aframax tanker is 40 tonnes LNG, which indicates a minimum requirements for LNG capacity of approximately 1 400 tonnes.

**Suitable bunkering solutions**

STS bunkering is the prime bunker solution based on the required volumes. In special cases also TPS may come in use especially if it is possible to do TPS from existing LNG infrastructure during normal operation.

**LNG availability and price**

Based on the typical trading patterns of Aframax tankers in the WCR the availability in possible bunkering ports are considered as good. Based on relatively simple additional supply infrastructure it would be possible to deliver LNG to vessels in these areas at a very attractive FOB price.

**Typical design limitation**

There are few design limitations for Aframax tankers and they are among the most suitable ship types to convert from FO propulsion to LNG propulsion.

**Present and future trade areas**

There are few special demands on Aframax tankers operated in the WCR, which means that any of these tankers may be moved to most other parts of the world if it is commercially viable. This makes it necessary to use fuels that are available globally. Therefore Aframax tankers are considered less suitable for a general introduction of LNG as long as LNG is not globally available as marine fuel. DF engines may be used to reduce this issue.

**Demand for renewal**

Of commercial reasons the tanker segment as such has a high renewal rate since most clients have clear age limitation both for short and long-term charters. A sample of tankers traded in the Texas city area indicated that most tankers within WCR are built after year 2000 indication that the fleet is rather young.

**Environmental considerations**

Since Aframax tankers primarily are used between main industrial ports the external environmental requirements in addition to the existing rules and regulations are considered limited.

**Conclusions**

Aframax tankers as such are not considered as suitable early adopters of LNG as marine fuel. The main reason for this is their typical trading pattern both in a short and long-term perspective, which requires a globally available fuel. At the same time Aframax tankers as such are easy to design or convert to LNG propulsion.
A typical example of an Aframax tanker suitable for LNG propulsion in the early stages is a crude tanker on a long-term charter delivering crude from the Venezuelan ports to the US ports along the Mexican gulf. Several existing and possible future sources of low prized LNG are available in both ends of the trading pattern.

Some key points that make such vessel suitable are:

- Clear availability of LNG in the designated trade area
- Suitable vessel type to use LNG as fuel in a technical and operational perspective
- Clients with high safety and quality standards

In a design perspective tankers in general are among the most suitable vessels to use LNG as main fuel since they usually have significant space available for LNG tanks on top of the cargo area. They also have crews that are skilled in handling dangerous cargo and they are designed with high safety standards when it comes to mitigating risk for fire and explosion etc. The demand for renewal is high based on strict age requirements from the main customers.

On the other hand their trading pattern usually requires a globally available fuel, which makes them less suitable to become early adopters of LNG. The range requirements are also relatively high.

If any tanker/tanker trade within the WCR should become suitable for LNG propulsion in a short or midterm perspective long-term commitments between the cargo and ship owner as well as the LNG supplier is the key. If such arrangement could be realised it would be possible to create tanker operations with high environmental standard in combination with a low overall cost.

5.3 General cargo

As described in chapters 2 and 3 there is a clear trend to an increased containerisation of all kinds of general cargo within the WCR. The number of communities connected directly to major transhipment ports are and will be limited and the demand of container feeders will grow. The suitability of container feeder using LNG as marine fuel is therefore interesting.

5.3.1 Container feeders

Range requirements

A typical container feeder route is between one or two weeks. A required minimum range is then approximately 3 000 nautical miles between bunkering. If the route is served by a 1 000 TEU container vessel such as the one in the figure below, it requires approximately 400 tonnes of LNG per bunkering.
Suitable bunkering solutions

STS bunkering is the prime bunker solution based on the required volumes. In special cases also TPS may come in use especially if it is possible to do TPS from existing LNG infrastructure during normal operation.

LNG availability and price

The key to secure LNG availability and price for the container feeder segment is that LNG will be made valuable in one or several of the large transhipment ports within the WCR. Today there is no available LNG infrastructure in any of the major transhipment ports but there are several projects planned or proposed in Panama, Jamaica and in the Florida/Bahamas region. If any of these project become realised, the condition for the introduction of LNG as main fuel for LNG feeders will become significantly improved.

Typical design limitation

In a design perspective and in comparison with other ship types container feeders are less suitable for LNG propulsion. The main reason for this is that it is difficult to find suitable space for the LNG tanks in a traditionally designed container feeder. Therefore a conversion of existing container feeders often implies significant reduction of cargo capacity, which makes it commercially challenging.

For new buildings the situation is different and less complex but requires some innovative ideas in the design phase to fit the tanks into the design without reducing the comparative cargo capacity.
Present and future trade areas

Container feeders operated in the WCR are similar to container feeders traded elsewhere. In this perspective it is necessary to use fuels that are available globally to maintain second-hand value and reduce the commercial risk. At the same time container feeders usually are more integrated in a specific supply chain operated long-term on fixed routes or in fixed areas. This implies that it is more likely for a container feeder to be operated in one region during its lifetime if for example comparing it with equally sized product tankers. Based on this and seen in a trade area perspective, it is difficult to give a general statement of the suitability of LNG propulsion on container feeders.

Demand for renewal

Based on the on-going change of the General Cargo/Container feeder market in the WCR as well as the coming augment maximum dimensions of the Panama Canal the most likely development is that the demand for container feeder capacity in the WCR will increase. Some of this demand will be fulfilled with second-hand vessels from other markets but there will also be a clear demand for newly built vessels.

A sample of container feeders operated in the Miami area indicates that an average age of the feeder fleet is approximately 10 to 15 years old.

Environmental considerations

Since container feeders usually are operated in the coastal areas as well as visiting ports of various kinds they may be more exposed to external environmental requirements than other ship types and segments. This is extra valid for vessels that primarily are operated close to populated areas or areas with a significant tourist industry. Examples of such areas within the WCR where this could be valid are between the Leeward and Windward Islands, South of Florida and the Houston area.

Conclusion

To use LNG as the main fuel for the container feeder segment within the WCR consist both of possibilities and challenges and it is difficult to make a general prediction with regard to suitability and early adaptation for LNG. Some factors that make the segment more interesting than others are the on-going change and consolidation of the cargo flows, which may open up for significant possibilities to introduce LNG as fuel for container ships especially if combined with the increased availability of LNG infrastructure as indicated in Chapter 4.

An underlying demand for new vessels in combination with a developed LNG infrastructure for LNG may open up for great opportunities to introduce LNG as fuel for the container feeder segment in the WCR. To make it work, it is important to see the fuel supply chain as one important aspect to consider when designing integrated container feeder systems. Cooperation between LNG suppliers, ship owners, port authorities as well as cargo owners is
necessary. The clear upside of such cooperation would be cost efficient and environmentally-friendly container transportation in the area to the benefit of both the economy and the environment.

5.4 Bulk
As described in Chapter 2 most of the dry bulk shipping within the WCR is related to shipments of dry-bulk commodities between the US Gulf Coast ports and ports outside the WCR. This kind of shipping will not be further discussed in this chapter.

The other type of dry bulk shipping is a more small-scale artisanal intra-regional dry bulk shipping which is very similar to the small general cargo segment. By reasons discussed in previous chapters, this segment is anticipated to decline and partly be replaced by container traffic and will not be further analysed.

5.5 Tug and supply
As described in chapter 2 there are two different dominating types of tugs used within the WCR, harbour tugs and tugs used for barge transports. Since they have totally different operational patterns, their suitability for LNG as fuel is different. Supply vessels are primarily used in the Mexican Gulf.

5.5.1 Harbour tugs
Harbour tugs are used in all major ports within the WCR. Their prime occupation is to assist vessels entering or leaving ports but they may also be used for towing, push barge operations, emergency response operations, etc.

Range requirements
For normal operation harbour tugs have very limited range requirements between bunkering since they usually return to the home port daily. But since they usually are designed for other applications they need to withstand longer range assignments. With a daily consumption in the range of 6 to 10 tonnes of LNG, a suitable LNG bunker capacity could be 20 to 30 tonnes if using dual-fuel machinery. If using pure gas engine the capacity increases significantly depending on the range requirements. Then the bunker capacity may be in the range of 60 to 140 tonnes of LNG.

Suitable bunkering solutions
The most suitable bunker solutions for Harbour tugs are TTS or TPS. Especially when operated from a dedicated tug port TPS could be very suitable since several units may use the same bunkering infrastructure. A TPS solution in a dedicated tug port is very similar to what has been used for several years in the Norwegian market for supply vessels.
LNG availability and price
Since the required volumes are relatively small it is possible to supply them with trucks independently if TTS or TPS bunkering solutions are used. As long as the desired bunker position is connected by road to any main LNG infrastructure and the range is reasonably short, the additional price of the LNG will be limited. If not, a more complex supply chain is necessary, which will increase the additional price.

Typical design limitation
The main challenge when designing an LNG fuel harbour tug is to find suitable space for the tanks. Therefore it is very difficult, if not impossible to convert existing harbour tugs to use LNG as main fuel. For new builds this is different since the tanks then may be included in the original design. Still, the available space is limited and as stated above, dual fuel-propulsion is probably necessary if ranges above a few days between bunkering are necessary.

Present and future trade areas
Harbour tugs operated in the WCR are similar to harbour tugs operated elsewhere but since the necessary supply chain is rather simple through the possibility of TTS and TPS bunkering the possibility to create a supply system on a new location is considered as possible. Since a dual fuel solution is considered as the most suitable solution based on the typical range requirements this also limits the impact of the possible problems with availability of LNG in new trade areas.

Demand for renewal
A sample of tugs operated in the St Thomas area indicates that an average age of the tug fleet is high with the bulk of the fleet built during the 1970s. This indicates a high demand for renewal that opens up possibilities to introduce LNG as marine fuel.

Environmental considerations
Since harbour tugs have their main operational area in the ports the environmental consideration and external environmental requirements may be significant depending on the specific port and its surroundings.

Conclusion
To use LNG as main fuel for harbour tugs is considered very suitable for newly built tugs operated in ports connected by road to any major LNG infrastructure. The additional price related to the required LNG infrastructure is considered limited and especially if there is a strong external environmental concern from people and activities adjacent to the operational area, there may be several commercial and PR related advantages to go for LNG. On the other hand if there is no available LNG infrastructure in the vicinity, the introduction of LNG as marine fuel within the harbour tug segment is less likely.
5.5.2 ATB/ITB/Push Barges

As stated in chapter 2 push barge solutions in general and ATB/ITB solutions in particular are commonly used in several areas within the WCR.

Range requirements

In relation to harbour tugs the tugs used for ATB/ITB solutions usually have significantly larger range requirements. With a daily fuel consumption of approx. 10 to 30 tonnes of LNG this a normal required bunker capacity of between 50 to 250 tonnes of LNG. With dual fuel machinery it may be possible to optimize the LNG capacity to a specific range requirement but independently a significant amount of LNG is required.

Suitable bunkering solutions

Based on the required volumes, ATB/ITB operations require bunkering solutions by TPS or STS since the capacity of TTS may be too limited.

LNG availability and price

The main operation areas for the ATB/ITB vessels within the WCR are along the US Gulf Coast, an area with a well-developed LNG infrastructure. In this area it will be rather simple and cost efficient to make LNG available as marine fuel at a competitive price.

In the northern Leeward Islands the situation is different since the LNG infrastructure availability is not as developed there. Additional infrastructure is necessary and the present lack of infrastructure reduces the potential of early adoption of LNG as marine fuel in that area.
Typical design limitation

The main challenge when designing a LNG ATB/ITB tug is to find suitable space for the tanks. Therefore it is very difficult, if not impossible, to convert existing tugs to use LNG as main fuel.

A possible solution that needs to be further evaluated is to store the main part of the LNG supply on the barge. This would be especially suitable for barges designed for oil products and chemicals.

For newbuildings this is different since the tanks then may be included in the original design. Still the available space is limited and as stated above dual fuel propulsion is probably necessary to be able to optimise the LNG capacity based on a certain range.

Present and future trade areas

ATB/ITB operation is not a global phenomenon and these types of vessels are primarily used in US waters and waters adjacent to US waters. This fact reduces the demand to use a globally available fuel.

Demand for renewal

A sample of tugs operated in the St Thomas area indicates that an average age of the tug fleet is high with the bulk of the fleet built during the 1970s. This indicates a high demand for renewal that opens up possibilities to introduce LNG as marine fuel.

Environmental considerations

Since ATB/ITB usually are operated in the coastal areas as well as visiting ports of various kinds they are more exposed to external environmental requirements than other ship types and segments. This is particularly valid for vessels that primarily are operated close to populated areas or areas with a significant tourist industry. Several of the main trade areas for these kinds of vessels are of this kind.

Conclusion

The main challenge if introducing LNG as fuel for ATB/ITBs is how to fit large enough tanks to fulfil the range requirements. For tug newbuildings used for ATB/ITB operation it will be possible but for the existing fleet it is almost impossible. One potential solution to solve this would be to put some of the fuel capacity on board the barge but that implies that additional safety precautions need to be addressed and new risk reduction measures developed. If the range requirement is disregarded, this type of shipping is suitable since there already is a well-developed LNG infrastructure available in its main area of operation.
5.5.3 Offshore supply vessels

The main areas of operation of offshore supply vessels are in the Mexican Gulf along the US Gulf coast.

Range requirements

An offshore supply vessel usually is operated for 14 days between port of calls with a fuel requirement of approximately 100 to 200 tonnes of LNG but the fuel consumption may vary considerably based on the specific task. Dual fuel machinery will increase the range flexibility.

Suitable bunkering solutions

Based on the required bunkering volumes for PSVs, TPS or STS bunkering solutions may be feasible. There are, however, few strict demands on short turnaround times in port and TTS bunkering with several trucks per bunkering occasion may also be possible. Since PSVs often are operated out of specific base ports a TPS solution may be the most suitable and cost efficient especially if several LNG fuel vessels are operated out of the same base port.

LNG availability and price

The main operation areas for the offshore supply vessels are in the Mexican Gulf and especially along the US Gulf Coast which is an area with a well-developed LNG infrastructure. In this area it will be rather simple and cost efficient to make LNG available as marine fuel at a competitive price.

Typical design limitation

The space availability for the fuel tanks may vary depending on type and design of the offshore supply vessel. It is therefore difficult to make a general assumption on the possibility to convert PSVs to LNG propulsion. PSV newbuildings are considered suitable for LNG propulsion.

Present and future trade areas

PSVs operate globally wherever offshore oil and gas supplies shall be explored but since LNG production often is available in the vicinity of this operation the problem with present and future trading areas is considered limited.

Demand for renewal

With an increasing interest in deep-sea offshore oil and gas reserves there is a plausible demand for new and more complex PSV within the WCR.

Environmental considerations

Oil and gas exploration and production is usually under stringent external pressure to improve its environmental performance. At the same time it is difficult to make significant changes to the environmental performance of the business as such. Therefore PSVs may be extra suitable for the introduction of LNG since it could be a rather simple way to improve the overall environmental
preference of the business. This development is also seen on the Norwegian continental shelf.

**Conclusion**

PSVs within the WCR are considered one of the most suitable segments for the introduction of LNG. In the main areas of operation the availability of LNG is good and there is a potential for significant demand for new vessels.

![Typical offshore supply vessel](image.png)

*Figure 54. Typical offshore supply vessel.*

### 5.6 Passenger vessels

#### 5.6.1 Cruise

Forty percent of the world’s total cruise capacity is operated in the area between Florida, The Bahamas, and the Northern Leeward Islands. Most of these vessels are on seven-day cruises using one of the main cruise ports in southern Florida as a base port.

**Range requirements**

A typical cruise ship has a daily consumption in the range of 100 to 150 tonnes of LNG. For a seven day trip the consumption is approximately 1 000 tonnes of LNG. If combined with dual fuel propulsion a fuel capacity of only seven days is sufficient as long as it is possible to increase the range with FO when moving for occasions when longer range is required.

**Suitable bunkering solutions**

Based on the required volumes and characteristics it is STS bunkering, which is the main bunkering solution for cruise vessels.

**LNG availability and price**

At present there is no available LNG infrastructure in the vicinity of the main base ports for the cruise industry on Southern Florida but a number of projects
are under development. If any of this will be realised the additional price for a supply system will be rather limited.

With a major change of main fuel with the cruise industry the potential volumes are of such magnitude that the cruise industry itself may be able to cover the full cost of a dedicated supply system including a regional LNG terminal.

**Typical design limitation**

To convert existing cruise vessels is challenging since the available space for LNG tanks are limited without losing too much valuable space. For new builds the situation is rather straightforward. The main concern may be the perceived risk of LNG among the consumers but with the vast number of LNG as marine fuel related projects on-going in other North American areas concerning passenger vessels of various kinds, this perceived risk among the consumers will probably sag during the year to come.

**Present and future trade areas**

A cruise vessel is likely to be operated on various areas during its lifetime and may also change trade areas for seasonal reasons. Therefore a globally available fuel may be necessary for cruise vessels.

**Demand for renewal**

The cruise industry thrives on new, bigger and better vessels and the renewal of the fleet is continuous for commercial reasons.

**Environmental considerations**

The cruise industry as such has very high external environmental requirements. Since there is public awareness of how passengers’ consumption affects the environment, it is important for the cruise industry to appear to be a responsible industry in terms of environmental performance. A similar situation is valid in relation to the ports and communities visited by these vessels since the emissions from the cruise vessels may have a negative impact both on local environment, health, and the competitiveness of the local tourist industry.

**Conclusion**

Newbuildings of cruise vessels dedicated to operate out from the cruise ports of southern Florida are among the most suitable vessels for LNG propulsion among all vessels types operated in the WCR since it combines excellent environmental performance with a potential for fuel cost. The main negative aspects to consider are a limited commercial flexibility in term of trade area and range as well as the present lack of the necessary LNG infrastructure in the vicinity of the main base ports.
5.6.2 Small ferries

Smaller passenger ferries, RoPax vessels and high-speed vessels, etc. are operated in many areas of the WCR. Since the characteristics of these vessels vary it is difficult to make any detailed conclusion but some general considerations may be pointed out.

Range requirements

Usually these types of vessels have rather limited range requirements since they usually only trade short distances between island communities, etc. and on regular time schedules.

Suitable bunkering solutions

All types of bunkering solutions may be suitable depending on bunker volume requirements, bunkering times and bunkering position.

LNG availability and price

If LNG may be sourced from existing LNG infrastructure in the vicinity of the normal area of operation a reasonable price is possible; if not it is more difficult to create a cost efficient supply system.

Typical design limitation

In general it is difficult to convert vessels in this segment but for new buildings there are few design limitations to consider.

Present and future trade areas

Vessels in this segment are usually operated more long term on specific routes than most other segments. This makes them more suitable to dedicated bunker solutions.

Demand for renewal

Usually the vessels in these segments have a long technical lifetime if well maintained. Instead it is usually changing commercial terms that induced investment requirements for new vessels. Therefore it is difficult to make any general assumptions since it very much differs from case to case.

Environmental considerations

Depending on where the vessels are operated, the external environmental requirements may vary but in general the environmental performance of the vessels in this segment is important since they usually are operated close to populated areas.

Conclusion

It is difficult to make a general statement for this segment since its circumstance varies on a case-by-case basis. A number of aspects are important, such as demand for renewal, a long-term perspective, as well as
available reasonable prices of LNG, and must be carefully considered to
determine whether a specific service is suitable or not for introducing LNG as
marine fuel. At a workshop within this project, the specific ferry service
between the Trinidad and Tobago islands was identified as an example of an
interesting potential pilot route for LNG adoption. LNG is available, the
potential operational savings are high and the operator is planning for long-
term renewal of its ferry fleet.

5.7 Overall conclusion and comparison

In this chapter a number of identified technical, operational and commercial
key aspects of LNG feasibility has been assessed for various ship segments
operating in the WCR. Some of the segments are considered more suitable and
likely to become early adopters than others but for all of them there are both
favourable and less favourable aspects identified and the segments show
different profiles with respect to suitability for introduction of LNG as fuel.

The respective profiles are summarised in the table below in which an
indicative ranking of the relative suitability for the different studied WCR
shipping segments is outlined.

Table 9. Ranking of overall suitability for LNG adaptation of different ship segments.
1 indicates high suitability, 2 medium and 3 less suitability.

<table>
<thead>
<tr>
<th>Ship type segment</th>
<th>Typical bunker volume (tonnes)</th>
<th>Suitable bunker solution</th>
<th>Estimated additional distribution cost</th>
<th>Trade area requirements</th>
<th>Possibilities for conversion</th>
<th>Demand for renewal</th>
<th>External Environmental demand</th>
<th>Overall suitability ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Tankers</td>
<td>20-200</td>
<td>STS</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Aframax tankers</td>
<td>1 400</td>
<td>STS</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Container feeder</td>
<td>400</td>
<td>STS</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Harbour tugs</td>
<td>20-30</td>
<td>TTS/TPS</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>ATB/ITB</td>
<td>50-250</td>
<td>STS/TPS</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>PSV</td>
<td>100-200</td>
<td>TPS</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cruise</td>
<td>1 000-1 500</td>
<td>STS</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Smaller ferries</td>
<td>5-500</td>
<td>TTS/STS/TPS</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
6 ANALYSIS

6.1 Approach for estimation of the future LNG demand

A number of factors will influence and determine the future demand for LNG as ship fuel in the WCR. The different shipping segments will show different rates of adaptation for LNG operation based on careful comparative assessment of the long- and short-term operational economy. Predictions of the LNG adoption rate figures can be made with guidance from the descriptions in Chapter 5 but are also a function of time. The demand is assumed to grow gradually over time and stepwise at the point at the dates when new stringent emission limits become effective.

In the table in section 5.7, an indicative overall suitability ranking for LNG adaptation is suggested in three levels from 1–3 where 3 indicates the highest suitability. From the development scenarios of future ECA regulations in the WCR outlined in section 3.4 it is reasonable to assume that high suitability ranked ship segments will be among the earliest adopters and show a relatively high adoption rate (fleet fraction adopting LNG as the main fuel) over time compared with segments with lower suitability ranking.

In order to estimate future LNG bunker demand for a specific segment, an average daily fuel consumption per vessel, average hours per day in operation and the number of vessels in service multiplied by an assumed adoption rate would result in an estimated LNG fuel consumption or demand for a particular ship segment engaged in a specific route service at a specific time of development scenario.

The REMPEITC database covers all ship movements including departure and destination ports defining each route. The most frequently trafficked routes were listed for each segment in the top-20 lists, but complete lists including also all low frequency trafficked routes would be very long. Distances travelled or time spent for each of the routes is unfortunately not included in the database and therefore it was not practically feasible to calculate the accumulated distances and fuel consumption for each ship segment in this study.

A number of examples for specific segments and services may, however, illustrate the described approach and give a quantitative indication on potential future increasing demand for LNG as ship fuel.
6.1.1 Cruising segment

According to the route analysis in Chapter 2 and the use of REMPEITC map application the following cruising route scenario is considered representative.

<table>
<thead>
<tr>
<th>Scope:</th>
<th>Large cruising vessels engaged in 7-day cruises between turnaround ports in SE Florida and the Puerto Rico area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical ship size</td>
<td>50 000 GT</td>
</tr>
<tr>
<td>FOC:</td>
<td>150 tonnes/day. Operating on average 16 h/day @ 20 knots is 100 tonnes /day</td>
</tr>
<tr>
<td>Route:</td>
<td>Total travelled distance 2 000 nautical miles per route</td>
</tr>
<tr>
<td>Number of vessels:</td>
<td>Totally 25 vessels in this ship and size segment engaged in this and similar services in the area</td>
</tr>
</tbody>
</table>
| LNG adoption: | LNG adoption rate assumed to be 5% by 2015  
LNG adoption rate assumed to be 20% by 2025 |
| LNG demand: | 875 tonnes LNG/week 2015, 3 500 tonnes/week 2025  
44 500 tonnes LNG/year 2015, 182 000 tonnes/year 2025 |

6.1.2 Container feeders

According to the route analysis in Chapter 2 and the use of REMPEITC map application, the following container feeder route scenario is considered representative for the Jamaica – Trinidad area.

<table>
<thead>
<tr>
<th>Scope:</th>
<th>Container feeder engaged in 7-day routes between Kingston Jamaica, Grenada and Trinidad area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical ship size</td>
<td>10 000 GT, 900 TEU</td>
</tr>
<tr>
<td>FOC:</td>
<td>50 tonnes/day. Operating on average 12 h/day @ 18 knots is 25 tonnes/day</td>
</tr>
<tr>
<td>Route:</td>
<td>Total travelled distance 3 000 nautical miles per route</td>
</tr>
<tr>
<td>Number of vessels:</td>
<td>Totally 10 vessels in this ship and size segment engaged in this and similar services in the area</td>
</tr>
</tbody>
</table>
| LNG adoption: | LNG adoption rate assumed to be 10% by 2015  
LNG adoption rate assumed to be 30% by 2025 |
| LNG demand: | 8 700 tonnes LNG/year 2015, 26 000 tonnes/year 2025 |
6.1.3 ATB/ITB tug

According to the route analysis in Chapter 2 and the use of REMPEITC map application, the following ATB/ITB tug services scenario is considered representative for US Gulf Coast area.

<table>
<thead>
<tr>
<th>Scope</th>
<th>ATB/ITB tug engaged in coastal operation between ports along the US Gulf Coast within the North American ECA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical ship size</td>
<td>500 GT</td>
</tr>
<tr>
<td>FOC</td>
<td>20 tonnes/day. Operating on average 18 h/day is 15 tonnes/day</td>
</tr>
<tr>
<td>Route</td>
<td>Total travelled distance 200 nautical miles per day</td>
</tr>
<tr>
<td>Number of vessels</td>
<td>Totally 50 vessels in this ship and size segment engaged in this and similar services in the area</td>
</tr>
</tbody>
</table>
| LNG adoption | LNG adoption rate assumed to be 20% by 2015
LNG adoption rate assumed to be 50% by 2025 |
| LNG demand | 8 700 tonnes LNG/year 2015, 26 000 tonnes/year 2025 |

6.1.4 Crude carrier

According to the route analysis in Chapter 2 and the use of REMPEITC map application, the following crude carrier services scenario is considered representative for the US import from Venezuela.

<table>
<thead>
<tr>
<th>Scope</th>
<th>Crude carrier engaged in 14-days routes between the Houston area and Puerto José, Venezuela.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical ship size</td>
<td>Aframax 100 000 dwt</td>
</tr>
<tr>
<td>FOC</td>
<td>40 tonnes/day. Operating on average 20 h/day @ 14 knots is 33 tonnes/day</td>
</tr>
<tr>
<td>Route</td>
<td>Total travelled distance 4 000 nautical miles per route</td>
</tr>
<tr>
<td>Number of vessels</td>
<td>Total of 5 vessels in this ship and size segment engaged in this and similar services in the area</td>
</tr>
</tbody>
</table>
| LNG adoption | LNG adoption rate assumed to be 20% by 2015
LNG adoption rate assumed to be 40% by 2025 |
| LNG demand | 12 000 tonnes LNG/year 2015, 23 000 tonnes/year 2025 |
From the above examples and taking into account that the presented segment services only represents a very small portion of the total WCR internal traffic, it is obvious that the LNG demand for ship fuel may increase rapidly if the LNG adoption rate will get high. The examples also indicate that segments with large ships and high fuel consumption may represent a large portion of the LNG demand even though the LNG adoption rate in the segment is low.

Given that the assumed LNG adaptation rate also corresponds to an MGO adoption rate and an HFO plus scrubber adoption rate with a sum of 1 (100%), the described approach can of course also be used to calculate corresponding MGO and HFO demand for the analysed scenarios.

6.2 LNG infrastructure for supply of LNG for LNG fuelled vessels in the WCR

As indicated in Chapter 5 one of the key enablers for the introduction of LNG as marine fuel is the ability to create a cost efficient and reliable supply chain from available sources of LNG to the LNG fuelled vessels.

As indicated in the map in Chapter 4, LNG is or will be available in the near future in most areas of the WCR based on demands not related to LNG as marine fuel. This must be considered as a valuable key enabler to make WCR suitable as such for the introduction of LNG as marine fuel. It is assumed that the basic price of LNG in these non-shipping related systems are attractive based on the available regional price indications such as the Henry Hub, etc.

At the same time the LNG price in these systems is irrelevant for the shipping industry. The only interesting price for the shipping industry is the FOB price and if the FOB price is not attractive in relation to the alternatives, LNG will not be the fuel of the future in the WCR.

In principle the difference between the LNG price in the non-shipping related LNG systems and the FOB price is the cost of the required additional infrastructure to create the necessary supply systems. The key to create cost efficient supply systems is to create systems with high LNG throughput in relation to the necessary investments in every part of the supply chain.

The following four examples demonstrate how the necessary additional supply systems could be created for three different types of shipping segments. For each example a corresponding FOB price for IFO380 is calculated based on the following figures, to allow for direct comparison with actual IFO380 price:

- HUB Price LNG: 4 USD/MMBTU = 190 USD/ton
- Net Calorific Value LNG: 13.7 MWh/tonnes
- Net Calorific Value IFO380: 11.3 MWh/tonnes
- Net Calorific Value MGO: 12 MWh/tonnes
6.2.1 The WCR cruise industry

As identified in earlier chapters, the cruise industry of the WCR has several characteristics that make it suitable for the introduction of LNG as marine fuel. The main bunkering area is considered to be the cruise ports of south-eastern Florida. At present there is no existing LNG infrastructure available in that area but there are two proposed projects in the Bahamas that if realised could be used as main sourcing infrastructure to the cruise industry. Otherwise it is probably necessary to invest in an intermediate LNG terminal in the southern Florida area.

To exemplify, the following assumption is made:

- Number of LNG fuel cruise vessels: 10
- Required bunkering volume: 910 tonnes
- Required bunkering interval: 7 days
- Bunkering position: Port Everglades
- Bunkering method: STS

Two different supply chains are evaluated, one with an intermediate terminal in vicinity of the selected bunkering position and one using one of the proposed Bahamas regasification terminals as the main source.

Cruise supply chain 1

The following figure describes the main part of supply chain one.

LNG source

Potential LNG source for this supply system is the Houston area, Savannah or Trinidad. Since Trinidad is already operative as an export terminal this is selected as the main source for this supply chain. In principle the selection of Trinidad as LNG source implies that the necessary additional infrastructure at the LNG source is limited.
**LNG feeder vessel**

The distance between Trinidad and Port Everglades is about 1 600 nautical miles and a return trip including cargo operation takes about 12 days. This implies that the feeder vessel has to be in the range of 20 000 tonnes.

The daily cost for a vessel with a LNG capacity of 20 000 tonnes including fuel is about 85 000 USD/day.

**LNG intermediate terminal**

The required size of the intermediate terminal in the vicinity of Port Everglades is estimated to 20 000 tonnes. The daily cost including both CAPEX and OPEX cost is estimated to 40 000 USD/day.

**LNG Bunker vessel**

For this case it is assumed that a bunker vessel with a capacity of 1 250 tonnes is required. The daily cost for such vessel including bunkers is estimated to 25 000 USD/day.

**The additional price estimate for supply chain 1**

In the table below the additional cost per tonne for the supply chain 1 is calculated based on that all components of the supply chain is dedicated to the supply of LNG to the 10 cruise vessels in this case.

<table>
<thead>
<tr>
<th></th>
<th>USD/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional cost at LNG source</td>
<td>0</td>
</tr>
<tr>
<td>Cost for feeder vessel</td>
<td>85 000</td>
</tr>
<tr>
<td>Cost for intermediate terminal</td>
<td>40 000</td>
</tr>
<tr>
<td>Cost for bunker vessel</td>
<td>25 000</td>
</tr>
<tr>
<td>Throughput per day</td>
<td>1 300</td>
</tr>
<tr>
<td>Estimated HUB price LNG</td>
<td>190</td>
</tr>
<tr>
<td>Supply chain cost</td>
<td>115</td>
</tr>
<tr>
<td>Estimated FOB Price LNG</td>
<td>305</td>
</tr>
<tr>
<td>Corresponding FOB price IFO380</td>
<td>252</td>
</tr>
</tbody>
</table>

**Cruise supply chain 2**

The following figure describes the main part of supply chain 2.
**LNG source**

Potential LNG source for this supply system is the planned LNG regasification terminals at the Grand Bahama Island. Some additional infrastructure is required to make export of LNG possible at these terminals. The daily cost of this additional infrastructure is estimated to 10 000 USD/day.

**LNG Bunker vessel**

The distance between the Grand Bahama Island and Port Everglades is about 85 nautical miles and a return trip including cargo operation takes about 24 hours. To be able to supply the 10 cruise vessels in this example it is assumed that there is time to do one trip to the LNG source per week implying the capacity of the Bunker vessel needs to be in the range of 10 000 tonnes.

The daily cost for a vessel with a LNG capacity of 10 000 tonnes including fuel is estimated to 55 000 USD/day.

**The additional price estimate for supply chain 2**

In the table below the additional cost per ton for the supply chain 2 is calculated based on the fact that all components of the supply chain are dedicated to the supply of LNG to the 10 cruise vessels of this case.

<table>
<thead>
<tr>
<th>Additional cost at LNG source</th>
<th>10 000 USD/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost for feeder vessel</td>
<td>0 USD/day</td>
</tr>
<tr>
<td>Cost for intermediate terminal</td>
<td>0 USD/day</td>
</tr>
<tr>
<td>Cost for bunker vessel</td>
<td>55 000 USD/day</td>
</tr>
<tr>
<td>Throughput per day</td>
<td>1 300 tonnes</td>
</tr>
<tr>
<td>Estimated HUB price LNG</td>
<td>190 USD/tonnes</td>
</tr>
<tr>
<td>Supply chain cost</td>
<td>50 USD/tonnes</td>
</tr>
<tr>
<td>Estimated FOB Price LNG</td>
<td>240 USD/tonnes</td>
</tr>
<tr>
<td>Corresponding FOB price IFO380</td>
<td>198 USD/tonnes</td>
</tr>
</tbody>
</table>

**6.2.2 The St Thomas tug industry**

As identified in earlier chapters there are a lot of different types of tugs operated in the St Thomas area. The most plausible bunkering solutions for tugs are supplied either by TTS or TPS.

At present there is no existing LNG infrastructure available on St Thomas but there is an existing regasification terminal at Puerto Rico.
To exemplify, the following assumption is made:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of LNG fuel tugs</td>
<td>10</td>
</tr>
<tr>
<td>Required bunkering volume</td>
<td>20 tonnes</td>
</tr>
<tr>
<td>Required bunkering interval</td>
<td>3 days</td>
</tr>
<tr>
<td>Bunkering position</td>
<td>St Thomas</td>
</tr>
<tr>
<td>Bunkering method</td>
<td>TPS</td>
</tr>
</tbody>
</table>

The following figure describes the main part of a suggested supply chain of these tugs.

**LNG source**

The Puerto Rice regasification terminal is selected as the source for this supply chain. Some additional infrastructure is required to make export of LNG possible at these terminals. The daily cost of this additional infrastructure is estimated to 10 000 USD/day.

**LNG feeder vessel**

The distance between the Puerto Rico LNG regasification terminal and St Thomas is about 100 nautical miles and a return trip including cargo operation takes about 24 hours days. Considering one trip per week the feeder vessels have to have a capacity of approximately 500 tonnes.

The daily cost for a vessel with a LNG capacity of 500 tonnes including fuel is about 20 000 USD/day. Note that the usage rate of the vessel in this case is only about 15%.

**LNG intermediate terminal**

The required size of the intermediate terminal including bunker station for tugs in St Thomas is estimated to 700 tonnes. The daily cost including both CAPEX and OPEX cost is estimated to 12 000 USD/day.

**The additional price estimate for supply chain 1**

In the table below the additional cost per ton for the supply chain 1 is calculated based on the fact that all components of the supply chain are dedicated to the supply of LNG to the 10 tugs in this case.
### Table 1: Costs and Prices

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional cost at LNG source</td>
<td>10 000</td>
<td>USD/day</td>
</tr>
<tr>
<td>Cost for feeder vessel</td>
<td>20 000</td>
<td>USD/day</td>
</tr>
<tr>
<td>Cost for intermediate terminal</td>
<td>12 000</td>
<td>USD/day</td>
</tr>
<tr>
<td>Cost for bunker vessel</td>
<td>0</td>
<td>USD/day</td>
</tr>
<tr>
<td>Throughput per day</td>
<td>67</td>
<td>tonnes</td>
</tr>
<tr>
<td>Estimated HUB price LNG</td>
<td>190</td>
<td>USD/tonnes</td>
</tr>
<tr>
<td>Supply chain cost</td>
<td>630</td>
<td>USD/tonnes</td>
</tr>
<tr>
<td>Estimated FOB Price LNG</td>
<td>820</td>
<td>USD/tonnes</td>
</tr>
<tr>
<td>Corresponding FOB price IFO380</td>
<td>676</td>
<td>USD/tonnes</td>
</tr>
<tr>
<td>Corresponding FOB price MGO</td>
<td>718</td>
<td>USD/tonnes</td>
</tr>
</tbody>
</table>

Compared to the additional cost per ton LNG for the cruise vessel supply chain the cost for the tug supply chain per ton is significantly higher. The main reason for this is that the average usage rate of each component in the supply chain is low and to reduce the additional price it is necessary to co use the required infrastructure with other users such as other shipping segments, energy production, etc.

Compared to HFO the LNG solution may be considered as more expensive but compared to MGO, which usually are used by this kind of vessels the LNG price still is to be considered as competitive based on this example.

### 6.2.3 The crude tanker industry

As described in an earlier chapter there is a continuous flow of crude oil shipped on Aframax tankers from the Puerto La Cruz area in Venezuela to the port in the Houston area.

To exemplify, the following assumption is made:

- **Number of Aframax tankers**: 4
- **Required bunkering volume**: 600 tonnes
- **Required bunkering interval**: 15 days
- **Bunkering position**: Puerto Jose
- **Bunkering method**: STS
The following figure describes the main part of supply chain 2.

![Supply Chain Diagram]

**LNG source**

The selected LNG source for this supply system is Trinidad. Since Trinidad is already operative as an export terminal this is selected as the main source for this supply chain. In principle the selection of Trinidad as LNG source implies that the necessary additional infrastructure at the LNG source is limited.

**LNG Bunker vessel**

The distance between Trinidad and Puerto Jose is about 250 nautical miles and a return trip including cargo operation takes about 48 hours. To be able to supply the one Aframax tanker per trip the bunker vessel needs to be in the range of 800 tonnes.

The daily cost for a vessel with an LNG capacity of 800 tonnes including fuel is estimated to 26 000 USD/day.

**The additional price estimate per ton LNG**

In the table below the additional cost per ton for the supply chain is calculated based on the fact that all components of the supply chain are dedicated to the supply of LNG to the four Aframax tankers used in this case.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost (USD/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional cost at LNG source</td>
<td>0</td>
</tr>
<tr>
<td>Cost for feeder vessel</td>
<td>0</td>
</tr>
<tr>
<td>Cost for intermediate terminal</td>
<td>0</td>
</tr>
<tr>
<td>Cost for bunker vessel</td>
<td>30 000</td>
</tr>
<tr>
<td>Throughput per day</td>
<td>160 tonnes</td>
</tr>
<tr>
<td>Estimated HUB price LNG</td>
<td>190 USD/tonnes</td>
</tr>
<tr>
<td>Supply chain cost</td>
<td>188 USD/tonnes</td>
</tr>
<tr>
<td>Estimated FOB price LNG</td>
<td>378 USD/tonnes</td>
</tr>
<tr>
<td>Corresponding FOB price IFO380</td>
<td>311 USD/tonnes</td>
</tr>
</tbody>
</table>
6.3 Potential barriers for LNG as ship fuel in the WCR

A number of various potential barriers for an introduction of LNG as a fuel for coastal and short sea shipping in the WCR are identified. These potential holdback aspects are related to safety issues, economy, infrastructure development, technical development and security.

6.3.1 Safety issues

LNG is a new and unknown fuel for most seafarers and port officers and it has completely different properties compared with traditional bunker fuel oil. It is well known to everyone that spillages or uncontrolled outflow of fuel oil may cause spectacular contamination and significant impact in the marine environment but spills do not usually impose severe hazards to human lives. For the use of LNG as ship fuel, the situation is contrary – an LNG outflow will evaporate and dissipate without any local environmental impact but if a cloud of vapourized LNG is ignited, fire and heat radiation will threaten human lives.

If incidents or a serious accident would occur at an early stage of the introduction LNG as ship fuel, this could constitute a serious barrier for further development and expansion of the use of LNG as ship fuel. Therefore it is of utmost importance that stringent safety standards and regulations are developed and implemented for LNG bunkering and for the operation of LNG fuelled vessels. Excellent safety records from many years of large-scale LNG carrier operations demonstrate that it is possible to control LNG hazards efficiently by adequate design, stringent regulations and competent personnel.

Gaps and adaptation of technical regulation and standards

The international trading with LNG by the use of large LNG carriers is a shipping segment with excellent safety records. In risk terms, it shows a very low accident frequency but the potential consequences of a large-scale accident are severe. A lot of the safety experience gained from the operation LNG carriers may be adopted for the use of LNG as ship fuel but incidents and accidents may become more frequent as the number of LNG bunkering operations will be very high compared with LNG carrier loading/unloading operations. The probability for incidents will thus increase but on the other hand, the potential consequences of minor bunker related LNG discharges will be less severe than those caused by LNG carrier accidents.

The table below gives some indicative size relations between large-scale export/import operations and small and medium scale LNG distribution and bunkering operations.
Table 10. Indicative size comparison of large, medium and small scale LNG operations.

<table>
<thead>
<tr>
<th>Typical characteristics</th>
<th>Large scale export/import operations</th>
<th>Medium size feeder/distribution operations</th>
<th>Small scale operations and LNG bunkering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ship size LNG capacity, m³</td>
<td>LNG carriers 100 000 – 270 000</td>
<td>LNG feeder vessels 10 000 – 100 000</td>
<td>Bunker vessels 1 000 – 10 000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bunker barges 200 - 500</td>
</tr>
<tr>
<td>Loading pipes diameter</td>
<td>≥ 16 inches</td>
<td>8 – 15 inches</td>
<td>2-7 inches</td>
</tr>
</tbody>
</table>

The operation of LNG carriers and handling of LNG as cargo are well regulated by the IGC Code, ISO 28460:2010 Standard, SIGTTO LNG ship-to-ship guidelines etc. and some of these requirements may also be applied for bunkering applications. There are, however, also a number of requirements that need to be "down scaled" with regard to the quantities of LNG handled and size of the bunker vessels involved and a gap is also identified regarding detailed standards and regulations on ship-to-ship bunkering operations. Development of the IGF Code and current work conducted within the ISO TC 67/WG 10 will hopefully establish clear-cut standard procedures and equipment requirements. The process of establishment of standards and regulations may take time and interim guidelines may be developed and applied from the start. Lack of international standards or application of different standards in different WCR countries may otherwise imply technical barriers for example regarding hose connections, ESD systems and ERS.

Training and education requirements

In order to avoid barriers and to minimize accident risks, it is just as important as regulating technical standards for LNG bunkering, it is also very important to address issues on training, education and awareness among all officers, crew members and land based staff involved in LNG bunkering. Some of the WCR countries are developing countries where the standard of seafarers and port officers has not yet reached the level of international quality shipping. Eight of the WCR flag states were listed on the grey or black lists of Paris MoU in 2011.

Training requirements for bunker vessel operators should be comparable to those for LNG carrier crew, though it may temporarily be difficult to fulfil required time at sea experience, if a fleet of bunker vessels will be put in service over a short time. For crew in LNG fuelled vessels and for staff in land based LNG bunkering facilities, adequate and harmonized training requirements should be established in consensus between international maritime regulators and national competent authorities regulating land based LNG activities in ports and for road transportation.
LNG specific hazards

Of the following identified LNG specific potential outcomes of an accidental release of LNG, fire scenarios are found to be the ones governing for necessary risk control measures including determination of safety distances and site selection for bunkering facilities and operations.

- Cryogenic damage – metal embrittlement, cracking, structural failure;
- Cryogenic injuries – frost burns;
- Asphyxiation – if the air oxygen is replaced methane asphyxiation may occur;
- Reduced visibility due to unignited vapour clouds;
- Thermal radiation from various fire scenarios;
  - delayed or immediate ignition of vapour clouds (flash fire),
  - slow fire front
  - delayed or immediate ignition of vapour-air mixture (fire ball),
  - rapid burn
  - LNG pool fires or
  - flame jets from leaks in pipes, hoses, tanks or pressure vessels
- Rapid phase transition, RPT;
- Vapour cloud explosion (in confined spaces and enriched with other hydrocarbons);
- Boiling liquid expanding explosions (BLEVE);
- Rollover in LNG storage tanks;
- Sloshing in on board LNG tanks;
- Geysering – expulsion of LNG from a quiescent liquid in piping.

The figure below illustrates the formation of an LNG pool and vapour cloud for a large-scale spill.

The flammability range for vapourised LNG (methane) in air is relatively narrow, 5% (LFL) – 15% (UFL) compared with many other flammable gases, but if ignited the emissive power from methane is higher than for example for propane. Methane is, in contrast to propane, lighter than air and vapourised LNG from small leakages will therefore dissipate relative quickly. For a large LNG spill, the visible white cloud of cold vapourised LNG will, however, initially have neutral buoyancy in air.
6.3.2 Economy related issues

A number of different potential barriers are related to the investments and operational costs for adaptation to LNG and the cost relation compared with other optional compliance strategies. The investment costs for LNG may be predicted accurately but the long-term price predictability of the LNG may be considered as a parameter of uncertainty.

The present Henry Hub LNG price of relevance for the WCR is low compared with other market regions and there are no indications identified that this situation will alter dramatically in the near future.

The increasing production of shale gas in the USA reduces the risk for lack of supply of LNG even with a continued increase of LNG consumption in the WCR. The main demand for LNG will most likely continue to be from land based industrial users and distribution networks and even with a quick maritime LNG fuel expansion the risk for lack of supply and increasing prices are low.

Also with possible future increased export of LNG from the USA, it is not anticipated that LNG prices will increase dramatically in the WCR (Medlock, 2012).

Taxation of maritime fuels are generally harmonised in order to avoid negative competitive factors. Possible introduction of national taxation schemes for LNG ship fuel might influence the economic feasibility of the LNG compliance strategy for inland and domestic shipping.
6.3.3 Lack of infrastructure development

There is an established infrastructure of liquefaction and regasification facilities in the WCR and LNG for use as ship fuel and is theoretically available in a number of strategically located locations. In areas close to existing LNG facilities, the infrastructure developments required to enable supply of LNG as a fuel to ships is normally relatively small. For example an import terminal may include a truck loading facility from which LNG can be delivered to ships in a nearby port or a small scale unloading jetty may be constructed to accommodate a bunker vessel as an integrated part of the import terminal.

A number of import terminals and regasification facilities are presently planned in various WCR locations, primarily for the supply of land-based power plants, gas network for distribution to household consumers and industrial activities. These projects also contribute to favourable conditions for the establishment of infrastructure components needed for the supply of LNG as fuel for ships. An economically attractive development of an LNG infrastructure for the supply of ship fuel thus goes hand in hand, as a cost effective complement, with the development of the land-based LNG infrastructure.

Conversely, any hindrance or reduction in the development of the land-based LNG infrastructure will also influence the development of the LNG for ships negatively in the region and act as barriers. Some of the aspects identified as potential barriers are the delay of development projects due to slow permit processes, difficulties identifying relevant national authorities to handle environmental permit applications, and site selection issues. Low LNG price, though an important enabler for introduction of LNG as a marine fuel, is sometimes also referred to as a cause for shelving advanced plans for land based LNG infrastructure projects and new liquefaction trains.

6.3.4 Optional compliance strategies

The optional SECA compliance strategies identified so far are basically LNG, MGO or use of HFO and scrubbers. It is unlikely that new other options will emerge but there is a long-term possibility that optional fuels like methanol/DME will become competitive to LNG.

The implementation of the North American ECA and the sulphur content restrictions introduced in August 2012 initiated discussions on the possibilities for waivers and exemptions from the 1% sulphur requirement. References have been made to the “compliant fuel oil non-availability”-clauses and for interim exemption during a conversion period for LNG operation. A cruising company operating in the WCR has applied for exemption referring to a scheme where some of the vessels of the operator’s fleet use fuel with sulphur content below the stipulated limit whilst other vessels use non-compliant fuel resulting in an fleet average compliant level of SO\textsubscript{x} emissions.
This type of dispositive application of the ECA regulations and scope for exemption may contribute to uncertainties in decisions on compliance strategies for ship operators and thereby act as barriers. It may, however, also facilitate and generate incentives for LNG adaptation if conditional interim waivers will be regularly issued for LNG retrofit projects.

Another aspect that may be added to the list of potential barriers is the fact that methane slip from LNG fuelled ship engines counteracts with the advantageous CO₂ emission characteristics of LNG compared with fuel oil. Recognising that methane is 30 times more aggressive as a greenhouse gas than CO₂, this may be considered a drawback with LNG if the levels of methane slip cannot be effectively reduced by the engine manufacturers.

6.3.5 Security

The WCR include a large number of countries also representing different political systems. Potential political disputes or conflicts in the region may temporarily influence the security of supply of LNG to some of the import facilities. This may cause temporary barriers for the development process but if one supply chain is closed it will likely be replaced by another source. Even if the LNG import price may increase, the price impact on the FOB price for LNG delivered as ship fuel may be moderate.

Some years ago the LNG import to the USA by the use of large-scale LNG carriers was criticised by opponents claiming that the LNG carriers and land based storage tanks may constitute attractive targets for terror attacks. Today, the seriousness of these threat scenarios has, however, been toned down with reference to results from risk analyses. Large LNG carriers as well as small bunker vessels or tanks in LNG fuelled vessels are designed with double walled high strength material and the consequences of or attractiveness as targets for terror attacks are not considered significant in comparison with other handling of dangerous and flammable substances.

6.4 Enablers

6.4.1 Clear safety regulations

LNG bunkering during loading/unloading operations

It is considered important that detailed and clear-cut safety standards and regulations are established for bunkering procedures and techniques. To make LNG an attractive compliance option, it is also important that the LNG bunkering operations do not significantly influence operability of ships in terms of frequency and duration of the bunkering. In order to make LNG a feasible option for passenger vessels and ferries it is further considered necessary that safety rules and bunkering procedures are designed to allow that bunkering
and embarking/disembarking of passengers can be conducted simultaneously. For general cargo vessels, container vessels, and bulk carriers bunkering should also be allowed in parallel with cargo handling. For tankers and other vessels carrying dangerous cargo, bunkering operations must not be conducted during cargo transfer.

Risk-based safety zones
Requirements on how to determine safety distances and exclusion zones for bunkering operations should preferably be risk based and take into account the quantities of LNG handled, bunker flow rates and pressure and possible credible accident scenarios.

6.4.2 Public consultation and awareness
Opposition from the public opinion is often identified as a cause of delay in LNG infrastructure development projects. Such reluctance is often based in lack of knowledge about LNG in its environmental advantages, its hazards and characteristics. Relevant information and increased public awareness may be gained by well-prepared public consultation processes as part of the site selection for intermediate LNG terminals and bunkering facilities. A number of examples where anti-LNG lobbyists have prepared and disseminated material aimed to stir fear and resistance are known from the region. To promote a shift from oil to LNG as ship fuel, information that de-mystifies LNG and presents good examples stressing the excellent safety records may form important components facilitating the process.

6.4.3 Economy and incentive schemes
Long-term LNG fuel price predictability is one important enabler. Pioneers in operating LNG fuelled vessels may initially have to pay a higher FOB LNG price but as the number of LNG fuelled ships increases, the utilisation rate for bunker vessels raise and the costs related to investments in distribution infrastructure and bunker vessels may be shared by more LNG consumers.

In order to encourage pioneering projects and to speed up the introduction of LNG as ship fuel, various types of economic incentive schemes may be introduced on national basis or in cooperation between authorities, ship owners, ship operators, LNG suppliers and ports in different countries or sub regions. Successful examples of similar incentives have been designed as port fee deduction schemes, differentiated port dues and by establishment of fund mechanisms designated for financial support of emission reduction investments. If such systems are designed to unilaterally support ships of a specific flag state, it may, however, distort the competitive conditions in different shipping segments.

A number of the WCR countries are developing countries that are subject for various international aid and development cooperation programs.
Modernisation of the transportation infrastructure sector is often specifically addressed in such programs, and may possibly also be expanded to include support to development of efficient SECA compliant maritime transportation systems based on LNG fuelled ships.

6.4.4 Infrastructure development

Many of the WCR countries are facing an increasing energy demand and also an increasing demand for fuel import for generation of electricity. This demand is partly fulfilled by the use of mobile floating power barges providing rapid establishment. The process of site selection, permit application, construction works, etc. for land based facilities may take several years, while hiring an existing power barge may provide an operational system in less than one year. If floating power barges are combined with FSRU and facilities for alongside mooring of LNG carriers, or a separate LNG import jetty, national electricity supply can be boosted significantly in WCR coastal areas and islands in an environmentally and efficient way. Such permanent or temporary infrastructural establishments may also provide important links, acting as enablers for supply infrastructure for LNG ship fuel.

6.4.5 Safe and efficient bunkering procedures and technologies

Effective interaction between manufacturers and regulators may enable adequate down scaling of established technologies from large-scale LNG handling to various concepts for LNG bunkering. Crucial system components and pieces of equipment include ESD-systems, ship-shore communication links, safe break away couplings, dry disconnection couplings, and procedures for purging and inerting bunker lines without venting of vapourised LNG, etc. In addition to prescriptive rules there is also a need for practical implementation guidelines and information on how to implement efficient and safe bunkering procedures.
CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDIES

Ship traffic in the WCR is intensive with more than 100,000 registered port calls per annum. About three quarters of the registered ship movements are WCR internal movements with both departure and destination ports located within the WCR. The remaining one quarter are Panama Canal passages and calls outside the WCR. General cargo traffic dominates in the WCR but tanker and passenger traffic are also frequent.

Thirtyseven percent of all registered port calls are from ships calling at ports located within the present North American ECA and when the US Caribbean ECA comes into effect in 2014, an additional 9% of the calls will be at ports located within ECAs. This is the basic scenario for the feasibility study but for future scenarios it is anticipated that the extent of the ECAs in the WCR will expand and possibly cover the entire WCR.

Decided future expansion and possible additional further expansion of the ECAs in the WCR will gradually increase the attractiveness of the option to use LNG as ship fuel.

The price of LNG in the WCR market is favourable in relation to conventional fuel oils and in particular in relation to MGO, which is an optional “wait and see” strategy for ECA compliance. One key issue of feasibility for introduction of LNG as ship fuel is the expected additional cost for making the LNG available as a bunker fuel in the areas where the ships are operating. These costs are highly dependent on the existing land based LNG infrastructure and the plans and prospects of future expansion of this infrastructure. Today LNG terminals are found on the US mainland, in Mexico, Trinidad & Tobago, the Dominican Republic and in Puerto Rico. Many of the WCR island nations have started implementing energy strategies based on increased use of natural gas for electricity production to cover increasing national energy demands. For the WCR island nations, import of LNG is often considered the most feasible way for supply but subsea gas pipelines are also discussed in some places. As part of this long-term implementation process, a number of LNG import terminals of various type and size are currently being planned and may form a basis for an efficient and economically attractive solution for an LNG infrastructure dedicated for the supply of LNG as ship fuel. Additional facilities for truck loading, for loading of bunker vessels or LNG feeder vessels in the LNG terminals are needed to form a basic infrastructure network for distribution and supply of LNG as ship fuel. Given such additional facilities can be established at reasonable costs and utilised at high capacity, an attractive LNG FOB bunker price can be ensured in many places in the WCR.

In addition to the LNG FOB price, other key feasibility issues for introduction of LNG as ship fuel are related the ships’ long-term geographical operational areas. Some ship segments and fleets are designed for a specific route or
engaged for long time charters and will basically operate in the WCR during its entire life cycle, while other ship types frequently are engaged in other routes and must be economically operational also in areas where LNG is not available.

The economic and technical feasibility aspects of different ships and ship segments also vary significantly with regard to age of the vessel or expected remaining lifetime and possibilities for conversion/retrofit of LNG versus the prospects and need for new building and replacement tonnage. Some ship segments, in addition to regulatory compliance requirements and commercial aspects also need to consider external environmental pressure and demand in their assessment of LNG and its potential competitive advantages.

A number of the identified short sea and coastal shipping segments are considered suitable for introduction of LNG as fuel but not only typical short sea and coastal segments may become early adopters due to attractive operational and commercial conditions.

PSV (Platform Support Vessel) in the WCR is a category considered to be suitable with respect to additional cost for LNG supply infrastructure. It is also considered suitable with regard to its operational area, the demand for newbuilding and external environmental demand and shows an overall high suitability for introduction of LNG as fuel.

A second WCR segment in which early LNG adopters are considered likely to be presented is for newbuildings in the cruising segment. Retrofit projects for LNG conversion of cruise vessels are costly but may also be feasible. In the small passenger ferry segment, the specific ferry service between the islands Trinidad and Tobago was identified as an interesting example of particular suitability for adoption of LNG as fuel.

Container feeder vessels are expected to gain an increasing market for WCR internal cargo transportation while the traditional general cargo sector probably will decrease. The location of the container hub ports in the WCR and possible WCR feeder routes are considered suitable for services with LNG fuelled vessels and for new building projects of container feeders, LNG can be assumed to be an attractive option.

Another WCR ship segment that is in contrast to the ones above, not associated with very high conversion costs for introduction of LNG fuel is the tanker segment. LNG is considered a possible attractive option for the route carrying crude from the northern coast of South America to the oil terminals in the US Gulf with Aframax tonnage. Even if only a minor part of this route is within ECA, LNG retrofit projects and full-time LNG operation may be found economically attractive compared with HFO-MGO swapping strategies. The fleet of coastal tankers operating with supplying various fuels to the islands in the eastern Caribbean Sea is another part of the WCR tanker segment that may include early adopters provided that an LNG bunker infrastructure will be established in the area.
Based on the ship segments identified as feasible for introduction of LNG, a number of indicative quantitative examples has been derived and presented in the report. An approach for estimation of future LNG demand is outlined based on a timeline and scenarios of gradually increasing LNG adoption rate. Examples of required additional LNG bunker distribution infrastructure, bunker vessels, etc. are also presented, indicating that introduction of LNG as ship fuel in the WCR is feasibility and that there are good prospects for LNG to become an attractive fuel option for specific ships segments operating in the WCR.

The presented analysis approach would require a lot of detailed calculation efforts to provide overall quantitative figures for the entire WCR and it would still be associated with a number of uncertainties related to adaptation rates, etc. If a more detailed study should be accomplished in the future it would also be valuable to examine the changes in the traffic patterns and statistics by comparing the 2007–2008 REMPEITC data used in this study with more recent data.

The presented examples together with the general suitability and trend analyses are, however, considered to provide a good overview of the possibilities and limitations for introduction of LNG as ship fuel for short sea and coastal shipping in the WCR and the feasibility for establishment of an LNG bunkering infrastructure.
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