Martinez Refining Company

3485 Pacheco Boulevard
Martinez, CA 94553

**Via Email: shorepower@arb.ca.gov**

May 24, 2022

Ms. Bonnie Soriano
Branch Chief
Freight Activity Branch
Marine Strategies Section
California Air Resources Board
1001 I Street Sacramento
Sacramento, CA 95812
shorepower@arb.ca.gov

**Subject: Response to Request Regarding MRC Terminal Plan for At-Berth Rule**
**Martinez Refining Company**

Dear Ms. Soriano:

Pursuant to your correspondence of March 02, 2022, regarding the Martinez Refining Company's (MFC) 12/21/2021 Termina Plan for At Berth Rule (Terminal Plan), this communication provides a response which addresses the deficiencies noted in your March 02 letter and provides further clarification as to the nature of the relationship and the division of responsibilities between the Port and the terminal.

The following language is included from your letter referenced above:

- *Section 93130.14(a)(3)(F) of the Regulation requires the terminal to provide a schedule for installing equipment; and*
- *Section 93130.14(a)(3)(H) of the Regulation requires a terminal operator claiming that a physical and/or operational constraint will delay its ability to implement its preferred CARB-approved control strategy to achieve emission reductions from vessels at berth according to the requirements of section 93130 et seq., must also include with its terminal plan a technical feasibility study evaluating if there are any other emission control options that could be implemented more quickly at the terminal:*
    - *Although the Martinez Refining Company Terminal plan did provide a milestone schedule that stated that shore power and barge/shore-based capture and control system would not be feasible for six to 13 years after equipment is commercially available, the plan did not include, and we request that you submit, a technical feasibility study evaluating if there are any other control options that could be implemented more quickly at the terminal.*

*With respect to the division of responsibilities, we request clarifying language to describe the relationship between the Port and the terminal. Although it is our understanding that the terminal is an independent marine terminal, we request information that specifically details the responsibilities of the terminal and any that the Port may have for infrastructure.*

As noted above, your letter acknowledges MRC's milestone schedule but requests a technical feasibility study evaluating if there are any other control options that could be implemented more quickly. To address this deficiency, MRC has included as Attachment A of this correspondence a document titled *CALIFORNIA AIR RESOURCES BOARD'S (CARB) OCEAN-GOING VESSELS AT BERTH REGULATION EMISSIONS CONTROL TECHNOLOGY ASSESSMENT FOR TANKERS* (DNV GL USA, Inc.) provided by the Western

States Petroleum Association (WSPA) (Report). This report examines technology that could be used to meet the requirements of the Regulation. This assessment served as MRC's technical feasibility study for the original Terminal Plan. MRC was not able to identify any other technology that can be implemented more quickly than the shortest time frame presented in the Terminal Plan.

Since the development of the Terminal Plan, MRC has been focusing efforts on variations of the technology identified in the Technological Assessment (Report) that may result in implementation closer to the shorter time frame estimated in the Terminal Plan. MRC has been considering capture and control systems, but where the system is located on land rather than on water or the wharf. In particular, MRC has been in contact with potential vendors who are evaluating prototypes for barge based systems that can be used on tankers. While MRC believes the narrow channel would preclude the use of a barge based system located on the waterside of tankers docked at the wharf (and two vendors have also acknowledged this likely limitation), MRC is looking at possibly taking elements of the barge based system and locating them on the shore. This would require additional engineering and design not associated with a strictly barge based system but where the technology may be available sooner than shore power. In addition, this variation may help to minimize the concerns around availability of spacing of the wharf and the ability for the wharf to handle the additional weight of the system. Though again, particularly considering these technologies are still being evaluated for tanker application, at this time, MRC does not believe a control option can be implemented more quickly than the shortest timeframe presented in MRC's 12/2021 Terminal Plan. MRC will continue to work with these vendors and others, and as the technology options further mature, MRC will continue to evaluate the implementation schedule in hopes the schedule can be accelerated at a faster pace than currently anticipated.

Lastly, CARB requested information regarding the relationship between the Port and Terminal. MRC wanted to clarify that there is no separate Port associated with the Terminal.

Thank you for your time in this matter. Should you have any further questions or concerns regarding this matter, please contact Mr. Rick Shih at (925) 313-0586 / richard.shih@pbfenergy.com or you may contact me at the numbers below.

Regards,

Michael Marlowe

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Attachment

cc: Elizabeth Melgoza, Air Pollution Specialist, Marine Strategies Section
elizabeth.melgoza@arb.ca.gov

**ATTACHMENT A**

*CALIFORNIA AIR RESOURCES BOARD'S (CARB) OCEAN-GOING VESSELS AT BERTH REGULATION EMISSIONS CONTROL TECHNOLOGY ASSESSMENT FOR TANKERS* (DNV GL USA, Inc.)

DNV

# CALIFORNIA AIR RESOURCES BOARD'S (CARB) OCEAN-GOING VESSELS AT BERTH REGULATION EMISSIONS CONTROL TECHNOLOGY ASSESSMENT FOR TANKERS

# Report

## Western States Petroleum Association

**Report No.:** 2021-9470 Rev. 0
**Document No.:** 11IHNF43-1
**Date:** 2021-11-30

| | | |
|---|---|---|
| Project name: | California Air Resources Board's (CARB) Ocean-Going Vessels at Berth Regulation Emissions Control Technology Assessment for Tankers | |
| Report title: | Report | |
| Customer: | Western States Petroleum Association | |
| Customer contact: | Sophie Ellinghouse | |
| Date of issue: | 2021-11-30 | |
| Project No.: | 10268233 | |
| Organization unit: | Advisory Americas | |
| Report No.: | 2021-9470, Rev. 0 | |
| Document No.: | 11IHNF43-1 | |

DNV GL USA, Inc. Maritime
Advisory Americas
1600 Sawgrass Corporate Parkway
Suite 110
Sunrise, FL 33323
USA

Objective:

Carry out a technical study, with relevant stakeholders' engagement and assessment of technology using a systematic and scientific approach following the DNV technology qualification process. The scope of the study includes the review of safety and reliability aspects of the given emissions control strategies, the timeframe for implementing the technologies, and alignment with applicable tanker/terminal regulations and standards.

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Keywords:
Tanker, CARB, Shore power, Emission

| Rev. No. | Date | Reason for Issue | Prepared by | Verified by | Approved by |
|---|---|---|---|---|---|
| 0 | 2021-10-13 | First issue | WANGANN/RAJIV | JHAND | MOCS |

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# ABBREVIATIONS & DEFINITIONS

| | |
|---|---|
| **Ship/Terminal related terms** | |
| **AC** | Alternate Current |
| **DC** | Direct Current |
| **HVAC** | Heating Ventilation & Air Conditioning |
| **ROG** | Reactive Organic Gases |
| **OPS** | Onshore Power Supply |
| **PV** | Pressure Vaccuum Valve |
| **MW** | Megawatt |
| **PPE** | Personnel Protective Equipment |
| **DWT** | Deadweight |
| **DG** | Diesel Generator |
| **IGG/IG** | Inert Gas Generator |
| **COP** | Coefficient of Performance |
| **Ex-proof** | Explosion Proof - Refers to fittings that need to be explosion proof |
| **IP** | Insulation Protection |
| **PS** | Port side |
| **SB** | Starboard side |
| **VHF** | Very High Frequency |
| **IR Monitoring/IR Camera** | Infrared Camera |
| **NDT** | Non Destructive Testing |
| **AIS** | Automatic Information System |
| **GPS** | Global Positioning System |
| **NPT** | Non Performing Time |
| **CMS** | Cable Management System |
| **SPO** | Shore Power Outlet |
| **Standards, rules or regulations mentioned** | |
| **MOTEMS** | Marine Oil Terminal Engineering & Maintenance Standards |
| **IEC** | International Electrotechnical Commission |
| **ISGOTT** | International Safety Guide for Oil Tankers and Terminals |
| **IBC** | International Bulk Chemical Code |
| **IACS** | International Association of Classification Societies |
| **CCR** | California Code of Regulations |
| **IEEE** | Institute of Electrical and Electronics Engineers |
| **NFPA** | National Fire Protection Association |
| **NEC** | National Electrical Code |
| **IMO** | International Maritime Organisation |
| **SOLAS** | Safety Of Life At Sea |
| **MARPOL** | International Convention for the Prevention of Pollution from Ships |
| **OCIMF** | Oil Companies International Marine Forum |

| | |
|---|---|
| **PIANC** | The World Association for Waterborne Transport Infrastructure |
| **ABS** | American Bureau of Shipping |
| **MEG 4** | OCIMF Mooring Equipment Guidelines 4th Edition |
| **API RP** | American Petroleum Institute Recommended Practice |
| **GHG** | Green House Gases |
| **NOX** | Nitrous Oxide -Pollutants from emissions |
| **SOX** | Sulphur Oxide - Pollutants from emission |
| **PM** | Particulate Matter - Pollutant |
| **CSLC** | California State Lands Commission |
| **Tier IV** | EPA emissions requirement for diesel engines |
| **USCG** | US Coast Guard |
| **CEQA** | California Environmental Quality Act |
| **ISPS** | International Ship and Port Facility Security Code |
| **MTSA** | Maritime Transportation Security Act of 2002 |
| **Risk assessment tools** | |
| **FMECA** | Failure Mode Evaluation & Criticality Analysis |
| **SIMOP** | Simultaneous Operations |
| **HAZID** | Hazard Identification |
| **HAZOP** | Hazard and Operability Analysis |
| **TQ** | Technology Qualification |

# 1 EXECUTIVE SUMMARY

Western States Petroleum Association (WSPA) engaged DNV to conduct a technology assessment of the emissions control strategies considered in the 2020 amendments to California Air Resources Board's (CARB) Ocean-Going Vessels At- Berth Regulation. The technology assessment determines if the emissions control technologies can be designed for tanker vessels to comply with the regulation safely and reliably, while still meeting other applicable tanker regulations and standards. The technology assessment also establishes design requirements, estimated cost, and the minimum timelines required to implement each emissions control strategy. DNV is an independent expert in maritime risk management and quality assurance, one of the world's leading certification bodies and classification societies and is a recognized leader across the maritime industry.

The amended regulation applies to tanker vessels at California (CA) ports and marine terminals and will require all tanker vessels that berth at a CA port or terminal to meet new emission standards as early as 2025. In order to conduct a thorough and systematic evaluation of the compliance alternatives, DNV conducted a series of workshops using DNV's technology qualification process (DNV Recommended Practice, DNV-RP-A203, September 2019).

DNV included an extensive array of subject matter experts and key stakeholders (see Appendix I – V) from government and public entities (e.g., CARB, U.S. Coast Guard, Port of Long Beach, Port of Los Angeles) industry and industry groups (e.g., Chevron, ConocoPhillips, PBF Energy, Shell, Phillps66, Intertanko, Oil Companies International Marine Forum (OCIMF), Valero, and third-party technology providers (e.g., Clean Air Engineering – Maritime (CAEM), GMB Marine Services, AECOM, Cavotec) for a comprehensive assessment. Over the course of multiple technical workshops, the experts discussed the current CARB-approved emission control technologies (CAECS): 1) shore-based power, 2) shore-based capture and control and 3) barge-based capture and control. The experts evaluated each CAECS and discussed in detail their degree of technical feasibility and maturity, safety concerns and safeguards, operational considerations, environmental aspects and regulatory dependencies

While key findings and conclusions are discussed in detail in subsequent sections, this report concludes:

- Onshore power together with modifications for design of tankers need significant development and risk mitigation before an industry-wide implementation for tankers which operate world-wide
- Capture and control technology for tankers does not currently exist. The systems currently used for container vessels in Southern California are not designed to withstand the variable conditions in Northern California including currents, winds, tide, depth, etc. Further, the equipment design and reliability in terms of taking exhaust quantity from tankers need to be established.
- The current regulatory timeline is insufficient to address and mitigate the outstanding safety and operational risks, some of which introduce their own unavoidable limitations and dependencies (e.g., regulatory permitting).
- An electrical grid feasibility study is needed to determine and assure that shore power demand can be provided safely and reliably.

In the broader context, the maritime industry globally is beginning a significant energy transition to reduce greenhouse gas emissions from the sector, some relevant trends of which are noted here:

- While the overall number of installations globally remains limited, the number of major ports with shore power facilities for cruise and container vessels is growing, increasing the viability of installations for these vessel segments.
- Several jurisdictions beyond California are now implementing or considering regulatory requirements for the use of shore power.
- A shift to a new generation of low or zero carbon fuels may significantly change the need for at-berth emissions management, either through an absolute reduction or a change in emission content from new fuels. Section 9 of this report presents a summary of the main regulatory drivers behind this transition as well as some of the potential alternative fuels being considered for the industry.

**Shore power:**

Assessment of the shore power technology indicates that the technology needs further development for large-scale implementation in the tanker segment. The development timescales may not meet the CARB proposed timeline. Some of the key findings and implementation challenges for tankers are listed below:

- Missing and/or gaps in existing industry standards, regulations, and classification societies rules to meet the specific shore power requirements for tankers including the requirements to setting up power generation and distribution system to cover main and emergency switchboard to be powered externally using shore power
- lack of standardization for tankers with regards to location of the shore power connection point on the ship, a common point of interface with terminal systems i.e., limitation of shore power connection within hazardous zones
- the wide range of the length of the tankers and the vessel orientations at the terminals, which when combined with the lack of connection point standardization may seriously restrict the vessels able to use the infrastructure.
- a suitable location for cable management system on shore and onboard, including material handling requirements to deploy electrical cables between shore and connection point on the vessel
- technology development of ex-proof certified electrical equipment, severely restricting suitable onboard connection points
- further risk evaluation with regards to handling of hazardous cargo while implementing the technology
- other risks related personnel safety, emergency evacuation, cybersecurity etc.
- consideration of potential demand on the electrical grid in the ports and terminals, as well as locally accounting for variable power and peak load power demands across vessels while ensuring voltage and frequency compatibility/ stability
- potential physical space constraints, including emergency vehicles
- need to develop maritime industry standards (for terminal and vessel operators) defining tasks and responsibilities, similar to those from International Chamber of Shipping (ICS), OCIMF, and

International Association of Ports and Harbors (IAPH), and International Safety Guide for Oil Tankers and Terminals (ISGOTT).

**<u>Shore and barge based capture and control technology:</u>**

Currently, a ready to use capture and control technology, either shore based, or barge based deployable for tankers does not exist.

The capture and control technology has certain unique risks relevant to its potential utilization on tankers. To mitigate the risks, the critical recommendations during the design, construction, and implementation are identified through this study. Third-party engineering firms have begun to understand and address these challenges with revised designs with focus on the barge based capture and control technology. A few key considerations are listed below:

- performance constraints, reliability concerns, with respect to safe and efficient handling of stack size and exhaust rate variability from auxiliary boilers and auxiliary engines, potential additional emission sources
- potential interference with hazardous zones on the ship and terminal
- compliance with Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) requirements in cases of terminal modifications and upgrades
- safety concerns including short circuits, fire and explosion hazards, collision, disruptions to vessel operations, safe evacuation of personnel
- environmental concerns such as potential damage to existing underground installations, noise pollution, potential obstruction of traffic in narrow channels
- design constraints such as terminal water depth, operational interference, physical space constraints, operational boundaries

The workshop also identified risks and benefits of a shore based versus a barge based capture and control technology, i.e.

- barge based has flexibility in terms of position and interface with the ship and the terminal
- shore based might have space constraints related to the terminal design and could require significant modifications to the terminal infrastructure
- barge-based has risks related to marine operations, environmental conditions, and emergency procedures
- shore based has marine civil/structural challenges engineering unique to each facility requiring significant modifications to terminal infrastructure

**Cost and Timeline**

Key findings related to the high-level expected timeline and cost for implementation for each of the three technologies assessed are below.

**Timeline for permitting, design, and construction:**

Based on a generalized timeline for a shore power or land-based capture and control technology installation a project is likely to take around 14 years once a feasibility study commences. For larger or more complex terminals, this could take longer. Hence, it is unlikely that any ports or marine oil terminals will be able to comply with the 2020 At-berth Regulation timeline.

For barge-based systems, the timeline is around 5 years. While there are currently no capture and control systems serving tankers, at least one vendor is nearly complete with detailed engineering for a capture and control barge. Following construction and a successful test, additional capture and control barges may be built and utilized by the tanker industry. This is a technology that, if successful may be replicated with relative ease, it is even possible some barge-based systems could be in operation on a few tankers prior to the regulatory deadline.

**Timing of Applicable Design and Operational Standards for Shore Power:**

- In DNV's opinion, for wide, large-scale implementation of shore power technology, further development of industry standards, regulations, and classification societies rules is required. To facilitate updating the standards, regulations, and industry guidelines, there need to be an initiative underway but there is currently no timeline for addressing these gaps, and the industry will need to initiate a collaborate effort to develop the standards and guidelines
- The timeline for updating the international standard IEC/IEEE 80005-1 to develop prescriptive requirements for the connection point on a tanker could be 2-3 years and is under discussion but no firm process is underway, since the working group need the industry participation and relevant inputs.
- Updating industry guidelines, e.g., ISGOTT, is also expected to take about 2-3 years.
- The updating of IACS or Classification society rules to cover tanker specific requirement for tankers typically can be completed within 1-2 years. This is also driven by the need from the industry, designers, and ship owners.

**Cost for Shore Power:**

- The costs for vessel upgrades for installation for shore power on new vessels are estimated to be between $350k and $700k.
- For existing vessels, the cost is dependent on the vessel type, size, age, and the need for an onboard transformer, as well the where and how the retrofit is performed, e.g., during a scheduled docking in a shipyard or during voyages. For smaller vessels, costs range from about $70,000 to $500,000, and for larger vessels, the costs range from about $500,000 to $1M. If a vessel requires new electrical cargo pumps/variable frequency drives (VFDs), the cost can increase to $2-3M.

- Costs may be significantly higher if the shore power connections will be at the cargo manifold area and within the hazardous zone that might require the design and construction of a specialized safe room for the connection point for the shore power.
- The costs for shoreside modifications vary greatly depending on the unique challenges of each terminal. This results in wide range of costs but our estimation for the installation of shore power costs between $2.5M – $14M per berth, including interconnections to the grid. Depending on the terminal complexity, costs can easily exceed $20M per terminal.

**Cost for Capture and Control:**

- There is still a lot of uncertainty the costs estimate. For land-based systems, CARB estimated costs at about $16.5 million per berth in capital expenses. In the absence of more information, this is a fair assessment of the capital expenses. For more complex terminals or terminal with limited wharf space, costs may be higher.
- For barge-based systems, the capital costs make up a smaller portion of the total costs due to higher operating and administrative costs. The CARB estimates of $4.9 million for the barge construction understate to total capital costs required for a barge-based system. In addition to the capital costs, there will also be leasing/port fees, fuel costs, labor costs, and maintenance costs, which could make up a higher portion of the total lifetime savings.

# 2 INTRODUCTION

## 2.1 California Air Resources Board's (CARB) ocean-going vessels at berth regulation

California Air Resources Board (CARB) has approved the Ocean-Going Vessels At-Berth Regulation in 2007 ("2007 At-Berth Regulation"). In 2020, CARB amended the Ocean-Going Vessels At-Berth Regulation ("2020 At-Berth Regulation"). Under the amended At-Berth Regulation, all tanker vessels would be required to control their auxiliary engine and auxiliary boiler emissions while at berth at ports and independent marine terminals in California where vessel visits exceed specified activity thresholds. To receive CARB approval, one must demonstrate that the emission control strategy achieves emission rates in Table 2-1. The timeframe for planning and compliance defined in "2020 At-Berth Regulation" is shown in Table 2-2.

**Table 2-1 Emission rates requirement for tankers in "2020 At-Berth Regulation"**

| | Oxides of nitrogen (NOx) | Particulate matter 2.5 (PM 2.5) | Reactive organic gases (ROG) |
|---|---|---|---|
| **Auxiliary Engines** | 2.8 g/kw-hr | 0.03 g/kw-hr | 0.1 g/kw-hr |
| **Boilers** | 0.4 g/kw-hr | 0.03 g/kw-hr | 0.02 g/kw-hr |

**Table 2-2 Timeframe for planing and compliance in "2020 At-Berth Regulation"**

| | Plan Submittal | Interim evaluation for new technologies and applications | Plan Revisions | Compliance |
|---|---|---|---|---|
| **Los Angeles/ Long Beach** | Dec 1, 2021 | Dec 1, 2022 | February 1, 2024 | Jan 1, 2025 |
| **All remaining** | Dec 1, 2021 | | February 1, 2026 | Jan 1, 2027 |
| **Description** | Terminal and port operators shall submit terminal plans to CARB. | CARB staff will assess the progress made in adopting control technologies for use with tanker and ro-ro vessels, as well as the status of landside infrastructure improvements that may be needed to support emission reductions at ro-ro and tanker terminals. CARB staff will review control technologies for use with bulk and general cargo vessels, and for ocean-going vessels at anchor, and potential requirements for these vessel types. CARB staff will evaluate the information provided by the port and terminal plans required by this Control Measure. CARB staff will also consider other public information provided to CARB including terminal-specific engineering evaluations, logistical considerations, public engagement, and independent studies that inform the implementation timeline. By December 1, 2022, staff will publish analysis and findings in a report and make it available for public review at least 30 calendar days prior to presenting the report to the Board at a public meeting. If staff finds that the compliance deadlines for ro-ro or tanker vessels need to be adjusted forward or backward in time, the report will include recommendations to initiate staff's development of potential formal regulatory amendments. | Ro-ro and tanker terminals shall revise and resubmit terminal plans on the following schedule, which must reflect any changes to the terminal since the initial plan | Tanker vessels that visit a berth or terminal shall meet the requirements. |

## 2.2 The study subjects

In "2020 At-Berth Regulation", "tanker vessel" means a self-propelled vessel constructed or adapted primarily to carry liquid bulk cargo and tanker vessels may carry petroleum crude, petroleum products, or non-petroleum-based products - finished and intermediate and are classified as either non-edible and dangerous or edible and non-dangerous. The study has focused on crude oil tankers, product oil tankers, and chemical tankers, i.e., the common tanker types that are visiting California ports and terminals for cargo operations.

The following at-berth technologies were studied:

- Shore power
- Shore-based emissions capture and control
- Barge-based emission capture and control

The above technologies have been evaluated for implementation on generalized tanker vessel designs that berth at generalized versions of a port terminal and marine terminal that are reasonably representative of California port and marine terminals.

## 2.3 Technology qualification process

Implementation of new technology introduces uncertainties that imply risk for its developers, manufacturers, vendors, operators and end-users. TQ is the process of providing the evidence that (for the purpose of this study – Shore power and Capture and Control technologies) will function within specified operational limits with an acceptable level of confidence. The DNV Recommended Practice (RP) A203 "Technology Qualification" is a procedure that covers a systematic approach to the qualification of a technology, and thus a tool to ensure that the technology functions within specific limits with an acceptable level of confidence. The main steps in the TQ work process are shown in **Figure 2-1**.

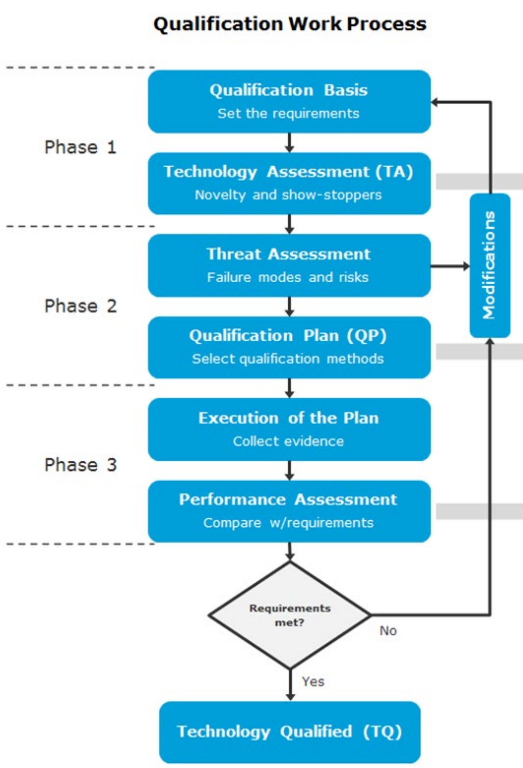



**Figure 2-1 Qualification work processes**

In a full TQ work process, the functional requirements and any critical performance parameters are described in a qualification basis, after which a technology assessment identifies the most significant areas of uncertainty associated with the technology.

Following this, a more detailed threat assessment is conducted, focused on these uncertainties, to identify potential failure modes, risks and concerns.

These identified risks would then be followed up through design and implementation processes, according to an associated qualification plan with clearly identified mitigations.

If the qualification plan is successfully executed and verified, a performance assessment against the qualification basis determines whether the qualification process has been successful, and the technology has met the intended functional requirements and performance.

For the purpose of this study, phase 1 as well as a threat assessment has been carried out. The remaining steps in the process are disregarded as they are not relevant to the scope of this report.

# 3 THE GENERAL CHARACTERISTICS OF THE TANKERS

The current status of the tanker fleet and terminals in California has been reviewed to understand the key stakeholders, the current facility set up, and identify potential challenges in terms of implementation of emission control technology.

The collected information from stakeholders and public resources and historical Automatic Identification System (AIS) data between 2017 January 1st and 2019 December 31st have been analyzed to review the status of the tanker fleet visiting California. (The data in 2020 is deemed as an outlier due to the COVID-19 pandemic.) Based on the analysis of the AIS data, Figure 3-1 shows the number of unique ships per tanker type visiting California terminals from 2017 - 2019. The majority are chemical/oil product tankers, crude oil tankers, and oil product tankers and the study will focus on these tanker segments.

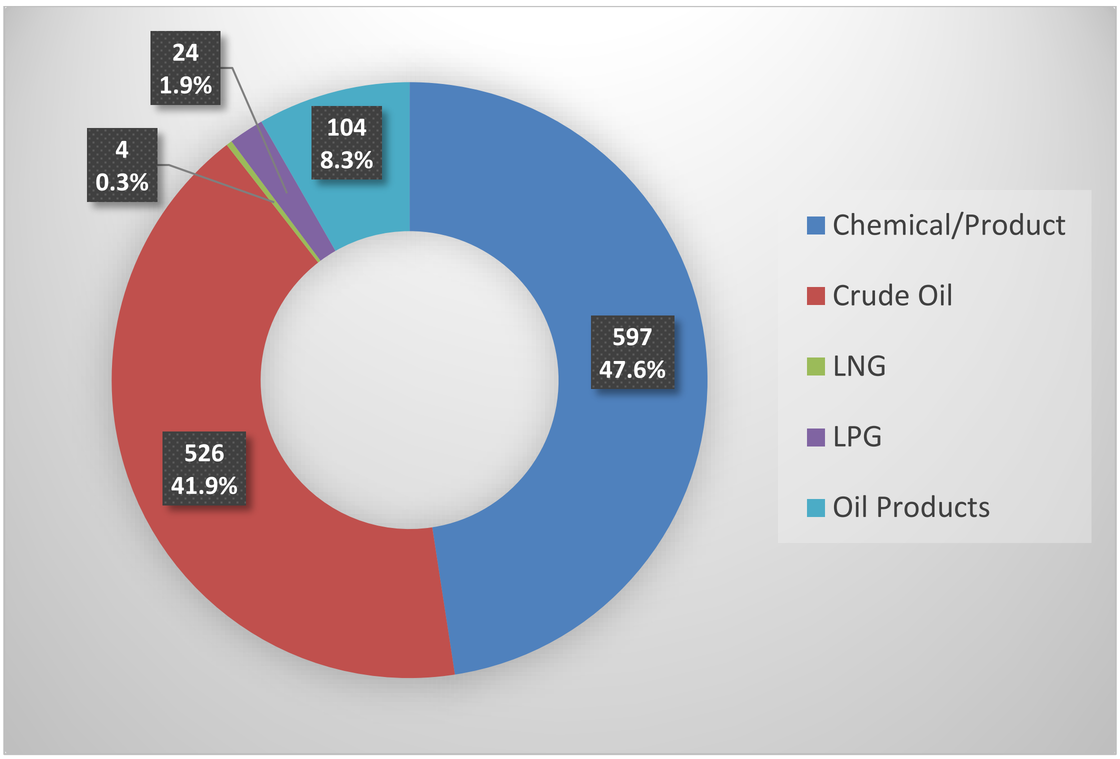



**Figure 3-1 Unique ships that visited California between 2017 January 1st and 2019 December 31st**

A substantial amount of the tankers calling California have deadweight below 80,000 DWT. But there are also many Very Large Crude Carriers (VLCC) and Ultra Large Crude Carriers (ULCC) visiting. It should be noted that the ship call visits based on AIS data includes all vessels classified as tankers visiting California ports and it intended to show the general mix of oil tanker types and sizes that called California in 2017-2019.

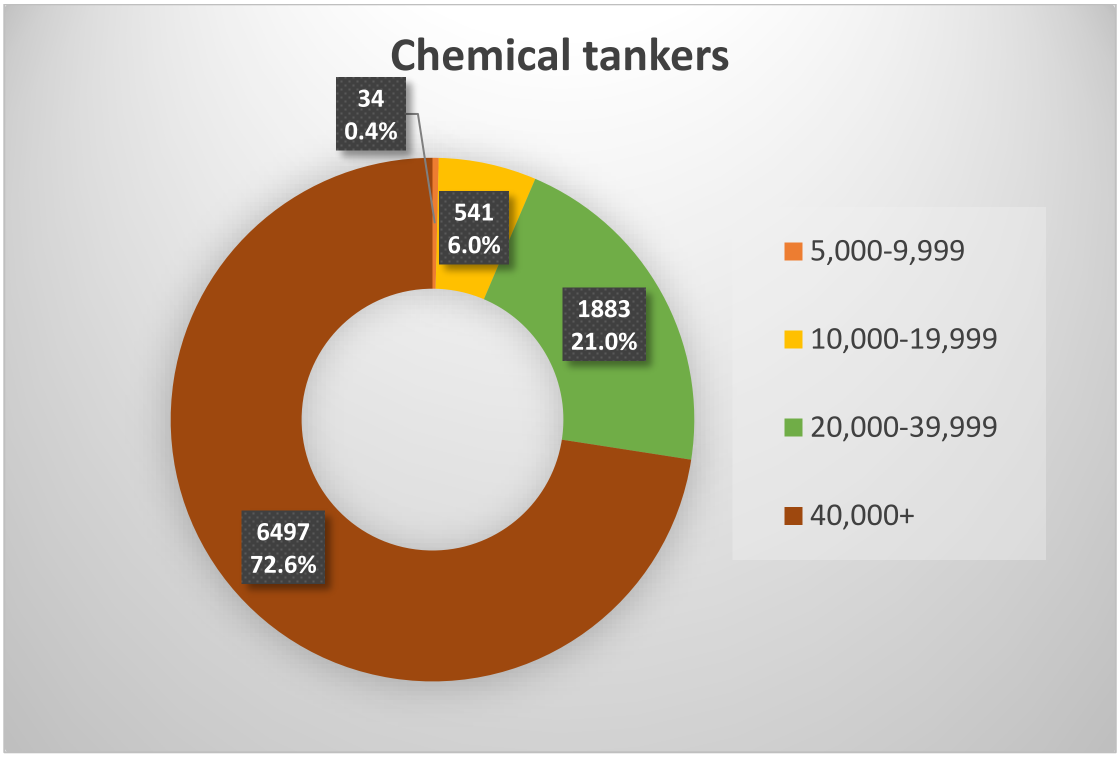



**Figure 3-2 Ship size (deadweight) distribution of chemical tankers that visited California between 2017 January 1st and 2019 December 31st**

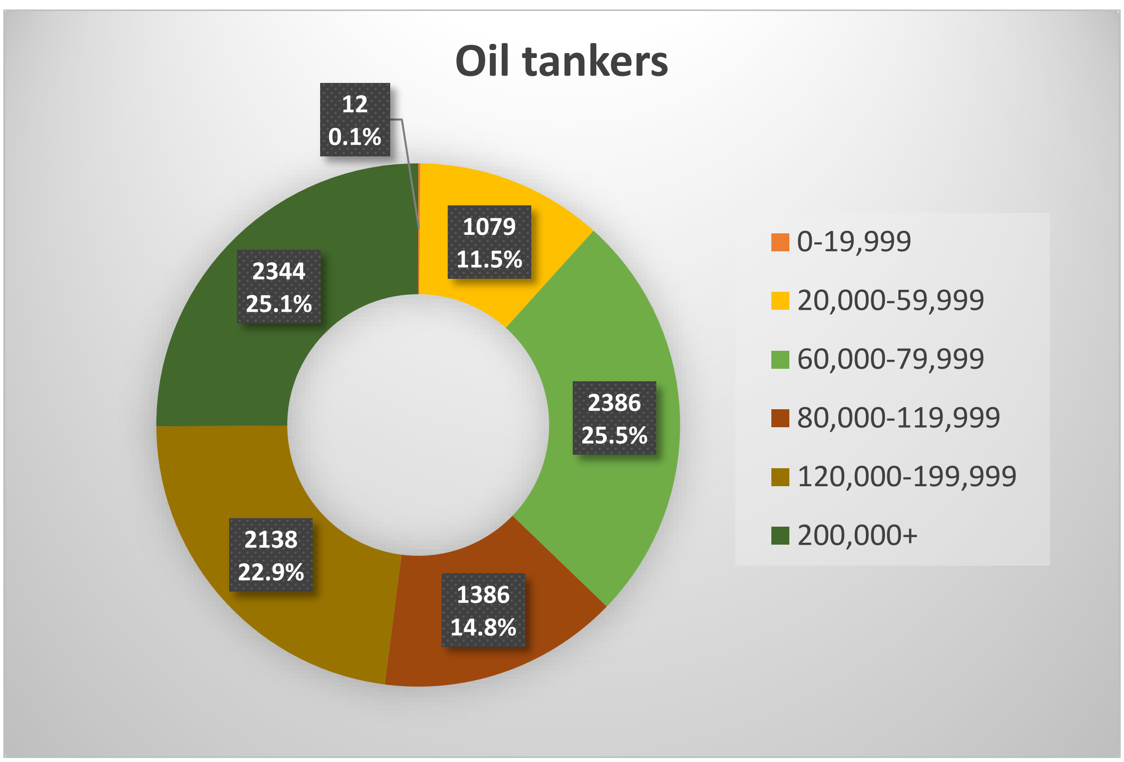



**Figure 3-3 Ship size (deadweight) distribution of oil tankers that visited California between 2017 January 1st and 2019 December 31st**

The following characteristics which are unique to tankers have been reviewed in the study:

- Hazardous zones and risks related to transportation of hazardous cargo
- Wide variation of vessel size
- Significant draft variations during loading/unloading
- Relatively high-power demand from both auxiliary engines and boilers
- Requirement of evacuation during emergency

# 4 THE GENERAL CHARACTERISTICS OF THE RELEVANT TERMINALS

There are 34 marine oil terminals in California where nearly two million barrels of oil and petroleum products are transferred (between ship and shore) daily.[1] The public and stakeholder-provided information from major terminals and ports in California has been reviewed towards developing an understanding of the current facility set up and the generalized settings of terminals that are reasonably representative of California port and marine terminals. The following characteristics of terminals are seen to be relevant to the study:

- The terminal type/arrangement, i.e. "near shore terminals" or "long-wharf (T-head piers)"
  - A majority of the existing oil terminals use the near shore design with a pier that goes into the water, as shown in Figure 4-4. Others new terminals systems are similar to the Marathon 121 in Port of Long Beach and are "platform and dolphin based (Figure 4-5). Most new terminals generally follow this standard.
  - Figure 4-6 shows an example of the long wharf typed marine oil terminal in California.[2] Some terminal infrastructure at San Francisco Bay and Carquinez Straits in Northern California stretched out over a mile into the water. These terminals can be affected by harsher weather conditions and stronger currents than the Southern California counterparts which are in relatively sheltered waters.
- Existence of hazardous zones compared with other type of marine terminals.
- The weather and environmental conditions prevalent at the different terminals such as the Port of Los Angeles and Port of Long Beach in relatively sheltered waters while the terminals at Northern California, such as Richmond and Carquinez strait are more exposed to harsh weather and strong currents. However, it is noted that Port of Richmond terminals are sheltered and not impacted by current or wind like those outside of the sheltered harbor.
- Navigational risks related to potential traffic congestion, collision risks, existence of underground pipelines, turning basins, etc.
- Existing traffic of tankers calling at the ports which impacts the potential energy and power demand

[1] California State Lands Commission

[2] https://ww3.arb.ca.gov/regact/2019/ogvatberth2019/isor.pdf

The next photos show examples of various ports and terminal arrangements discussed above.

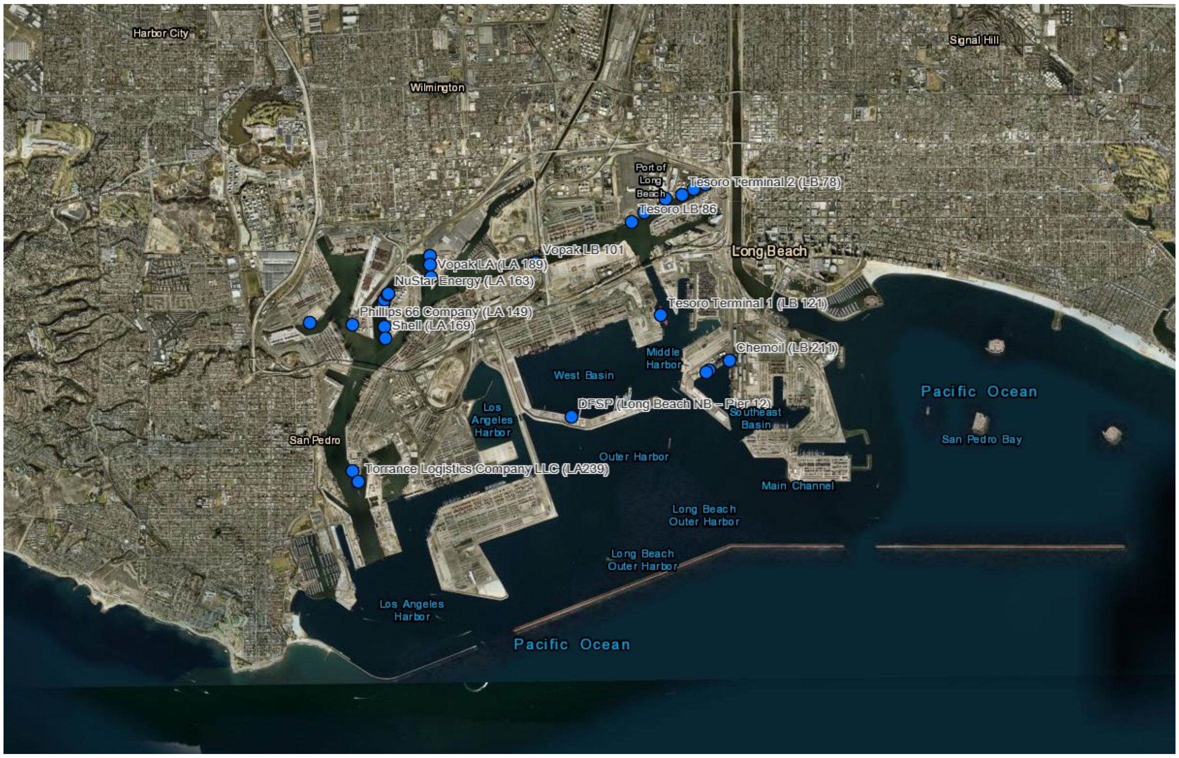



**Figure 4-1 Oil terminals at Port of Los Angeles and Port of Long Beach**[3]

[3] www.arcgis.com

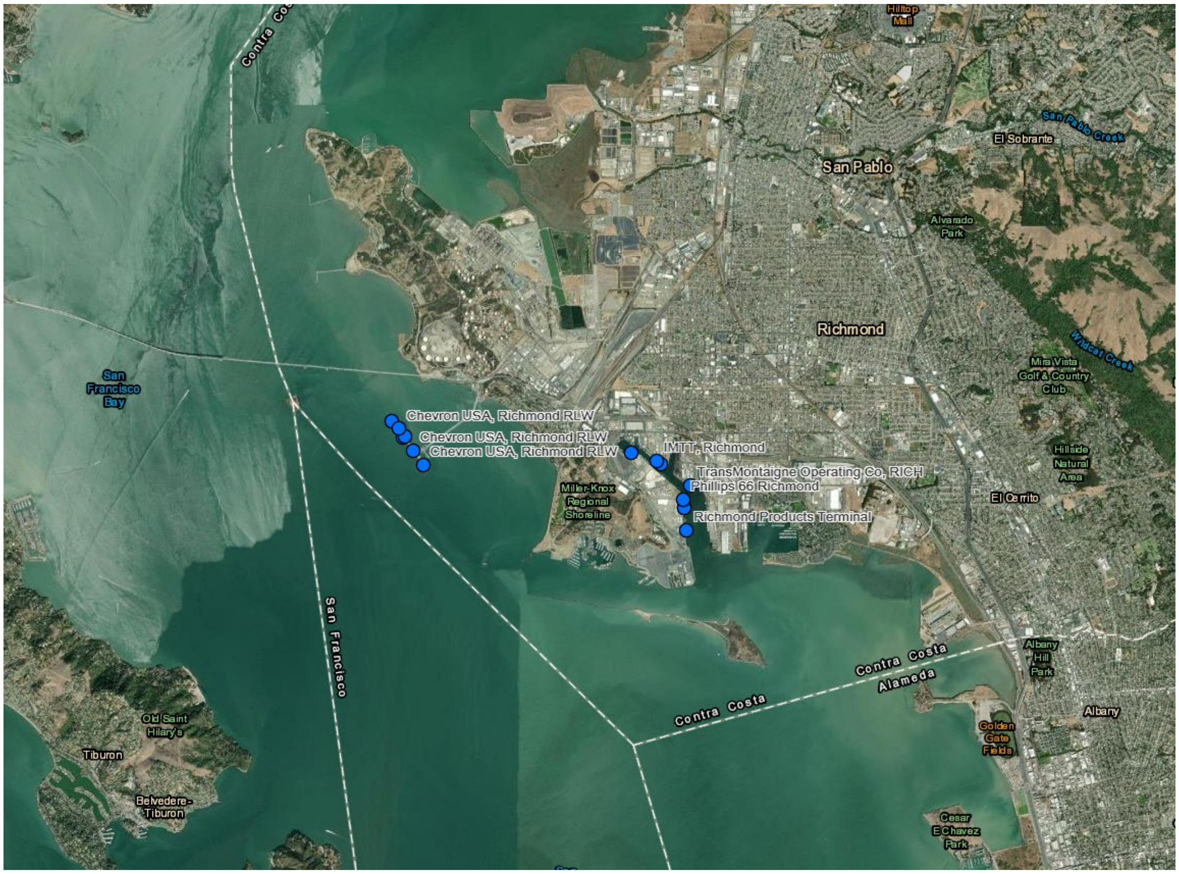



**Figure 4-2 Oil terminals at Richmond**[4]


**Figure 4-3 Oil terminals at Carquinez Strait**[5]

[4] www.arcgis.com

[5] California Energy Commission

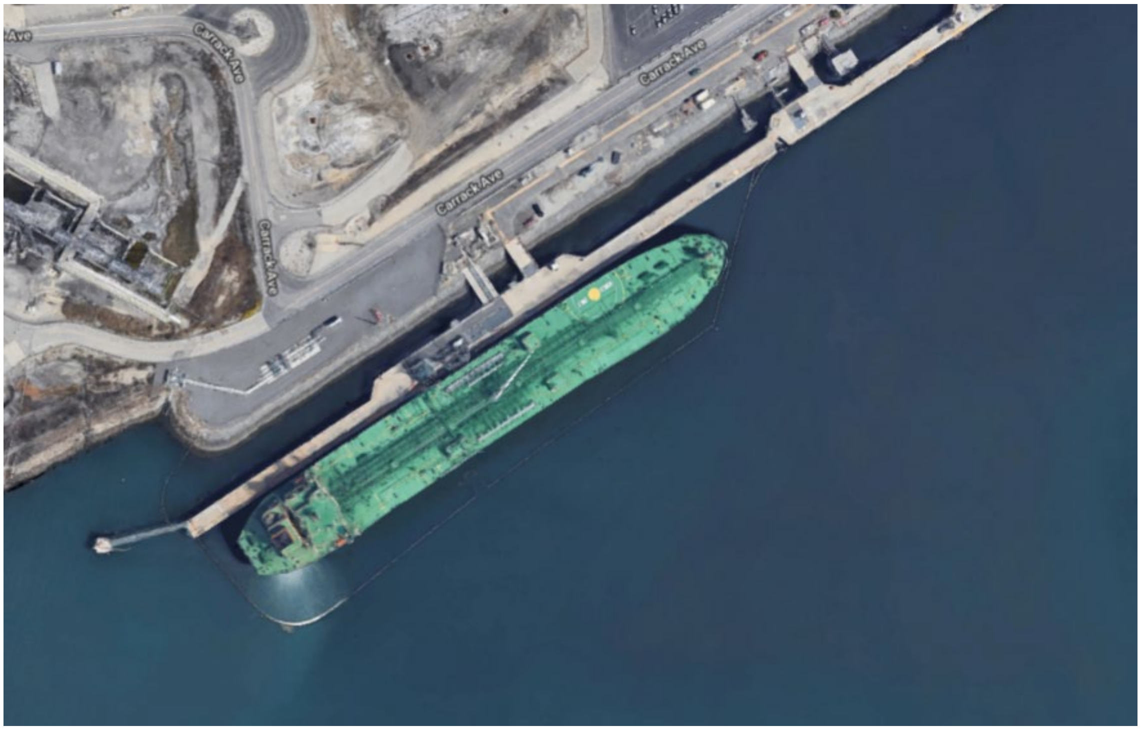



**Figure 4-4 Example of a Port-Based Marine Oil Terminal in Southern California**

**Figure 4-5 Example of a "Platform and Dolphin" based Terminal (Marathon 121 POLB)**

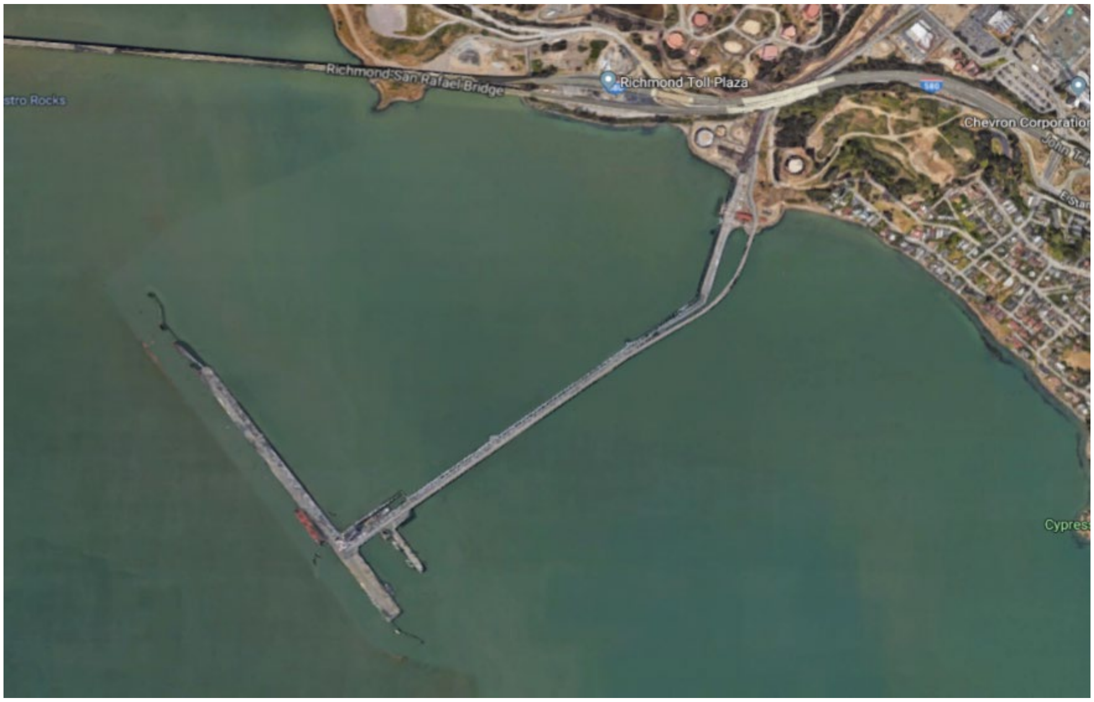



**Figure 4-6 Example of a "Long Wharf" T-shaped Marine Oil Terminal in Northern California**

# 5 STAKEHOLDER ENGAGEMENT

DNV included an extensive array of subject matter experts and key stakeholders (see Appendix I – V) from government and public entities (e.g., CARB, U.S. Coast Guard, Port of Long Beach, Port of Los Angeles) industry and industry groups (e.g., Chevron, ConocoPhillips, PBF Energy, Shell, Philips 66, Intertanko, Oil Companies International Marine Forum (OCIMF), Valero, and technology providers (e.g., Clean Air Engineering – Maritime (CAEM), GMB Marine Services, AECOM, Cavotec) for a comprehensive assessment.

Based on experience from structuring and facilitating stakeholder processes to develop mutually agreeable approaches to policy development and implementation among parties with different and, in some cases, conflicting interests, DNV considers the following approach as relevant to developing and implementing the stakeholder engagement plan.

DNV worked closely with WSPA Steering Committee to develop a clear articulation of WSPA's objectives for the stakeholder process. The objectives for the stakeholder engagement are identified as following:

- Gain recognition from authorities on the feasibility assessment methods applied and the outcomes of the feasibility study.
- Solicitation of fact-based evidence from the stakeholders.

A list of key and potential stakeholders with contact information has been generated together with the Steering Committee. DNV has also utilized internal resources as subject matter experts to provide insights on safety and compliance with relevant tanker technical standards, regulations, and class rules, electrical supply technologies and infrastructure, etc.

DNV developed a stakeholder engagement plan including:

- description of the activity: site tour, review of draft materials, workshops
- objectives of the activity
- list of participants
- the role of the Steering Committee members and DNV staff in the activity

The stakeholder engagement plan has been reviewed and finalized with the Steering Committee.

WSPA's and DNV's own network have been utilized to contact the candidate members, inform them of the objectives, schedule, and expectations of participants, and establish a contact database of those who have agreed to participate.

One-on-one interviews, focused group workshops, email exchanges, and meetings have been performed with selected stakeholders at different stages of the project to ensure engagement.

# 6 TECHNOLOGY ASSESSMENT OF SHORE POWER

## 6.1 Qualification basis

The purpose of the technology qualification basis is to provide a common set of criteria against which all qualification activities and decisions will be assessed.

The technology qualification basis shall describe the technology; define how the technology will be used; the environment in which it is intended to be used; specify its required functions, acceptance criteria, and performance expectations. This includes the performance requirements throughout the life cycle of the technology.

### 6.1.1 Technology Description

In this report, the so-called “shore power technology”, also known as onshore power supply (OPS), means the system supplying a vessel with electrical power using a shore connection while at-berth.

The boundary of OPS starts at the ports’ grid reception point and stops at the ships’ switchboard.

The assessment is mainly performed for assessing the onshore power safety and reliability for tankers while at-berth in California oil terminals.

### 6.1.2 Performance Expectations

This section lists the performance expectations for on shore power.

**Electricity Characteristics and Quality**

**Compatibility of Voltage and Frequency**

When a vessel is powered by the shore power supply, the system voltage and frequency compatibility with the shore utility supply shall be ensured by provision of transformers or other relevant equipment to ensure compatibility.

Based on IEC/IEEE 80005-1:2019, the connections for tankers should be made at a nominal voltage of 6.6 kV. For tankers, the nominal voltage level onboard is normally 440 V AC.  Some tankers may have 6.6 kV / 11.0 kV AC. A voltage transformer may be needed for transforming the voltage to be compatible with the ships’ needs.

In terms of frequency, close to 90% of tankers engaged in worldwide trade use 60Hz electricity. This is beneficial for visiting the US where 60Hz electricity is used in the electrical grid. However, tankers generally have a worldwide operating profile. When ships visit the area using 50Hz electricity, the incompatibility on the power supply’s frequency would have to be resolved by the installation of a frequency converter.

**Power Supply Sufficiency and Continuity**

The shore power shall facilitate sufficient power supply for the normal at-berth operation. Further, the shore power shall facilitate power supply that is reliable and maintains the continuity (whether the electrical power is subject to voltage drops or overages below or above a threshold level thereby causing blackouts or brownouts).

**Variation in Voltage Magnitude**[6]

The shore power's voltage and frequency should be stable. It should not cause malfunction of shipboard systems, e.g., ER/Cargo Control Room alarm and monitor system, gas detection, etc.

- The frequency shall not exceed the continuous tolerances ± 5% between no-load and nominal ratings
- For no-load conditions, the voltage at the supply point shall not exceed a voltage increase of 6% of nominal voltage
- For rated load conditions, the voltage at the supply point shall not exceed a voltage drop of -3.5% of nominal voltage

**Voltage and Frequency Transients**

The response of the voltage and frequency at the shore connection when subjected to an appropriate range of step changes in load shall be defined and documented for each high voltage shore supply installation.

The maximum step change in load expected when connected to a high voltage shore supply shall be defined.

Based on the above, it should be verified that the voltage transients' limits of +20% and −15% and the frequency transients limits of ±10 % will not be exceeded.

**Galvanic separation**

The shore-side electrical system shall ensure that each connected ship is galvanically separated from other connected ships and consumers.

**Harmonic Distortion**

For no-load conditions, voltage harmonic distortion limits shall not exceed 3% for single harmonics and 5% for total harmonic distortion.

**Electromagnetic Compatibility**

The shore power instrument should be compatible with (i.e., no interference is caused by) its electromagnetic environment and it should not emit levels of electromagnetic energy that cause electromagnetic interference in other devices in the vicinity.

**Table 6-1 Electricity characteristics for the shore power supply**[7]
**(Only AC supply characteristics are presented)**

| Parameter | Reference(s) | High Voltage Shore Connection (HVSC) | Low Voltage Shore Connection (LVSC) |
|---|---|---|---|
| **Voltage** | IEC/IEEE 80005-1<br>IEC/IEEE DIS 80005-3<br>IACS Unified Requirements Electrical (Rev.1 Sept 2005) | **6.6kV**<br>**11kV** | **400V**<br>**440V**<br>**690V**<br><br>**230V also possible for less demanding consumption <50kW** |
| **Voltage** | | No-Load Conditions: | No-Load Conditions: |

[6] IEC/IEEE 80005-1
[7] EMSA

| | | | |
|---|---|---|---|
| **Tolerances** | | **6% of nominal Voltage increase**<br>Load Conditions:<br>**3.5% max voltage drop** | **6% of nominal Voltage increase**<br>Load Conditions:<br>**5% (3.5%)[8] max voltage drop** |
| **Frequency** | | 50/60 Hz<br>DC for Fast DC Charging systems | |
| **Frequency Tolerances** | IEC/IEEE 80005-1<br>IEC/IEEE DIS 80005-3<br>IACS Unified Requirements Electrical (Rev.1 Sept 2005) | Continuous tolerance: ±5% | |
| **Transient Response** | | **dV** (voltage transient peak variation): -15% < dV < 20% (1.5sec)<br>**df** (frequency transient variation): ±10% (5sec)<br><br>Transient Response should be well known and documented for:<br>1. Shore side, for the voltage and frequency response, when subject to an appropriate range of different load step changes,<br>2. Ship side for the maximum step change in load expected (this can be an Air Conditioning compressor, electrical pump, crane or electrohydraulic group).<br>The part of the system subjected to the largest voltage dip or peak in the event of the maximum step load being connected or disconnected shall be identified;<br>Combining 1 and 2 it should be verified that the voltage transients limits of +20 % and −15 % and the frequency transients limits of ±10 % will not be exceeded. | |
| **Harmonic Distortion** | | For no-load conditions, voltage harmonic distortion limits:<br>< 3 % (single harmonics)<br>< 5 % (for total harmonic distortion) | |

**Safety and Security for Personnel and Property**

The OPS should provide sufficient safety and security during normal operations and emergencies. It should comply with the relevant regulations and rules. The system should also follow the industry standards and guidelines. These are further discussed in Section 6.1.3.

Safety of personnel shall be ensured by means of suitable barriers to reduce or eliminate hazards. Such barriers need to be considered at design and construction stages by choice of relevant components and their place of installation along with a proper interlocking system, operational procedures and controls as well as considerations in terms of suitable protective gear.

Specifically, for emergencies, an independent system for emergency disconnection shall be arranged with an “Emergency Shut-Down” (ESD) system. There must be a provision to disconnect the supply from ship to shore in case of:

- loss of equipotential bonding
- over tension on the flexible cable
- maximum cable payout reached
- loss of safety circuit
- manual activation of alarm

[8] IEC/IEEE DIS 80005-3 – mentions 3.5%, aligning the maximum voltage drop under loading conditions with the HVSC standard (IEC/IEEE 80005-1). Irrespective of the alignment between the standards, it is important to keep the voltage drop under the shore-power loading condition

-	activation by a protective relay for e.g., short circuit, overload, undervoltage etc
-	disconnection of plugs

In case of emergency shutdown:

-	all switches on board ship and shore must open
-	plugs, sockets, and cable must be earthed automatically

In case of a black-out situation while on shore supply, potentially creating a critical situation for crew or cargo operation, at least one source of main electrical power should be made available to be readily used in such situations. The process and the details of the requirement to restore ships power is covered in the IEC/IEEE 80005-1 standard, section 8.6, as well as in the relevant section of SOLAS CH II and classification societies rules.

The vessel's designed earthing system/ grid configuration shall be maintained in electrical shore connection operation.

**Suitability for Tanker and Oil Terminals**

The shore power system should be suitable for tankers and oil terminals, especially considering the nature of operations involving hazardous cargo.

Ship-to-shore interconnection systems shall be able to compensate for tidal variations and vessel movements due to cargo operation.

**Environmental Protection**

The shore power should be capable of meeting the environmental requirements imposed by regulations, rules, and standards.

### 6.1.3 Applicable Regulations and Standards

The following regulations and standards are relevant for using shore power onto the tankers and terminals.

**Table 6-2 Regulation and standards for using shore power on tankers**

| Category | Tanker and Terminal |
|---|---|
| **Safety:**<br>**Design and operation** | **IMO Regulation**<br>Safety of Life at Seas (SOLAS) Chapter II-1, Part D<br>Interim Guidelines on safe operation of on-shore power supply (OPS) service in port for ships engaged on international voyages (Draft – MSC 103 defers to MSC 105) |
| | **USCG Marine Inspection Notice 02-11 (May 06, 2011)**<br>High Voltage Shore Power Installation of on US Flagged Ships<br>(refer to 46 CFR Subchapter J and to the draft [at that time] IEC/IEEE 80005- 1 |
| | **California State Lands Commission Regulation**<br>Marine Oil Terminal Engineering & Maintenance Standards (MOTEMS) |
| | **Classification Society Rules** |
| | **European Union Standards**<br>EN 15869-1:2019, Inland navigation vessels - Electrical shore connection, three phase current 400 V, 50 Hz, up to 125 A - Part 1: General requirements |
| | **International Standards regarding Interoperability**<br>– IEC / IEEE 80005-1:2019, High voltage shore connection<br>– IEC / IEEE 80005-2:2016, Communication protocol<br>– IEC / IEEE PAS 80005-3:2014, Low voltage shore connection<br>**International Standards regarding Plugs & Socket Outlets**<br>– IEC 62613-1:2019, Plugs, socket-outlets and ship couplers for high-voltage shore connection (HVSC) systems, Part 1:General requirements<br>– IEC 62613-2:2018, Plugs, socket-outlets and ship couplers for high-voltage shore connection |

| | |
|---|---|
| | (HVSC) systems, Part 2:Dimenstional compatibility and interchangeability requirements for accessories to be used by various types of ships<br>– IEC 60309-5:2019 Interconnectivity<br>**International Standards regarding Electrical Installations in Tankers**<br>IEC 60092-502:1999, Electrical installations in ships – Part 502: Tankers – Special features<br>**International Standards regarding Explosive Atmospheres**<br>IEC 60079-19:2019, Explosive atmospheres - Part 19: Equipment repair, overhaul and reclamation |
| | **Maritime Industry Guidelines**<br>OCIMF - Marine Terminal Operator Competence and Training Guide<br>OCIMF - Linked Ship/Shore Emergency Shutdown Systems for Oil and Chemical Transfers<br>International Safety Guide for Oil Tankers and Terminals (ISGOTT)<br>The World Association for Waterborne Transport Infrastructure (PIANC):<br>- Aspects affecting the Berthing Operations of Tankers to Oil and Gas Terminals (2012)<br>- Recommendations for the Design and Assessment of Marine Oil and Petrochemical Terminals (2016) |
| | **Petroleum Industry Standards**<br>API-RP-500 Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2 |
| **Safety: Personnel** | Standards of Training, Certification, and Watchkeeping (STCW) |
| **Environmental protection** | California Air Resources Board's (CARB) ocean-going vessels at berth regulation |

### 6.1.4 Critical Parameters

The critical parameters are parameters that can lead to an unacceptable level of failure, or risk, either alone or in combination with other parameters that have a similar level of risk or failure. The parameters list documents limits that shall not be exceeded either for or by the technology. Hence, when the project has been completed, the boundary limits for the critical parameters will represent the limits for qualification or operating envelope within which the technology is considered qualified.

Key parameters such as dimensioning loads, capacities, boundary conditions and functional requirements shall be summarized in a critical parameters list used in the TQ process. This ensures that the relevant input parameters used for analyses and tests are updated, as changes in design or procedures are made.

The critical parameters for failure mechanisms shall be identified. The critical parameters list shall include the limits/boundaries of these parameters. Where the qualification covers a range (e.g., sizes of the product or material grades) these ranges should be defined by their respective critical parameters. For uncertain parameters, available information about the level of uncertainty should be included.

The critical parameters list should be established in the initial phase of the TQ process. It is anticipated that both the parameters and their limits shall be refined or changed as the project progresses and the understanding of the failure modes and mechanisms develops.

During the technology assessment workshop on May 20, 2021, the following critical parameters have been identified for shore power. The dimensioning loads and operational parameters are to be included in a list to be used to check that these have been considered and addressed in the qualification tests, and that any change to these parameters is reflected in the qualification activities.

**Table 6-3 Critical parameters for using shore power on tankers**

| |
|---|
| **Ship size**<br>If the terminal has various sizes of tankers visiting, the shore power technology should be capable of accommodating the different sizes of ships. The ship length may vary between 100 meters and 350 meters.<br>This may be decided on a case-by-case basis for each terminal. |
| **Height distance between pier and ship board connection point**<br>The shore power technology should be capable of accommodating the height difference, e.g. 16m, between pier and ship board connection point. The variation from tide e.g. maximum 6m and draft e.g. maximum 15m should also be considered. |
| **Crane reach**<br>The crane reach should be sufficient for the gap between shipboard and pier. |

| |
|---|
| **Weather**<br>The wind speed should not impact the normal safe operation of cranes.<br>The wind speed expected are within 35 knots and gusts within 45 knots. |
| **Temperature**<br>The temperature is generally above 0 °C. |
| **Visibility and illumination**<br>The visibility and illumination should be sufficient for the safe crane operations. A light level of not less than 100 lux is recommended. |
| **Life time**<br>The target service time is around 20 years for shipboard instrument. |

## 6.2 Technology assessment

The purpose of the technology assessment is to break down the system into manageable elements to assess which elements involve new technical aspects and identify the key challenges and uncertainties.

The TQ qualification basis forms the input to the technology assessment. The purpose of the TQ basis is to provide a common set of criteria against which all qualification activities and decisions will be assessed. The TQ basis intends to describe the technology; define how the technology will be used; the environment in which it is intended used; specify its required functions, acceptance criteria and performance expectations. This includes the performance requirements throughout the life cycle of the technology. The output is an inventory of the novel technology elements, and their main challenges and uncertainties. The technology assessment shall include the following steps:

— Technology composition analysis

— Assessing the technology elements with respect to novelty (technology categorization).

The novelty assessment can be complemented with an assessment of the maturity of the technology. As an option, this can be aided by using technology readiness levels (TRLs).

In order to fully understand the novel elements of compound technology and provide a means of communication between people within different disciplines, the technology composition shall be analysed. This is a top-down assessment that starts with the system-level functions and proceeds with decomposing the technology into elements including interfaces. The technology composition analysis was conducted during the workshop on May 20, 2021 and the result is given in the table below.

**Table 6-4 Shore power technology composition analysis**

| ID | Subsystem | Main Function | Major Components |
|---|---|---|---|
| - | Power source | The source of power is the one that supplies electrical energy. It is designed to provide electricity with determined values for parameters such as current, amplitude, phase, or frequency.[9] | The major components could include an electricity grid, or port generators, or energy storage facilities, etc. |
| 1 | Main incoming station | To provide power reception interface and to transform the voltage and frequency and provide power management | - Transformers with on-load tap changer (OLTC) or static frequency converter (IEC recommended way for all installations) and conversion transformers which are installed outside ATEX area<br>- Cooling system if frequency converter is installed<br>- Switchgear/distribution gear, if needed |

[9] EMSA

| ID | Subsystem | Main Function | Major Components |
|---|---|---|---|
| 2 | Power cables | The primary functions of power cables are to transfer electrical power between designated locations, within prescribed performance, operating and environmental conditions and to insulate energized components from earthed structures at rated operating voltages and specified switching and lightning impulses. | - Cables (single or multi-core)<br>- Connections (to provide electrical and mechanical connections between power cable sections)<br>- Terminations (to provide an electrical connection between power cables and other electrical plant, principally overhead lines or substation infrastructure)<br>- Cable link boxes (to provide a waterproof, accessible, and explosion-proof enclosure for components forming part of a cable bonding and earthing system including surge arrestors, stand-off insulators and removable links for testing purposes. Bonding systems may include cross-bonding, single-point bonding and mid-point bonding.)<br>- Monitoring system (for temperature and partial discharge monitoring) |
| 3 | Onshore installations, other than cable management system | The main function of onshore installations, other than cable management system, is to provide power control and monitoring. | - Shore-side control panel<br>- Switchgears with earthing switch<br>- Control and safety circuits |
| 4 | Cable management system | The cable management system is mainly for handling the power-supply and control cables as well as the connection devices. | - Cable management system excluding crane<br>- Crane, if needed (either onshore or onboard the ship)<br>- Control panel for cable management<br>- Plug |
| 5 | Shipboard installation | The shipboard installation is mainly for receiving power-supply and control cables for the ship. | - Shore connection switchboard with protection equipment to connect shore side cables, including socket which needs to match the plug<br>- Quick-release physical mechanism and signal system if deemed necessary<br>- Control interface between shore and a ship<br>- Main switchboard and protection equipment<br>- Safety circuits<br>- Automatic Voltage Regulator (AVR) tuning or upgrade for auxiliary generators, for example, ABB Unitrol<br>- Governor tuning or upgrade for auxiliary engines<br>- Power management system with integrated shore power system<br>- Step-down transformer, where applicable, to match shore voltage with ship voltage<br>- Graphic panel-based human-machine interface (HMI) to operate the shore power system |

The cable management system is a crucial part of the shore power technology. It shall[10]:

- be capable of moving the ship-to-shore connection cable, enabling the cable to reach between the supply point and the receiving point
- be capable of maintaining an optimum length of cable which minimizes slack cable, and prevents the tension limits from being exceeded
- be equipped with a device (e.g. limit switches), independent of its control system, to monitor maximum cable tension and maximum cable pay-out
- address the risk of submersion by prevention or through the equipment's design
- be positioned to prevent interference with ship berthing and mooring systems, including the systems of ships that do not connect to shore power while berthed at the facility

[10] IEC/IEEE 80005-1:2019

-   maintaining the bending radius of cables above the minimum bending radius recommended by the manufacturer during deployment, in steady-state operation and when stowed
-   be capable of supporting the cables over the entire range of ship draughts and tidal ranges
-   be capable of retrieving and stowing the cables once operations are complete

Where the cable management system employs cable reel(s), the high voltage shore connection system rated power shall be based on the operating condition with the maximum number of wraps of cable stowed on the reel that is encountered during normal operations. Where applicable, the cable sizing shall include appropriate de-rating factors.

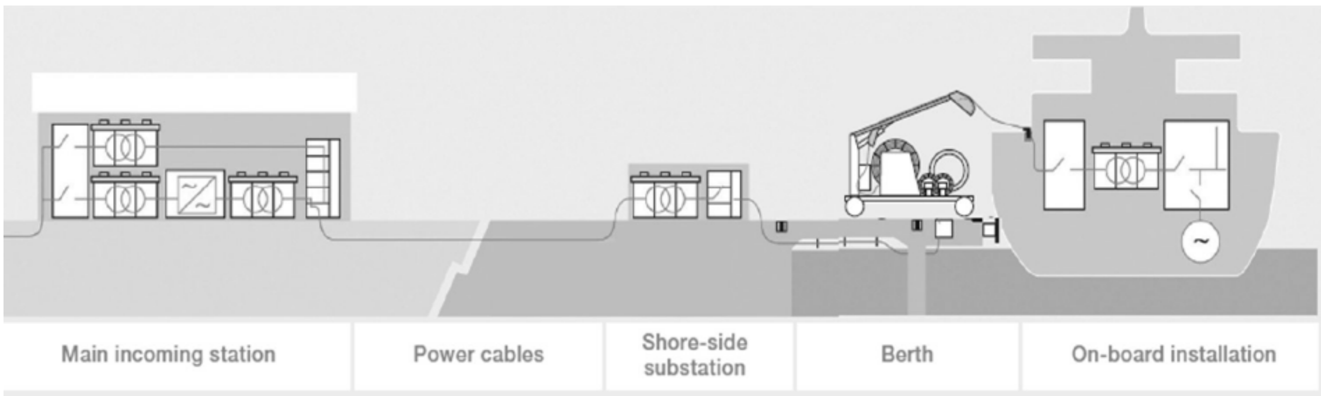



**Figure 6-1 Overview of shore power connection**[11]

Novel technologies typically evolve from existing proven technologies. Normally only some elements of the technology are novel. Therefore, uncertainty is associated mainly with the novel elements. In order to focus on greatest uncertainty, the novelty categorization shown in Table 6-5 has been used. Both the novelty of the technology itself and its application area affect the uncertainty.

Elements categorized as novel (category 2, 3 and 4) shall be taken forward to the next step for further assessment.

Only knowledge and experience that is documented, traceable and accessible to the qualification team should be used to reduce the degree of novelty.

**Table 6-5 Categorization according to DNV Recommended Practice**

| **Application area** | **Degree of the novelty of the technology** | | |
|---|---|---|---|
| | **Proven** | **Limited field history** | **New or unproven** |
| **Known** | 1 | 2 | 3 |
| **Limited knowledge** | 2 | 3 | 4 |
| **New** | 3 | 4 | 4 |

This categorization indicates the following:

- **Category 1:** No new technical uncertainties (proven technology).
- **Category 2:** New technical uncertainties.
- **Category 3:** New technical challenges.
- **Category 4:** Demanding new technical challenges.

[11] ABB

Technology in Category 1 is proven technology where proven methods for qualification, tests, load and relevant analysis can be used to document margins to failure. It is assumed that acceptable margins to failure for these items are achieved through the regular project activities in order to ensure a reliable qualification process for the components in this technology category.

Technology defined as Category 2, 3, or 4 is defined as new technology and requires qualification. Components assigned to these categories will later be subject to the threat assessment, i.e. FMECA and HAZOP. For sub-components that fall into Category 2, 3, or 4, further subdivision of these components may be necessary based on the risk ranking and complexity of the sub-components.

The components and functions were assessed with the industry stakeholders and subject matter experts during the workshop. DNV has reviewed the response from the workshop participants and developed the novelty categorization as below. Some high-level challenges/uncertainties which are relevant to using the components onto tanker and oil terminals discussed during the workshop are also listed in the table below. Detailed risk assessments have been performed and presented in Section 6.3.

**Table 6-6 Components and categories**

| System | Category | Challenge/uncertainty |
|---|---|---|
| Power source | - | The power source may not be able to provide a sufficient and continuous power supply for tankers at-berth. |
| Main incoming station | 1 | - The frequency and voltage between the shore power and shipboard electricity may not be compatible with each other.<br>- The accidental or unexpected power loss of shore power may impact the safety and cargo operation. |
| Power cables | 1 | The oil terminal may not have enough space or strength to carry the power cables. |
| Onshore installations, other than the cable management system | 2 | The terminals may not have sufficient space for the shore power installation. |
| Cable management system | 4 | - The wide range of ship length and berthing configurations may limit access to the shore side supply point.<br>- The crane's reach may not be sufficient for mitigating the gaps between the tanker and the pier. |
| Shipboard installation | 4 | - A short circuit may cause fire or explosion during the transfer of hazardous cargo.<br>- Lacking unified standards for shore power especially the plugs and sockets may induce the tankers cannot use the shore power connection due to its worldwide operation profile. |

In addition to the specific challenges and risk identified in Table 6-6, a general challenge is the lack of shore sided critical electrical components with US and international certifications/ex-ratings that will allow installations and use in hazardous zones on the terminal and ship-shore interfaces.

## 6.3 Threat assessment

The objective of this step is to identify relevant failure modes with underlying failure mechanisms for the novel technology elements and assess the associated risks. **It focuses on the unique risks associated with the application onto tankers.**

The inputs to the threat assessment are the technology qualification basis and the list of the novel technology elements developed in the technology assessment. The output is a failure mode register containing all identified failure modes of concern and their associated risks. Risk is defined by the failure probability and consequence of failure. Its determination shall be undertaken as follows:

- A failure mode assessment shall identify all possible failure modes with their underlying failure mechanisms and shall take into account each of the phases in the service life of a system, equipment or component. The failure modes shall be ranked based on their risk (defined by the probability of occurrence and consequence) or their contribution to overall risk.
- All failure modes shall be registered and handled using an appropriate register, keeping track of all inputs to - and results from - the assessment, including assumptions, risk category, category of technology novelty, failure probability and references to sources of evidence used in the threat assessment.

The threat assessment consists of the following key steps:

— Refine the technology composition assessment performed in the technology assessment step, if necessary.

— Define various categories of probability and consequence severity. This is done prior to the identification of failure modes.

— Define acceptable risk by constructing a risk matrix showing fully acceptable combinations (low risk) and unacceptable combinations (high risk) as well as intermediate combinations (medium risk) of the probability and consequence categories.

— Identify all potential failure modes and rank their risk by using the appropriate method.

— For each failure mode, rank the risk by assigning a consequence class and probability class, or by assessing their contribution to overall system risk. This can be based on previous experience, existing evidence and expert judgments. In the latter case, uncertainties shall be reflected by conservative categorization.

— Store the information for each failure mode in the failure mode register.

There are several threat or failure mode identification techniques in common use. The selection of method should take into consideration the complexity and maturity of the compound technology. The threat assessment shall cover all novel elements defined in the technology composition analysis. The output is a record (failure mode register) of all identified failure modes, failure mechanisms, consequences and probabilities and their associated risk. Various methods for risk analysis can be used for the Threat Assessment.

Failure mode, effect and criticality analysis (FMECA) has been used since it is a simple systematic and structured methodology to determine the effect of a failure. It only investigates ONE failure mode at a time and may not identify critical combinations of failures.

Hazard and operability study (HAZOP) has also been used as it is a systematic method that enables identification of the hazard potential of operation outside the design intention or malfunction of individual items.

Consequences of failure have, when relevant, been detailed for:

- the functions of the technology itself
- impact on surrounding and interfacing systems
- operation and repair
- safety, health and environment (SHE).

The threat assessment process has been carried out as workshops facilitated by DNV via Microsoft Teams on June 7, 2021 and June 8, 2021, involving a panel of experts covering the necessary fields of competence and experiences.

The participants of the workshop are given in Appendix 2.

The detailed results of FMECA and HAZOP are given in Appendix 6.

The critical risks which are unique to the application onto tankers are discussed in this section. A common risk matrix, with pre-defined consequence and probability scales, was applied across the threat assessments. The risk matrix utilized towards ranking the different failure modes and hazards are as indicated in Figure 6-2.

The consequence scale has focused on impact to personnel safety, environment & operation of vessels, terminals & operation of the technology itself. The consequence scale for personnel safety ranges from no impact to multiple fatalities while the environment focuses on no impact to massive impact to the environment. The impact on vessel, terminal, and the technology itself focuses on ranges from seamless operation to los of vessel, failure of essential systems and also the potential underperformance of the technology though this is not captured in the risk matrix explicitly.

The probability scale has focused on rare instance of the event occurring to very high chance of the event occurrence.

The consequence and probability are mapped on to a risk matrix that indicates low (L), medium (M) and high (H) risks. This is based on:

- Categorization of failure scenarios or HAZID by severity and occurrences of failures
- Need for further actions
- Ranking by expert judgement

| Consequence | | | | Probability | | | | |
|---|---|---|---|---|---|---|---|---|
| Personnel safety | Environment | Impact on vessel, terminal or its operation | | **Rare** | **Infrequent** | **Moderate** | **Frequent and high** | **Very high** |
| | | | | Technically to be excluded, or a failure can only occur by combination of two causes | Not probable, to be expected that failure does not occur during lifetime of vessel/component under consideration (once in 100yrs) | Remotely probable, to be expected that failure can occur during lifetime of vessel/component under consideration (once in 10 years) | Probable, to be expected that failure occurs once per year of operation (1 year) | Highly probable, to be expected failure occurs more often than once/yr of operation (<1yr) |
| | | | | **1** | **2** | **3** | **4** | **5** |
| No impact on persons | None | No damage / undisturbed operation | **1** | L | L | L | M | M |
| Single severe or few minor injuries | Minor effect, non-compliance event | Local damage/Operation of non-essential systems disturbed | **2** | L | L | M | M | M |
| Multiple severe injuries | Localized effect, response required | Non-severe ship damage/Failure of non-essential systems | **3** | L | M | M | M | H |
| One fatality | Major effect, significant response required | Severe damage to asset/ops of essential systems disturbed for <1h | **4** | M | M | M | H | H |
| Multiple fatalities | Massive effect damage over large areas | Loss of vessel/Failure of essential systems | **5** | M | M | H | H | H |

**Figure 6-2 Risk Matrix with consequence and probability scale**

<u>Risk classification & explanation</u>

A low risk, indicated by green color and by letter 'L' in the figure above, means that the risk is acceptable.

A medium risk, indicated by yellow color and by letter 'M' in the figure above, means that the risk is manageable but will require monitoring of the risk.

A high risk, indicated by read color and by letter 'H' in the figure above, mean that the risk is unacceptable and needs mitigating actions or risk transfer or other risk reduction measures.

### 6.3.1 FMECA

The FMECA focused on potential failure modes and their effects for the operation of the shore power technology. During the workshop, failure modes from perspective of applicability towards all vessel types were considered and later categorized/filtered to identify the failure modes that would be more relevant specifically for tankers. Ranking of the failure modes are captured in the Figure 6-3 below with risk ids denoted with a # followed by number that relates to type of failure mode considered. Also refer to Appendix 6.

| CONSEQUENCE \ PROBABILITY | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | #5.4 | #0.3 #5.6 | #4.2 #4.3 | | |
| | #5.3 | #1.1 | #5.5 | | |
| | | #0.2 #2.1 #5.2 | #0.1 #4.1 #5.1 | | |

**Figure 6-3 Risk ranking for FMECA**

The overall risk ranking indicated 29 risks in total with one risk left unranked. Out of the 28 risks identified, 14 of them were found more relevant for tankers. These are indicated in the risk ranking figure above. Out of the 14 risks identified, 3 x risks were high risks, 10 x risks were medium risks, and one risk was low risk. This section describes the details of all the risks relevant for tankers when it comes to utilizing the shore power technology.

Without mitigation, the three risks ranked as high may present serious challenges to the feasibility of implementation, namely: insufficient power to meet potential demand, and possible restrictions on the fleet able to utilize shoreside infrastructure due to terminal and berthing arrangements, exacerbated by equipment location restrictions.

#### 6.3.1.1 FMECA 0.1 – Insufficient power supply from the electrical grid for the potential demand from the tankers calling at the ports.

For all tankers, the energy is normally generated by auxiliary engines and boilers while at berth.

For chemical/product tankers, the energy generated by auxiliary engines and boilers at berth is mainly consumed by:

- Accommodation load (lighting, HVAC, etc.)
- Ballast/de-ballast

- Cargo pumping operations (normally there is one cargo pump for each cargo tank)
- Heating/cooling, as applicable to the cargo type
- Inert gas generation, as applicable

For crude oil tankers, the power generated by auxiliary engines and boilers at berth is mainly consumed by:

- Accommodation load (lighting, HVAC, etc.)
- Ballast/de-ballast
- Cargo pumping operations (normally there are 3 cargo pumps)
- Cargo heating system, as applicable in the slop tanks

According to the CARB at-berth regulation, "for tanker vessels with steam driven pumps, **unless the tanker is using shore power to reduce emissions from auxiliary engines**, a person must demonstrate that the CAECS achieves emission rates less than 0.4 g/kW-hr for NOx, 0.03 g/kW-hr for PM 2.5, and 0.02 g/kW-hr for ROG for tanker auxiliary boilers." As such, only the auxiliary engine power output is assessed for the potential power demand of shore power.

The auxiliary engine power output is referred to Fourth IMO GHG Study 2020 and quoted below. It shall be noted that this only provides a high-level estimation. The detailed power output varies a lot depending on the vessel's configuration and actual operations at berth.

**Table 6-7 Potential at berth auxiliary engine power output for tankers**[12]

| Ship type | Size [DWT] | At berth Auxiliary Engine Power Output [kW] |
|---|---|---|
| **Chemical tanker** | 0-4,999 | 110 |
| | 5,000-9,999 | 330 |
| | 10,000-19,999 | 330 |
| | 20,000-39,999 | 790 |
| | 40,000+ | 790 |
| **Oil tanker** | 0-4,999 | 250 |
| | 5,000-9,999 | 375 |
| | 10,000-19,999 | 690 |
| | 20,000-59,999 | 720 |
| | 60,000-79,999 | 620 |
| | 80,000-119,999 | 800 |
| | 120,000-199,999 | 2,500 |
| | 200,000+ | 2,500 |

AIS data in 2017, 2018, and 2019 (2020 has been disregarded due to the impact of the COVID-19 pandemic) has been analyzed for Port of Long Beach, Port of Los Angeles, and Port of Richmond to analyze the tankers' traffic and the port stay duration per the categories given in Table 6-7.

[12] International Maritime Organization - Fourth IMO GHG Study 2020

If it is assumed that all tankers are equipped with shore power technology, combining the estimated at berth auxiliary engine power output in Table 6-7 and the port stay duration based on the AIS data, the monthly potential shore power energy demand [MWh] is shown below.

- For tankers berthing at Port of **Los Angeles**, the **average** estimated monthly auxiliary engine energy output is 708MWh and **maximum** estimated monthly auxiliary engine energy output is 1,019MWh. The average estimated yearly auxiliary engine power output is around 40% of the installed shore power system.[13]
- For tankers berthing at Port of **Long Beach**, the **average** estimated monthly auxiliary engine energy output is 3,108MWh and **maximum** estimated monthly auxiliary engine energy output is 5,422MWh.
- For tankers berthing at Port of **Richmond**, the **average** estimated monthly auxiliary engine energy output is 1,558MWh and **maximum** estimated monthly auxiliary engine energy output is 1,898MWh.

In this analysis based on AIS data, the estimated power is for all the oil terminals in each port and not an analysis per terminal. As can be seen from the above, Port of Long Beach potentially has the highest total shore power demand from tankers.

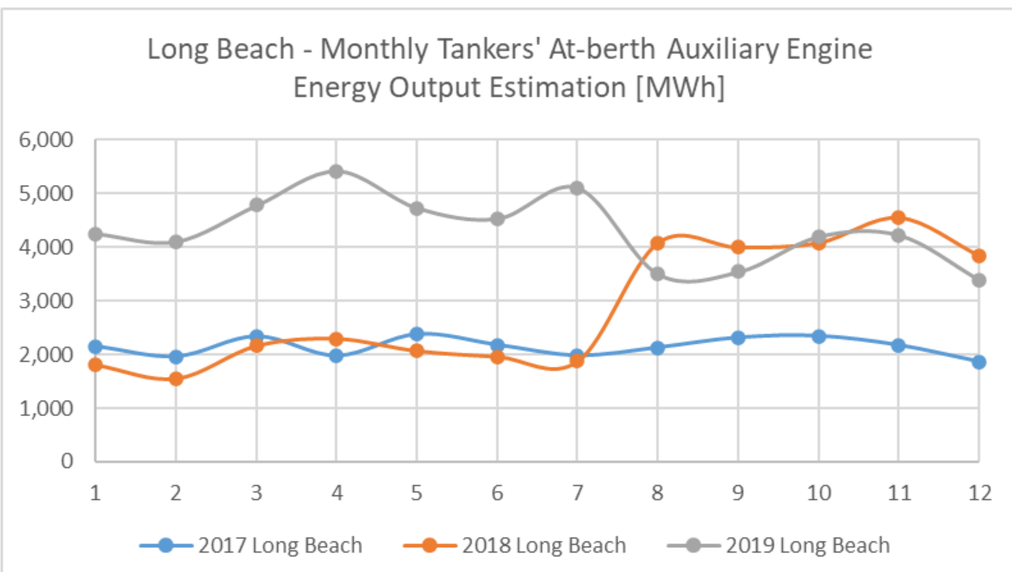



**Figure 6-4 Long Beach - Monthly Tankers' At-berth Auxiliary Engine Energy Output Estimation**

[13] United States Environmental Protection Agency Office of Transportation and Air Quality - Shore Power Technology Assessment at U.S. Ports, March 2017

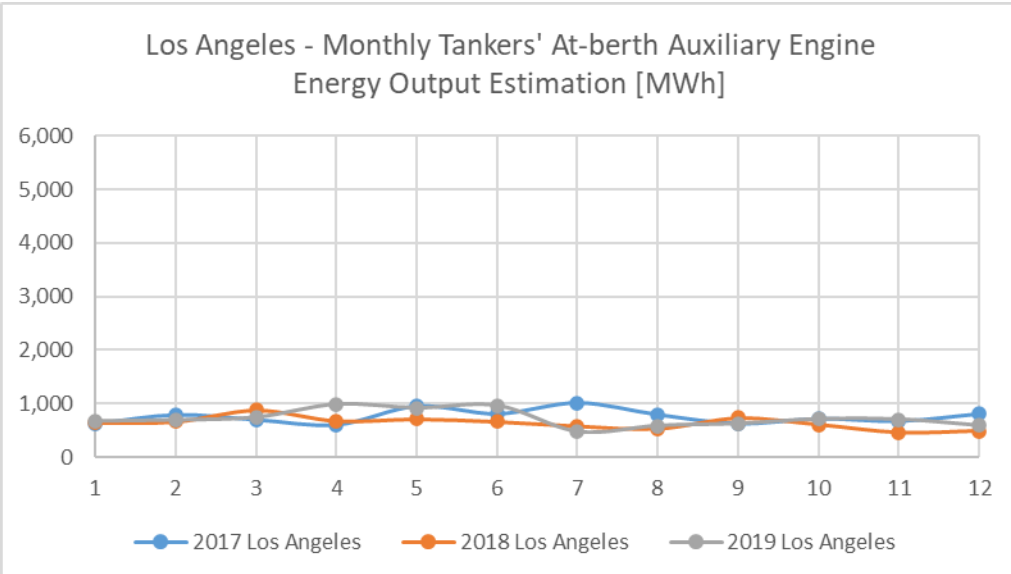



**Figure 6-5 Los Angeles - Monthly Tankers' At-berth Auxiliary Engine Energy Output Estimation**

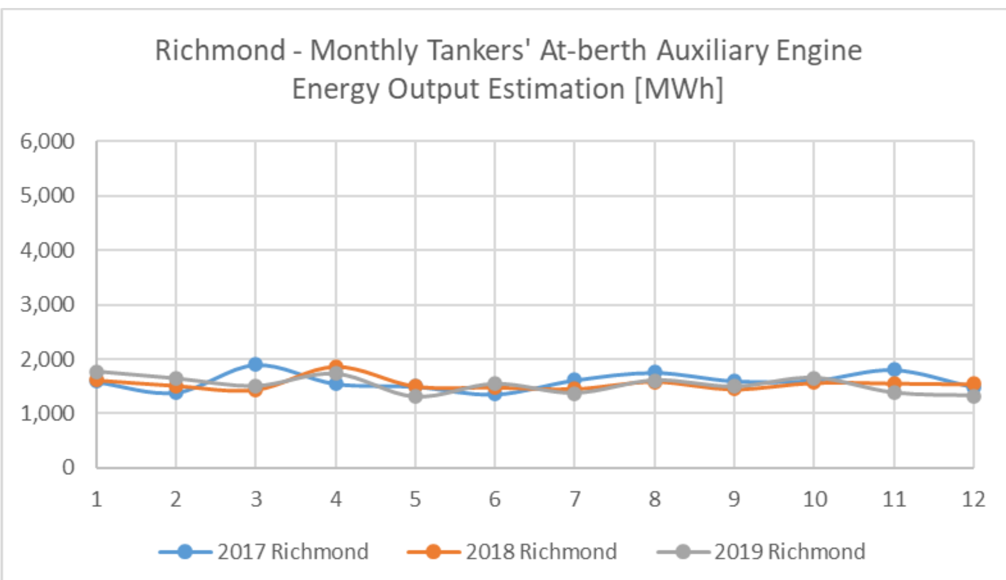



**Figure 6-6 Richmond - Monthly Tankers' At-berth Auxiliary Engine Energy Output Estimation**

The technical specifications for the existing high voltage shore power systems at Port of Los Angeles and Port of Long Beach are cited from "Shore Power Technology Assessment at U.S. Ports, March 2017" and shown below. As shown, to accommodate the potential maximum power demand [MW] from visiting tankers, the capacity of the existing shore power system may need to be almost doubled.

**Table 6-8 Technical specifications for high voltage shore power systems**[14]

| | Vessel Type using OPS | Year of Installation | Maximum Capacity [MW] | Frequency [Hz] | Voltage [kV] | Manufacturer |
|---|---|---|---|---|---|---|
| **Los Angeles** | Container<br>Cruise | 2004 | 40.0 | 60 | 6.6 | Cavotec |
| **Long Beach** | Container<br>Cruise | 2009<br>2011 | 16.0 | 60 | 6.6 & 11 | Cavotec; Cochran Marine |

The auxiliary engines' power output [MW] from tankers while at berth is also estimated based on the following inputs and assumptions:

- The average auxiliary engine output per tanker category is assumed based on IMO 4th GHG study. It shall be noted that this may not be on the conservative side as the auxiliary engines' peak load is not reflected.
- Historical AIS data in 2017, 2018, and 2019 is used to analyze the visiting tankers' number, size, and port stay duration.

As shown in Figure 6-7, for Port of Los Angeles in 2017, 2018, and 2019:

- There has been a maximum of 6 tankers at berth at the same time and on average there are 2 – 3 tankers at berth at the same time.
- On average, the estimated tankers' at berth auxiliary engine output is around 2.8 MW.
- The maximum estimated tankers' at berth auxiliary engine output is around 12.0 MW. This is around 30% of the existing shore power facility's maximum capacity which is at 40MW according to EPA's report about Shore Power Technology Assessment.[15]

As shown in Figure 6-8, for Port of Long Beach in 2017, 2018, and 2019:

- There has been a maximum of 9 tankers at berth at the same time and on average there are 3 – 4 tankers at berth at the same time.
- On average, the estimated tankers' at berth auxiliary engine output is around 4.9 MW.
- The maximum estimated tankers' at berth auxiliary engine output is around 13.9 MW. This is around 87% of the existing shore power facility's maximum capacity which is at 16MW according to EPA's report about Shore Power Technology Assessment.[16]

[14] United States Environmental Protection Agency Office of Transportation and Air Quality – Shore Power Technology Assessment at U.S. Ports, March 2017

[15] United States Environmental Protection Agency Office of Transportation and Air Quality - Shore Power Technology Assessment at U.S. Ports, March 2017

[16] United States Environmental Protection Agency Office of Transportation and Air Quality - Shore Power Technology Assessment at U.S. Ports, March 2017

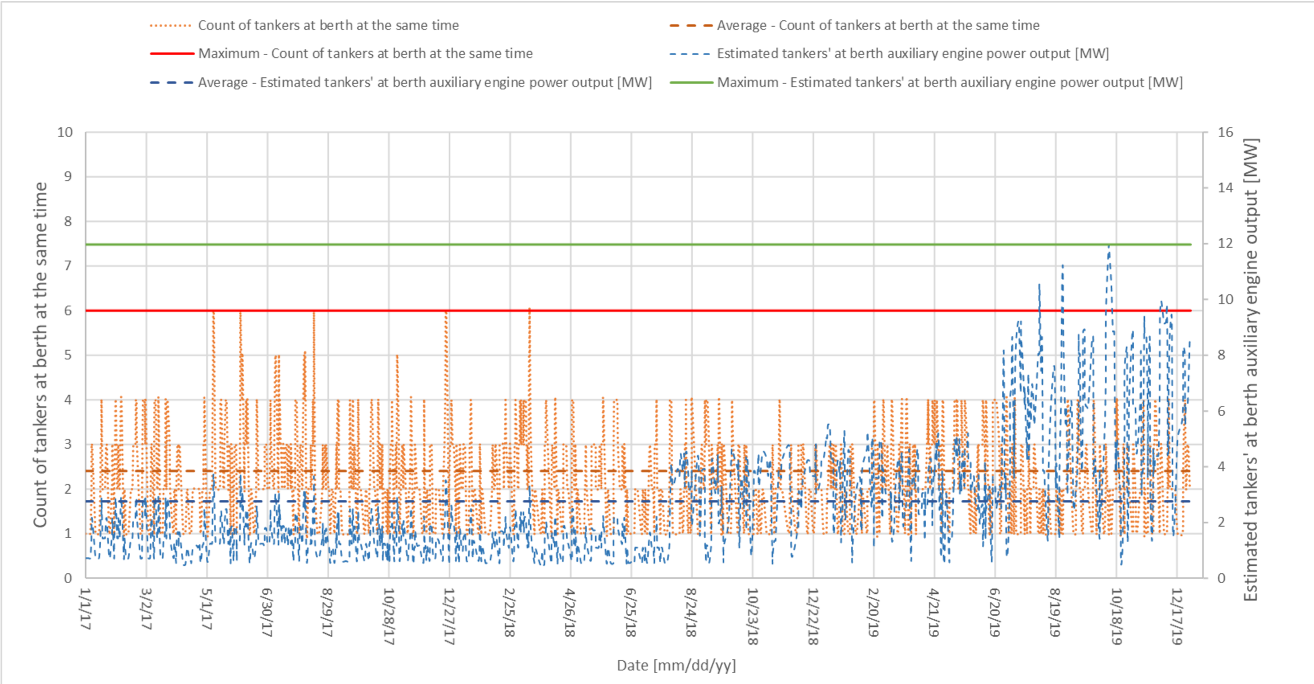



**Figure 6-7 Los Angeles – Count of tankers at berth at the same time and estimated at berth auxiliary engine power output [MW] in 2017 ~ 2019**

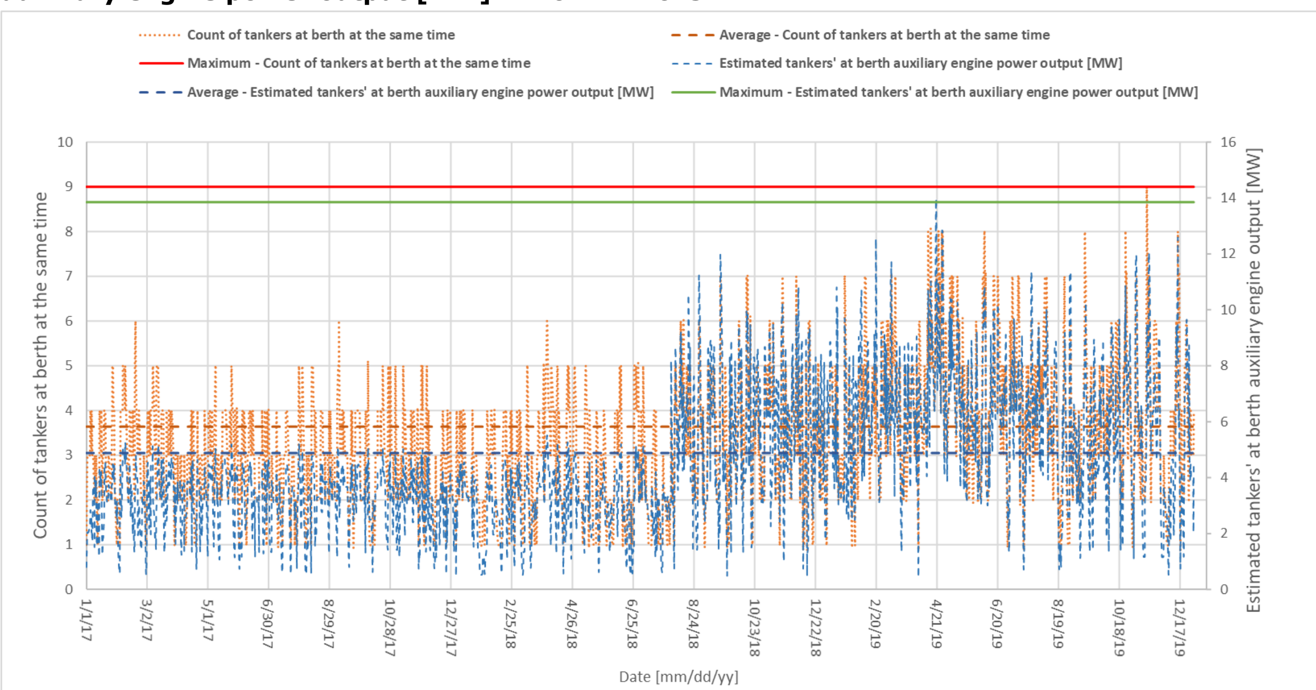



**Figure 6-8 Long Beach – Count of tankers at berth at the same time and estimated at berth auxiliary engine power output [MW] in 2017 ~ 2019**

The potential power demand from tankers depends on the uptake of the shore power technology from the terminals and tankers. Applying shore power onto tankers visiting California will increase the power demand for a port. Ports' existing power infrastructure may not be sufficient to provide the additional power load, particularly with the consideration of hot weather when significant demand and strain have been put on California's energy grid..

To evaluate and mitigate this risk, the energy agencies, ports, and their electrical utility companies (such as Southern California Edison, Pacific Gas and Electric Company, etc.) will need to be involved to review the feasibility and develop a plan for providing the additional power load – adding additional layers of complexity to an implementation process and likely prolonging the timeline.

#### 6.3.1.2 FMECA 4.1 - Limited access to the shore side supply point for some tankers due to varied dimensions and berthing configuration of such tankers

The potential locations of installing the shore power connection points have been discussed in Section 6.3.1.9. If shore power connection points are not installed around the midship, the wide range of tanker sizes and two possible berthing orientations would seriously restrict the number of tankers able to utilize such a connection.

For tankers calling California in 2017, 2018, and 2019, the ship's overall length has been analyzed based on Lloyd's List vessel database. It shows that the tankers' size has large variations variety, and it may be between 104 meters to 340 meters [340 feet – 1100 feet].

**Table 6-9 Tankers' overall length**[17]

| Ship type | Size [DWT] | Minimum Overall Length [m] | Maximum Overall Length [m] |
|---|---|---|---|
| **Chemical tanker** | 0-4,999 | - | - |
| | 5,000-9,999 | 117 | 127 |
| | 10,000-19,999 | 127 | 162 |
| | 20,000-39,999 | 141 | 200 |
| | 40,000+ | 175 | 250 |
| **Oil tanker** | 0-4,999 | 104 | 330 |
| | 5,000-9,999 | - | - |
| | 10,000-19,999 | - | - |
| | 20,000-59,999 | 171 | 224 |
| | 60,000-79,999 | 183 | 236 |
| | 80,000-119,999 | 227 | 256 |
| | 120,000-199,999 | 250 | 292 |
| | 200,000+ | 300 | 340 |
| **Length range** | | **104** | **340** |

[17] Lloyd's List database

Using Marathon Long Beach Berth 121 marine terminal as an example, the terminal could accommodate VLCC of as long as 340m [1100 feet]. An example is shown in Figure 6-9. Comparing with the Alaskan Navigator (LOA 290m [950 feet]), which is equipped with shore power (shown overlayed), a VLCC can be about 50m [150 feet] longer. The existing cable management system may not be able to cover the required horizontal reach for various sized tankers visiting the terminal (i.e. to reach a shipboard connection point on the far side of the ship), which might prevent the largest of tankers from utilizing the connection.

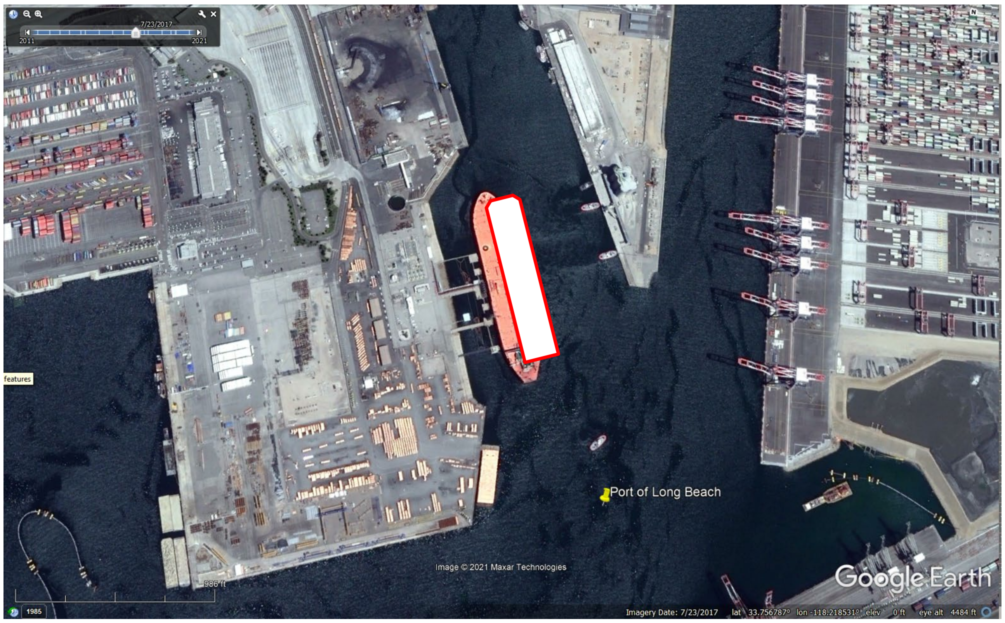



**Figure 6-9 Satellite photo of a VLCC (IMO No.: 9302968) calling Marathon Long Beach Berth 121 on 23-July-2017**

In addition, for some terminals, the tanker may have the possibility of berthing either along the portside or the starboard side. This depends on the channel's navigation condition, weather condition, where the loading/offloading connections on the vessel are located etc. An example of Marathon Long Beach Berth 78 is shown in the figures below. For the scenarios of a VLCC or Suezmax berthing on the port side and a VLCC or Suezmax berthing on the starboard side, it may induce a range of around 500 ~ 600 m [1600 feet – 2000 feet] to be covered by the shore power cable management system. This range of length may pose challenges and may require special considerations for shore side connection to the cable management system while considering the need to account for tidal and draft variations.

Similar technical challenge applies to the container vessels. At Port of Long Beach, to maximize shore power connection at the container terminals, the Port staff established design criteria, which requires shore power outlets every 200 feet [61m], combined with a 100-foot [30m] movable supply point. This type of arrangement may not be feasible considering the restrictions for hazardous zones applicable for tankers and oil terminals. Further, space constraints as discussed in Section 6.3.1.11 may not facilitate this arrangement. In this context the IEC/IEEE 80005 standard doesn't permit the use of extension cables, due to possible safety risks associated with the additional connecting plugs, cable design, and maintenance.

Based on the above discussions, the wide range of the length of the tankers visiting the California oil terminals, the two scenarios of vessel orientations at the terminals and hazardous zones are identified as significant challenges to the implementation of shore power to tankers. These issues may impose risks on shore power connection compatibility between the tanker, the cable management system, and the onshore installation on the terminal.

An industry standardized solution on the installation location of the shore power connection is recommended. If the connection location is agreed to be arranged in the non-hazardous area, e.g., stern of the tanker, a cost-effective cable management system that is complying with the standards to accommodate the existing portfolio of tankers is recommended to be developed. The solutions or design changes will need to be reviewed for compliance with the existing technical standards to avoid introducing additional safety and operational risks as noted in the above paragraph.

Before an industry standardized solution is available, the shore power connection locations will need to be investigated closely for each terminal based on the terminal configuration and the portfolio of visiting tankers.


**Figure 6-10 Satellite photo of a tanker berthing on the port side at Marathon Long Beach Berth 78**

**Figure 6-11 Satellite photo of a tanker berthing on the starboard side at Marathon Long Beach Berth 78**

### 6.3.1.3 FMECA 5.1 – Fire or explosion risk from ignition sources during transfer of hazardous cargo

Potential sources of ignition from electrical equipment include:

- Electric sparks
- Arcs and flashes
- Electrostatic discharges
- Electromagnetic waves
- Hot surfaces
- Flames and hot gases
- Mechanically generated sparks
- Chemical reaction[18]

For electrical systems, there are hazardous areas defined for both tankers and marine oil terminals.

- For tankers, it generally follows the Classification rules which are normally aligned with IEC standard 60092-502:1999.
- For marine oil terminals, MOTEMS provides minimum standards for electrical systems. According to MOTEMS, hazardous area classifications shall be determined in accordance with API RP 500[19], API RP 540[20] and Articles 500, 501, 504, 505 and 515 of the California Electrical Code.

[18] International Safety Guide for Oil Tankers and Terminals (ISGOTT 6) 6th Edition, 2020

The International Convention for the Safety of Life at Sea (SOLAS) is an international maritime treaty which sets minimum safety standards in the construction, equipment and operation of merchant ships. In SOLAS, it prescribes that for tankers **electrical equipment, cables and wiring shall not be installed in hazardous locations unless it conforms with standards not inferior to those acceptable to the Organization**.[21] This is also stated in the International Electrotechnical Commission standard, IEC 60092-502:1999 Electrical installations in ships – Tankers.

According to DNV Rules for Classification: Ships, Part 5 Chapter 5 Oil tankers and Chapter 6 Chemical tankers, **electrical equipment and wiring shall in general not be installed in hazardous areas**. Where essential for operational purposes, the arrangement of electrical installations in hazardous areas shall comply with DNV Rules for Classification Part 4 Chapter 8 Section 11. This principle is aligned with the other International Association of Classification Societies (IACS) members.

Hazardous areas are described in SOLAS Chapter II-1, Part D, Regulation 45. The hazardous areas are divided into three zones. The typical hazardous areas for each zone and equipment installation alternatives according to DNV Rules for Classification: Ships are given in Table 6-7. The typical hazardous area arrangement for a tanker is shown in Figure 6-12 and Figure 6-13. The detailed definition of hazardous areas and requirements shall refer to SOLAS and class rules.

In summary, based on SOLAS, IEC standards, and Classification Rules, electrical equipment and wiring shall in general not be installed in hazardous areas. If the shore power connection has to be installed within the hazardous zone, the electrical equipment generally has to be explosion-proof (ex rated). However, currently, there is not yet a marine use socket complying with the explosion-proof requirement. Further evaluation would be necessary to determine the feasibility of developing an explosion-proof socket suitable for marine use within the CARB at-berth regulation timeframe, the lack of which would restrict the number of tankers able to utilize infrastructure.

**Table 6-10 Typical hazardous areas for a tanker and Ex protection requirements according to zones in DNV Rules Pt.5, Ch.5, Sec.8**

| Zone | Typical areas | Ex protection requirements according to zones in DNV Rules[22] |
|---|---|---|
| **Zone 0** | - Cargo tanks, slop tanks<br>- Pipes and equipment containing cargo or developing flammable gas | a) Electrical equipment installed in zone 0 shall normally be certified safe for intrinsic safety Ex ia, or certified safe with EPL Ga.<br>b) For zone 0 systems, the associated apparatus (e.g. power supply) and safety barriers shall be certified safe for Ex ia application.<br>c) Equipment specially certified for use in zone 0. |
| **Zone 1** | - Space adjacent to Zone 0, e.g. void spaces, cofferdams, pump rooms, trunks, fore peak tanks etc.<br>- Some areas on the open deck, or semi-enclosed spaces on deck, e.g.:<br>o Areas on open deck, or semi-enclosed spaces on deck, within 3 m of any cargo tanks outlet, gas or vapor outlet, cargo manifold valve, cargo valve, cargo pipe flange, cargo pump-room ventilation outlets and cargo tank openings for pressure release provided to permit | a) Certified safe for zone 0 application, or certified safe with EPL Ga.<br>b) Certified safe for zone 1 application, or certified safe with EPL Gb.<br>c) Normally, Ex o (oil filled) and Ex q (sand filled) are not accepted. However, small sand filled components as i.e. capacitors for Ex e light fixtures are accepted. |

[19] American Petroleum Institute (API), API Recommended Practice 500 (API RP 500), "Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2," 3rd edition, December 2012

[20] American Petroleum Institute (API), API Recommended Practice 540 (R2004) (API RP 540), "Electrical Installations in Petroleum Processing Plants," 4th edition, 1999

[21] The International Convention for the Safety of Life at Sea (SOLAS) Chapter II-1, Part D, Regulation 45.11

[22] DNV Rules for Classification: Ships, Part 4 Chapter 8 Section 11, July 2021

| | | |
|---|---|---|
| | the flow of small volumes of gas or vapor mixtures caused by thermal variation.<br>○ Areas on open deck, or semi-enclosed spaces on open deck above and in the vicinity of any cargo gas outlet designed for the passage of large volumes of gas or vapor mixture during cargo loading and ballasting or during discharging, within a vertical cylinder of unlimited height and 6 m radius centered upon the center of the outlet, and within a hemisphere of 6 m radius below the outlet.<br>○ Areas on open deck over all cargo tanks (including ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and the aft-most cargo tank bulkhead, up to a height of 2.4 m above the deck. | |
| **Zone 2** | - 1.5 meters from Zone 1 in open and semi-enclosed spaces<br>- 4 meters from Zone 1 surrounding high-volume Zone 0 outlet<br>Fore peak tank connected to main ballast system in case separated from cargo tanks by a cofferdam<br>- On the top of the deckhouse it may have a small hazardous zone for the battery room, paint store, chemical room | a) Certified safe for zone 0 application, or certified safe with EPL Ga.<br>b) Certified safe for zone 1 application, or certified safe with EPL Gb.<br>c) Certified safe for zone 2 application, or certified safe with EPL Gc.<br>d) Have a manufacturer conformity declaration stating that it is made in accordance with an Ex n standard.<br>e) Documented by the manufacturer to be suitable for zone 2 installation. This documentation shall state compliance with a minimum enclosure protection as per IEC 60079-15, maximum temperature for internal or external surfaces according to the temperature class for the area and that the equipment contains no ignition sources during normal operation. |

Examples of one crude oil tanker and one product tanker's hazardous areas are given below.

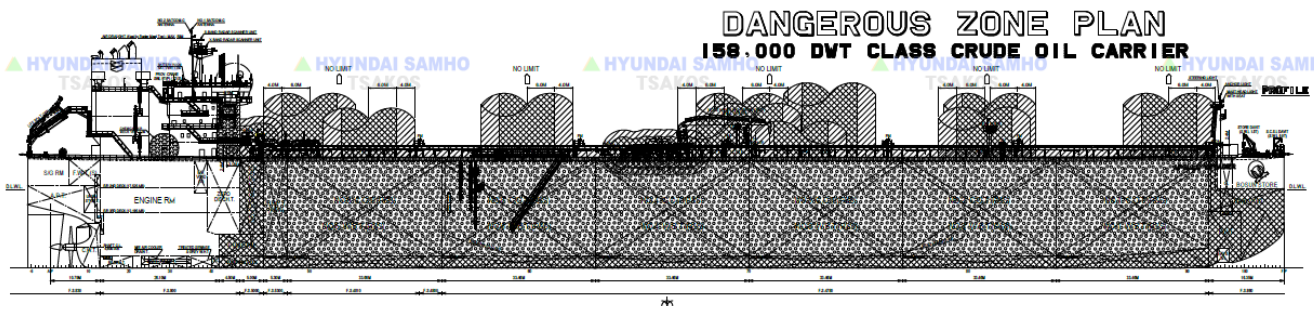



**Figure 6-12 Example of one crude oil tanker's hazardous areas**

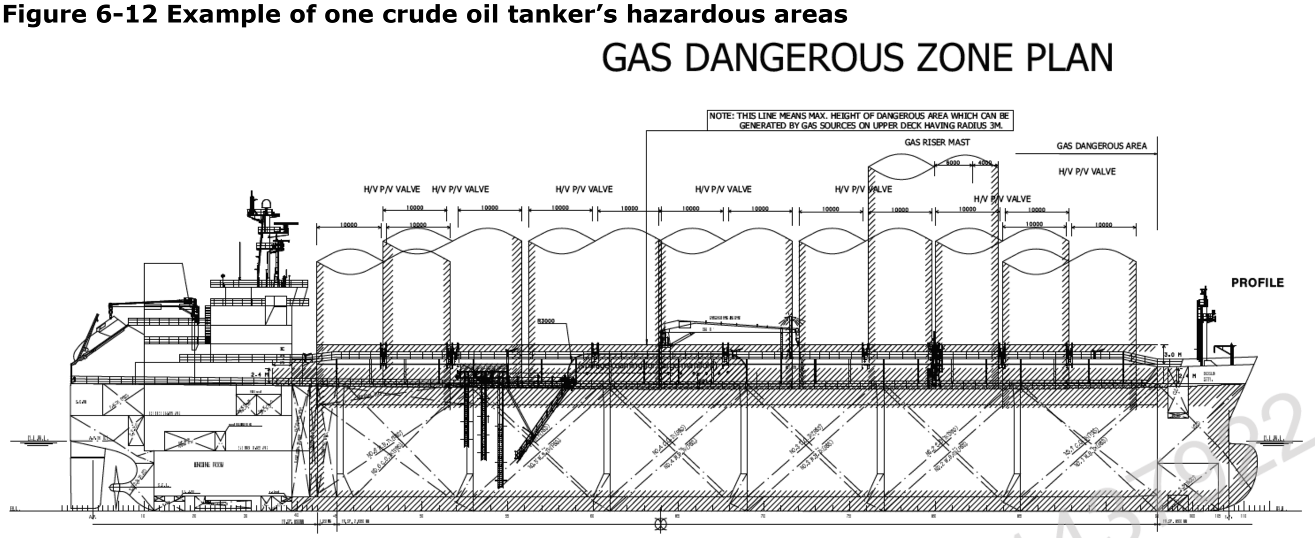


**Figure 6-13 Example of one product tanker's hazardous areas**

As mentioned earlier, the marine oil terminals also have their definition of hazardous area. According to API-RP-500[23], the hazardous (classified) location at marine terminals handling flammable liquids is shown in Figure 6-14. The marine terminals regulations around minimum standards for electrical systems, hazardous area classifications & other requirements should be complied with similar to requirements around hazardous zone for tankers.

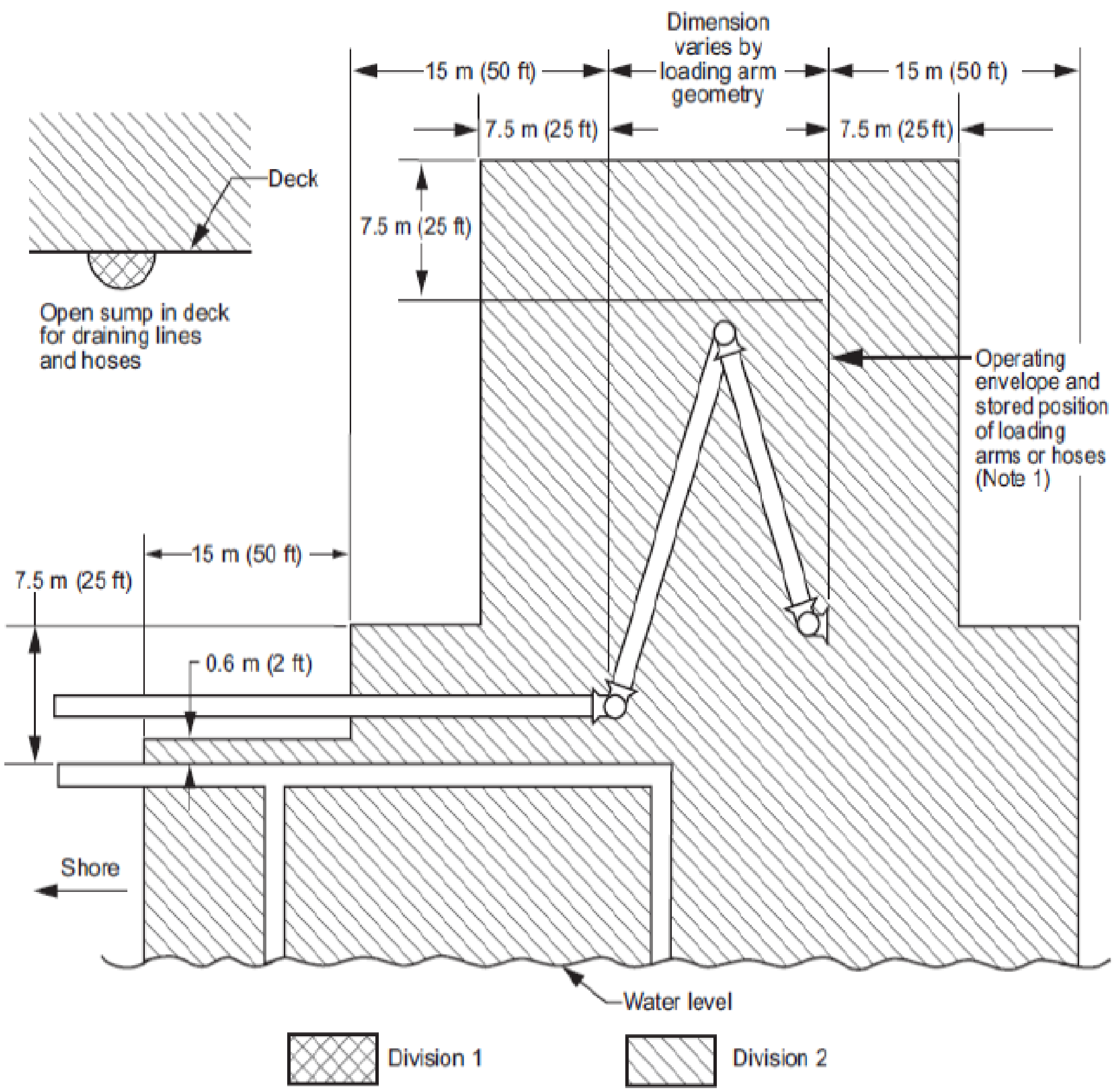



**Figure 6-14 The hazardous (classified) location at marine terminals handling flammable liquids***

[23] American Petroleum Institute (API), API Recommended Practice 500 (API RP 500), "Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2," 3rd edition, December 2012

* Note 1: The operating envelope and stored position of the outboard flange connection of the loading arm (or hose) should be considered the "source of release".
* Note 2: The berth area adjacent to tanker and barge cargo tanks is to be Division 2 to the following extent:
a. 7.5 meters (25 feet) horizontally in all directions on the pier side from that portion of the hull containing cargo tanks.
b. From the water level to 7.5 meters (25) feet above the cargo tanks at the highest position.
* Note 3: Additional locations may have to be classified as required by the presence of other sources of flammable liquids on the berth, or by the requirements of the Coast Guard or other authorities having jurisdiction.

During the study, a few other alternatives have also been discussed from a shipboard perspective and are given below.

- **Installing the connection point at the stern which is out of hazardous zones**

  This approach is adopted by Alaskan Navigator which is the first tanker equipped with shore power. However, for terminals that need to accommodate different sized tankers, it is challenging to manage the horizontal length difference as discussed in Section 6.3.1.2.

- **Installing the connection point at the foreship which is out of hazardous zones (Also refer FMECA 5.3)**

  This approach could avoid the challenge of currently unavailable explosion-proof marine use sockets. For terminals that accommodate different sized tankers, the cable management system may have the challenge to manage the horizontal length difference, similar to the discussion in Section 6.3.1.2.

  In addition, there is a long distance between the main switchboard which is normally located at the stern. The long cabling may increase the cost and maintenance efforts. The system will also need to be protected from green water. This scenario also brings in the potential need for a material handling system ashore to lift the cable up on the forecastle. This may pose challenges in terms of accounting for tidal and draft variations during the discharge operations at the terminal. Further, If the shore power connection point is arranged at the bow out of hazardous zone, the installation connection may enter the berth hazardous zone during slipped mooring.

- **Installing the connection point above the hazardous zone at the midship (Also refer FMECA 5.4 & FMECA 5.5)**

  Installing the shore power connection point at the midship on open deck could facilitate handling of all sizes of tankers calling the terminal, since the location of the manifold is relatively fixed.

  The risk for this option is that there may not be an available non-hazardous area at the midship for installing the connection point. The midship area has the following main hazardous zone arranged:

  - Hazardous zone 1: areas on the open deck over cargo tanks (including ballast tanks within the cargo tank area) where structures are restricting the natural ventilation and to the full breadth of the ship plus 3 m fore and aft of the forward-most and the aft-most cargo tank bulkhead, **up to a height of 2.4 m above the deck**. Therefore, in general, a platform will be needed to lift the connection point above the hazardous zone at the midship.

  - Hazardous zone 1: Areas on open deck, or semi- enclosed spaces on deck, within 3 m of any cargo tanks outlet, gas or vapour outlet, cargo manifold valve, cargo valve and/or cargo pipe flanges.

- Hazardous zone 1: areas on the open deck, or semi-enclosed spaces on the open deck above and in the vicinity of any cargo gas outlet designed for the passage of large volumes of gas or vapor mixture during cargo loading and ballasting or during discharging, **within a vertical cylinder of unlimited height and 6 m radius centered upon the center of the outlet, and within a hemisphere of 6 m radius below the outlet**.
- Hazardous zone 2: 1.5m above zone 1 on open deck within the cargo area (i.e., 2.4m + 1.5m) and 4 m beyond the cylinder caused by the large cargo vapor outlet defined in the above bullet (i.e., 6m + 4m).

Further, the midship area may fall into the hazardous locations as defined by the marine oil terminal which will require electrical equipment to be certified accordingly.

The specific hazardous area arrangement of the visiting tankers and marine oil terminals must be studied for each terminal. In addition, if a platform is installed for arranging the shore power connection point, assessment on visibility from bridge and potential stability issues need to be considered.

- **Installing the connection point in a pressurized electrical house at the midship (Also refer to FMECA 5.6)**

A pressurized electrical house with adequate positive-pressure ventilation may be used to reduce or eliminate hazardous areas. The concept is based on the principle that positive pressurization and purging can be established with clean air at sufficient continuous flow and positive pressure to reduce the original concentration of flammable gas or vapor to a safe level and to maintain this level in an enclosure or room located in a hazardous location.

The non-explosion-proof electrical instruments may then be used inside the pressurized electrical house. Detailed engineering must be performed to analyze the feasibility of pressurization in the hazardous zone together with relevant safeguards to mitigate any fire or explosion hazards. Necessary operational safeguards to avoid opening the room when the shore power system is energized should be considered in addition.

However, with the concept of arranging a pressurized electrical house on the main deck, a high-voltage cable will still need to be arranged in the hazardous area. All cable installed in hazardous areas onboard the ships need to comply with Classification Societies installation requirement, e.g., all cables installed in hazardous areas shall have an outer non-metallic impervious sheath. Impervious Sheathed Cable is a cable constructed with an impervious metallic or nonmetallic overall covering that prevents the entrance of gases, moisture or vapors into the insulated conductor or cable. This applies to the fixed cable installation as well as for the flexible shore-to-ship cable. Research is needed to determine whether HV cable (fixed installation onboard and flexible shore-to-ship connection cable) which meet these requirements are available on the market. In addition, the cable penetration into the deck house might result in loss of positive pressure in the pressurized space.

Further, the current classification rules generally deem the enclosed space immediately above cargo tanks as hazardous area zone 1 unless the special protection has been reviewed and accepted by the appropriate authority. For access and openings to non-hazardous spaces other than accommodation and service spaces, the following provisions in the DNV classification rules apply:

— entrances shall not be arranged from hazardous spaces

— **entrances from hazardous areas on open deck shall normally not be arranged**. If air locks are arranged such entrances may, however, be approved following the below requirements:

- Entrance through air locks to non-hazardous spaces shall be arranged at a horizontal distance of at least 3 m from any opening to a cargo tank or hazardous space containing gas sources, such as valves, hose connections or pumps used with the cargo.
- Air locks shall comply with the requirements regarding gas-tightness, height, geometrical form, and ventilation.

A thorough examination and potential updates of the existing regulations and industry standards (e.g., SOLAS, IBC code, Class rules, ISGOTT, PIANC standards) for the pressurized electrical house concept are needed to ensure compliance.

To summarize this section, the tanker segment brings its set of unique challenges related to the hazardous cargo while implementing shore power technology. The industry level development on explosion proof equipment, a more adaptable cable management systems, feasibility of pressurized electrical house on the main deck at midship etc. are some of the key issues to be considered before a large-scale implementation of the shore power technology in the tanker segment.

#### 6.3.1.4 **FMECA 0.2** – Uncertainties on power demand that accounts for different peak factors across different ship type

When calculating the power demand based on the historical fuel (energy) consumption, the result will be an averaged value. This is the case when using the auxiliary engine power output given in Table 6-7. This may not be sufficient for momentary or short-term peak consumption.

Each ship type will have a different peak factor which should be considered when designing shore-power infrastructure. During the design stage, the decision is recommended to be taken together with tanker operators whether to design for average power demand, peak power demand, or any design point in between.

Future changes in the size and portfolio of the visiting fleet would also need to be considered, so that design decisions based on the current fleet would not render infrastructure un-suitable for future tanker calls.

#### 6.3.1.5 **FMECA 2.1** - Insufficient pier strength due to additional loads by way of added equipment for shore power technology

In addition to the space availability of the terminal, its strength, especially for the wharf-typed terminals, may not be sufficient for installing shore power equipment including cable, winch, switchboard, and potentially crane.

A structural evaluation, including seismic analysis, shall be performed following MOTEMS to evaluate if upgrades of the structural system of the causeway and terminal is needed.

During the workshop, the stakeholders also informed that upgrading the causeway and terminal is costly and time-consuming. It may impact the compliance timeframe.

#### 6.3.1.6 FMECA 5.2 - Lack of unified standards for shore power limiting its use on tankers, known to have a worldwide operational profile

This risk is more relevant to the cost-effectiveness of the installation of shore power technology onboard a tanker. It is listed here as it has been discussed during the workshop as a relatively unique situation for tankers considering their worldwide operation profile.

IEC/IEEE 80005-1:2019 Utility connections in port - High voltage shore connection systems have been established for shore power. This standard has provided some provisions regarding ship-to-shore connection and interface equipment. However, it mainly focuses on safety, e.g., the requirements regarding grounding lines and safety circuits. There are also requirements for standardized plug and sockets but none of them consider 'ex' certification requirements which could be of importance here.

Tankers typically have a worldwide operation profile and the majority do not call the same port frequently. Based on the analysis of AIS data between 2017 January 1$^{st}$ and 2019 December 31$^{st}$, Figure 6-15 to Figure 6-17 are generated to show the count of ships distribution versus the count of port calls at the same port. It shows that around 96% of the tankers calling California between 2017 January 1$^{st}$ and 2019 December 31$^{st}$ call the same port (Port of Los Angeles, Port of Long Beach, or Port of Richmond) less than 10 times in the 3 years.

To mitigate this risk, standardization of the shore power design for tankers including a unified design of safety and physical design of the plugs and sockets through e.g., IEC/IEEE 80005-1:20199 Annex F is suggested. Additional requirements for tankers with contribution from the industry stakeholders is recommended. Before this standardization is in place, it is recommended to confirm the compatibility of the shore power system with the terminal. prior to the tankers' arrival in port.

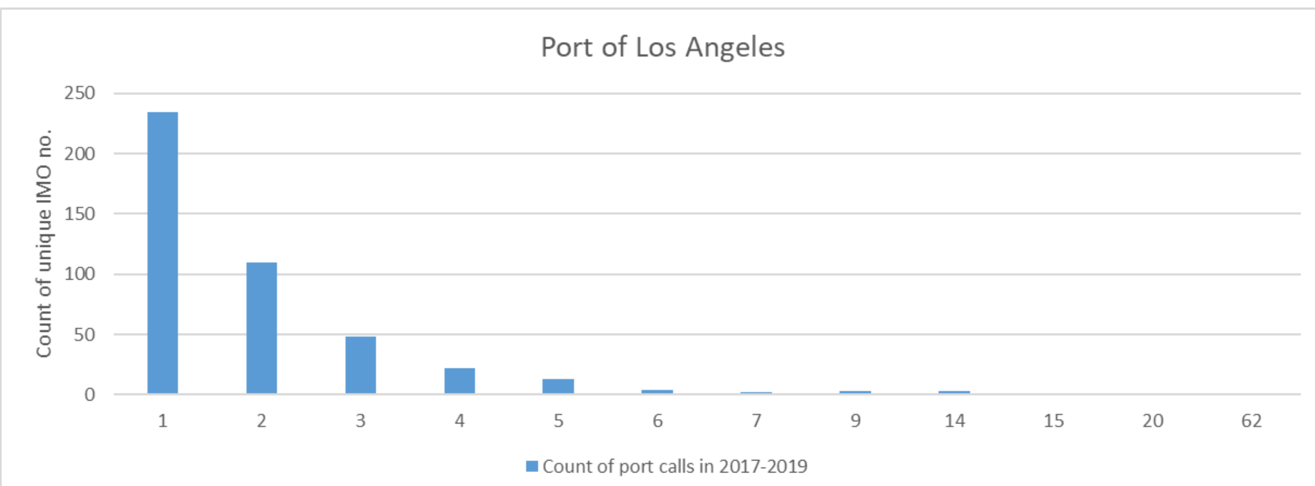



**Figure 6-15 Port of Los Angeles - The distribution of tankers' count of port calls in 2017 – 2019**

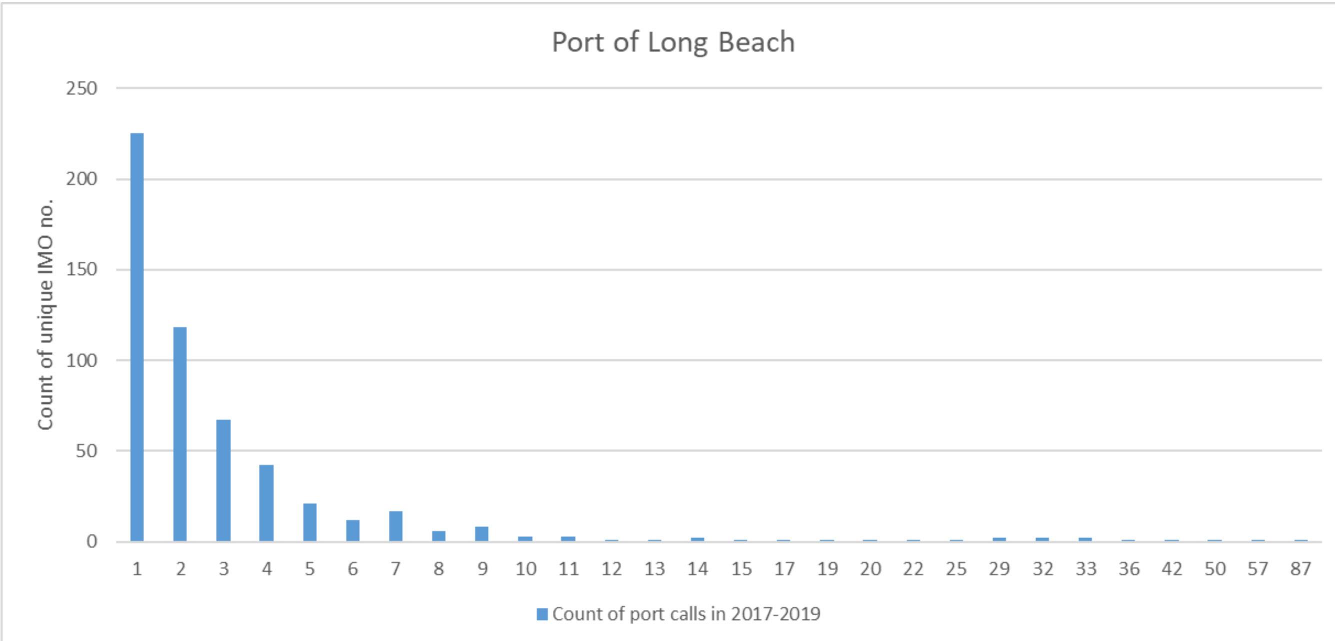



**Figure 6-16 Port of Long Beach - The distribution of tankers' count of port calls in 2017 – 2019**

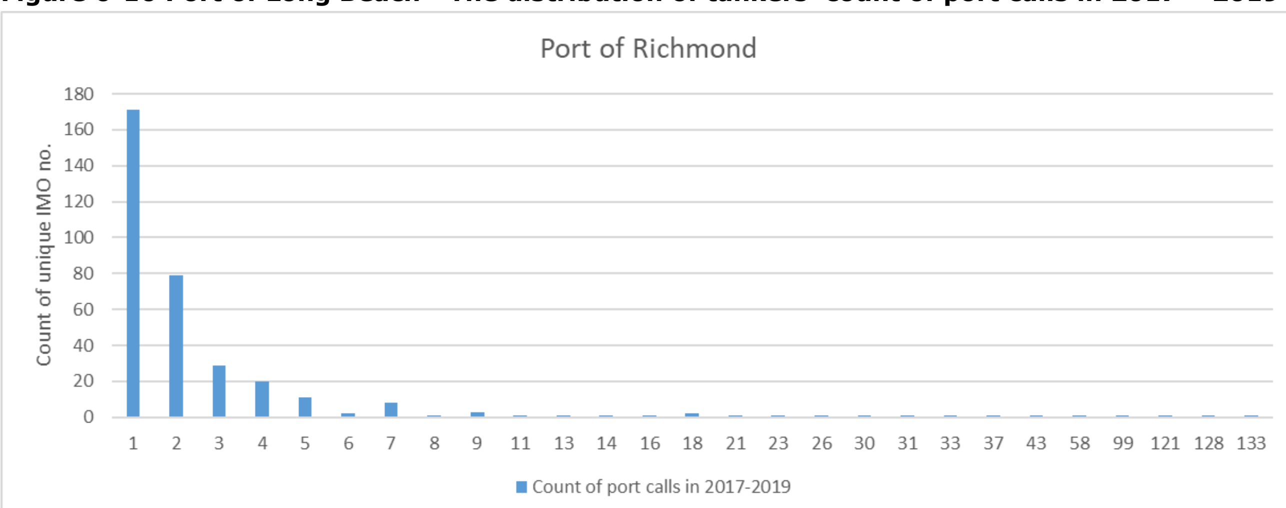



**Figure 6-17 Port of Richmond - The distribution of tankers' count of port calls in 2017 – 2019**

#### 6.3.1.7 FMECA 1.1 – Voltage and frequency incompatibility between shipboard power and shore power

Based on IEC/ IEEE 80005-1:2019, the connections for tankers should be made at a nominal voltage of 6.6 kV. For tankers, the nominal voltage level is normally 440 V AC. Some tankers may use 6.6 kV / 11.0 kV AC. To mitigate this risk, a voltage step-down transformer may be needed onboard the tankers for transforming the voltage to be compatible with the ships' needs.

The majority of tankers use 60Hz electricity. This is beneficial for visiting the USA where 60Hz electricity is used in the electrical grid. However, tankers generally have a worldwide operating profile. When ships visit areas using 50Hz electricity, e.g., some European and Asian countries, the incompatibility on the power supply's frequency would have to be resolved by the installation of a frequency converter, adding to the size and complexity of the shipboard installation required to make use of the shoreside infrastructure.

During the workshop, the installation location of the frequency converter, i.e., on the berth or on the ship, has also been discussed briefly. The cost, space availability and safety considerations are understood to drive such decisions. While a container (with a footprint of $30m^2$) could house a transformer together with the switchgear, power conversion or frequency converter and associated switchgear might need larger space. This poses space constraints on vessels of smaller size and might entail shore-based location considerations.

#### 6.3.1.8 FMECA 0.3 – System voltage dip and subsequent faults caused by high inrush current during startup of high-capacity machinery

If there is a load restriction from the power source, the high inrush current may be induced by starting a high-capacity consumer, e.g., electrical driven cargo oil pumps. The inrush current may cause a system voltage dip. If the electrical system is designed with a low fault level, the voltage dip may exceed the allowance.

It is recommended to:

- size the transformer according to the terminal's traffic and potential peak load from the visiting tankers
- establish a communication procedure beforehand between the ship and terminal about if there are load restrictions from the shore power system and the ship's required average and peak load
- performing the start-up of electrical machinery onboard the tankers in a manner that will limit the peak currents, e.g., using a soft start or frequency-controlled motor

#### 6.3.1.9 FMECA 4.2 - Personnel injuries during handling of heavy shore power connections

For the high voltage shore connection system, the weight of the power cable is around 10 kg/meter. It may be too heavy for personnel to handle manually. A suitable material handling equipment is required for the operation to avoid potential injuries induced by handling heavy cables.

Normally, tankers have hose handling cranes installed in the midship and provision cranes at the accommodation area. Some tankers may also have a store and/or searchlight davit at the foreship. Some tankers may have trolley rails that could reach both the portside and starboard side of the ship.

The hose handling crane normally has the longest reach at around 20m. The provision crane’s capacity is typically at 2 ~ 6 tons while the crane reach is typically around 4 ~ 7m. An additional crane onboard may be required to be installed at the place of shore power connection. The location of existing crane onboard the vessels, may not be installed suitably in a location facilitating handling of the shore power connection and the crane reach may be insufficient to cover the horizontal distance between the pier and the ship side.

A new crane may be needed onboard the ship. Otherwise, a crane on the terminal side could be used. In that case, the space availability and the strength of the terminal and the wharf will need to be evaluated.

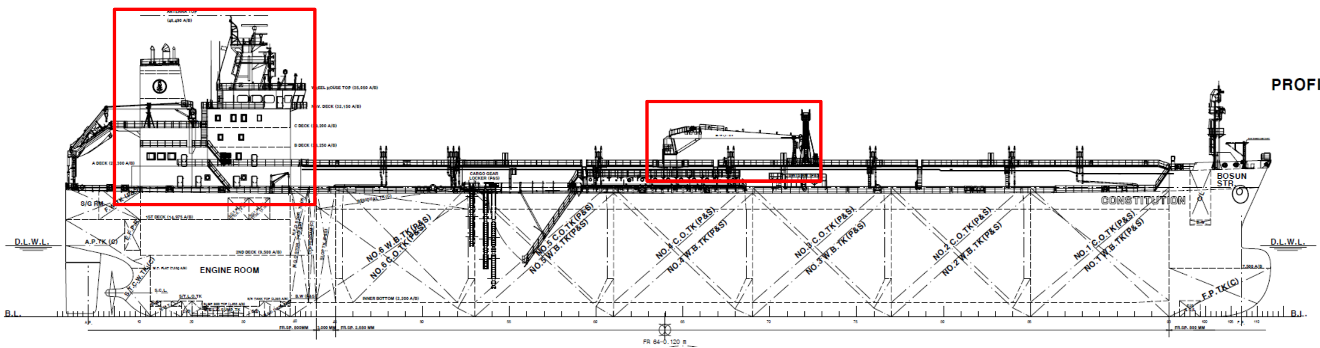



**Figure 6-18 The typical cranes’ location onboard a tanker**

#### 6.3.1.10 FMECA 4.3 - Personnel injuries from exposure to electrical equipment/operations

Handling high voltage equipment may involve risk to personnel safety. The personnel should not be exposed to live plug-in accordance with relevant standards, e.g., IEC standards and Class society standards.

Normally, the shipboard crew will be responsible for connecting the shore power to the ship’s system. According to Oil Companies International Marine Forum (OCIMF) Vessel Inspection Questionnaires 5.1, for handling electrical equipment that is above 1 kV, a specific certification for the electrician is needed.

The qualification and safety training of the shore side and shipboard crew, e.g., high voltage operation and dedicated training on using shore power technology with appropriate working procedures (including potential LOTO training) and PPE, will be needed.

#### 6.3.1.11 FMECA 3.4 - Potential upgrade of terminals to account for space constraints for installation of shore power technology

The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) establish minimum engineering, inspection, and maintenance criteria for all marine oil terminals in California, to prevent oil spills and protect public health, safety, and the environment. The MOTEMS was first published on August 10, 2005 and became effective on February 6, 2006.

Following implementation of MOTEMS requirements, a majority of the oil terminals’ new designs use the design with a pier that goes into the water. This leaves limited space for additional land-side infrastructure. There is a risk that the terminal may not have sufficient space for the shore power technology given the new designs. It is not a risk relevant to safety and reliability but imposes risk on cost and compliance timeframe as a new dedicated pier(s) may need to be constructed. Hence, this risk has not been ranked but noted for further consideration.

The Marathon Long Beach Berth 121 marine terminal which is the first and only shore power facility for tankers also needed a dedicated platform located south of the gangway tower to be constructed specifically for providing shore power.

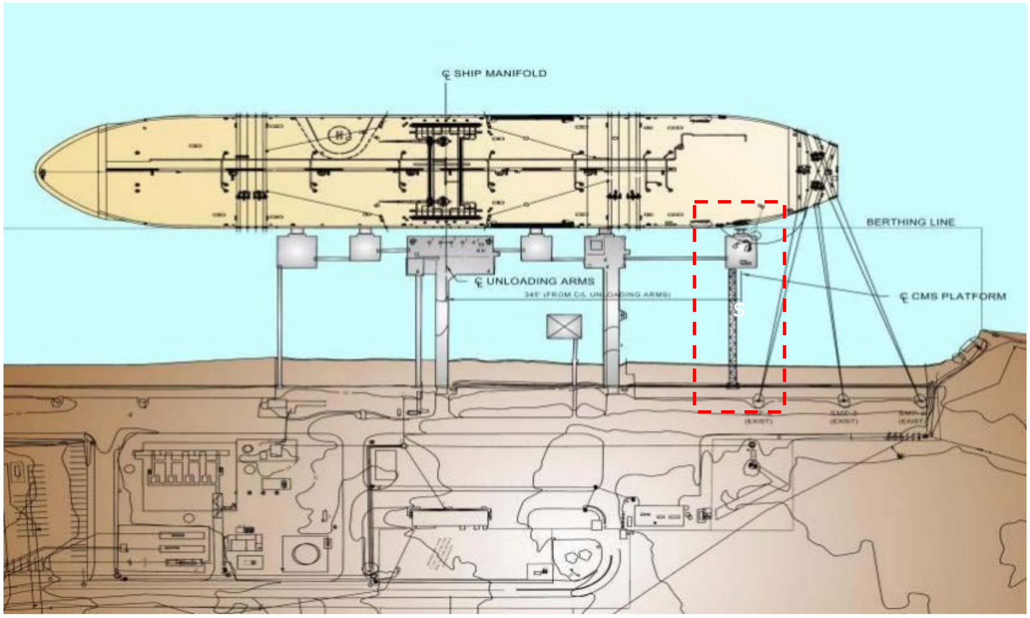



**Figure 6-19 Dedicated pier for shore power facility at Marathon Long Beach Berth 121 marine terminal** [24]

[24] The Port of Long Beach, Port of Long Beach Pier T Berth T121 BP Cold Ironing Project For Alaska Class Tankers

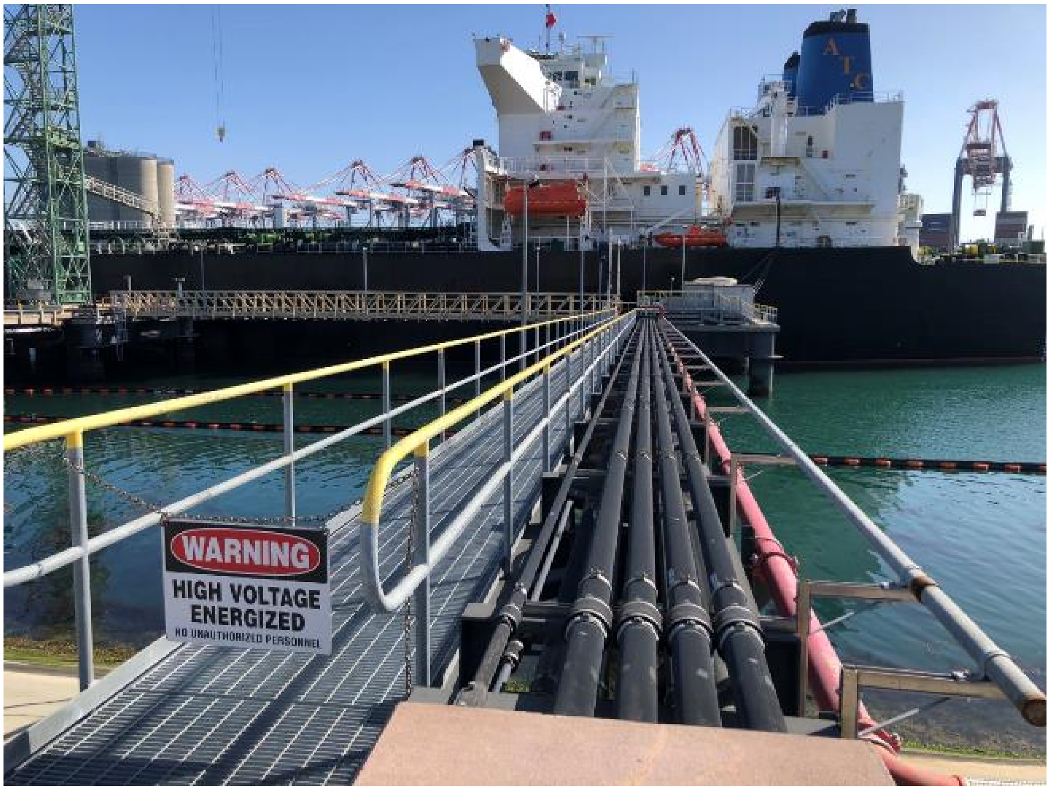



**Figure 6-20 Dedicated pier for shore power facility at Marathon Long Beach Berth 121 marine terminal**

### 6.3.2 HAZOP

The HAZOP workshops identified a total of 13 risks with one of the risks unranked. Out of the 13 risks, 6 risks were seen to be more relevant for tankers. There were 4 x risks that were medium risks and 1 x risk that was a low risk and one risk unranked. All the risks relevant for tankers are highlighted in this section. The risk matrix is as indicated in Figure 6-21 below with risk ids denoted with a # followed by number that relates to type of risk considered. Also refer to Appendix 6.

| CONSEQUENCE \ PROBABILITY | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | #10 | #2 | #8 | | |
| | #13 | | | | |
| | #1 | | | | |

**Figure 6-21 Risk matrix for HAZOP**

#### 6.3.2.1 HAZOP 1 – Current shore power design may not meet specified evacuation time in the event of an emergency

California Code of Regulations 2 CCR 2340 (c)(28) requires a vessel's boilers, main engines, steering machinery and other equipment essential for maneuvering to be maintained in a condition that a vessel has the capability to move away from the berth **within 30 minutes** under its own power. Where a vessel does not have such a capability, appropriate tug assistance is available so that the vessel can be moved away from the berth within 30 minutes.

For a ship using shore power, in an emergency, the disconnection process is normally as follows:

- An emergency alarm is sounded.
- A crew pushes the stop button on the shore power control panel in the engine control room to deactivate the shore power connection. This may induce a momentary blackout of the ship before the shipboard emergency generator and auxiliary engines are started to provide power.
- The shore power connection would require a manual disconnection. (Otherwise, the connector may be broken by forcing it. The shore power cable may be broken unwillingly and drops into the water.)

Based on the expert's input, the above operation may cause around 10-15 minutes delay in the evacuation of a tanker.

To avoid unnecessary delays from disconnecting shore power, the following mitigation actions have been identified during the risk assessment workshop:

- Ensure the emergency response button for disconnecting the power is implemented in the design and installation phase at reasonable locations, e.g., engine control room, local control cabinet at the connection room, shore side control room, etc.
- Implement a breaking signal system and auto-ejection mechanism
- Implement a quick-release / weak-link arrangement using an in-line breakable coupler on the cable. Once the breaking signal system sends the signal for quick release, the coupler will be unlatched and allow for disconnection
- Implement scheme and devices for handling the loose cables from both shore side and ship side;
- Develop an emergency response procedure including handling the shore power connection with a clear definition of responsibility, safety precautions, and necessary operations for the involved parties including the ship crew, the terminal and port operators
- Evaluate the time required for emergency response when connecting to shore power (disconnect shore power, turn on engine power, maneuver away from the berth) and ensure that it is within 30 minutes.

#### 6.3.2.2 HAZOP 2 - Safety of cargo operations compromised in case of a sudden loss of power when using shore power

When tankers use auxiliary engines for generating power while at berth, the ships normally have at least two auxiliary engines running with one auxiliary engine running as a redundant measure. If one auxiliary engine fails, the remaining auxiliary engine(s) will be still capable of supplying power. If all auxiliary engines fail, the emergency electrical power supply systems will start automatically.

When the ship is using shore power, in the event of shore power having a sudden loss of electrical power supply induced by e.g., electrical storm, rolling blackout, fault in the grid, etc., it will result in a momentary blackout before the emergency electrical power supply system starts.

According to DNV classification rules[25], power to all required emergency services shall be automatically available within 45 seconds when power is automatically restored after a black-out, including those supplied from main distribution systems. (These consumers may be supplied from main switchboards or sub-distribution boards). Emergency services are those services essential for safety in an emergency condition, e.g., emergency lights, navigation equipment, safety communication equipment, fire pumps, firefighting systems, steering gear, watertight doors and hatches, alarm systems, lifeboats, etc. The cargo operation is not necessarily deemed as an emergency service. Some cargo operations, e.g., ventilating fans for gas dangerous spaces and for gas safe spaces in the cargo area on tankers, inert gas systems, are deemed important (secondary essential) which need not necessarily be in continuous operation for maintaining the vessel's maneuverability but are necessary for maintaining the vessels functions. To investigate the potential impact of blackout when using shore power, the following bow tie is generated. A bow tie diagram is a form of risk assessment or a visualization of the path a hazard may take where a visual summary of all plausible accident scenarios that could exist around a certain Hazard is identified followed by identification of control measures the Bowtie displays to control those scenarios. The safety risk of a sudden loss of electrical power in the shore power system is deemed similar to the sudden failure of auxiliary engines. See Figure 6-22 & Figure 6-23 below.

[25] DNV Rules for Classification: Ships, Part 4 Chapter 8, July 2021

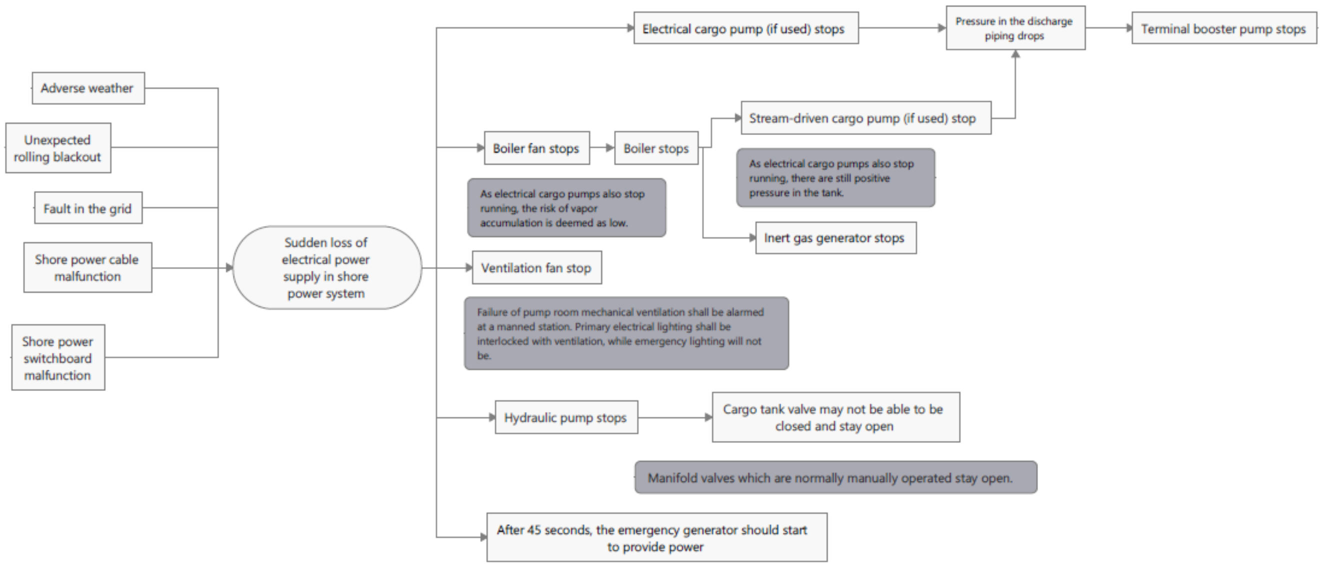



**Figure 6-22 Bow tie analysis of a sudden loss of electrical power supply in shore power system during cargo discharging**

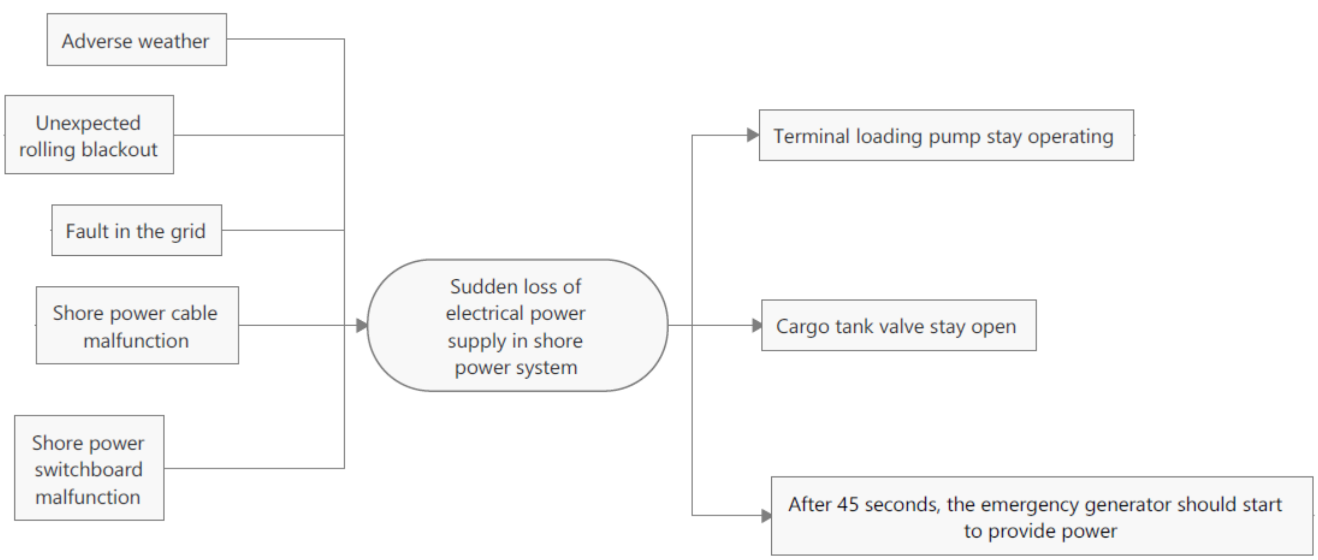



**Figure 6-23 Bow tie analysis of a sudden loss of electrical power supply in shore power system during cargo loading**

### 6.3.2.3 HAZOP 8 - Cybersecurity may impact the safe operation of hazardous cargo

Currently IEC standard does not require data communication for tanker shore power installation. The current standard requires a monitoring function, but not a control function. The risk of unexpected blackout induced by human error, system vulnerabilities, cyberattacks is relevant when the data communication function is incorporated into the system.

If the shore power system is equipped with data communication capability, it is recommended to identifying the vulnerable subsystems (e.g., service interface of switchgear, service interface of cable management system), performing cybersecurity assessment, and ensure air gap is in place.

#### 6.3.2.4 HAZOP 13 – Lack of compliance with CARB at-berth regulation towards diesel driven power packs' emissions

According to CARB at-berth regulation, "auxiliary engine" means an engine on an ocean-going vessel designed primarily to provide power for uses other than propulsion, except that all diesel-electric engines shall be considered "auxiliary engines".

It is understood that some chemical tankers may have diesel-driven hydraulic power packs, e.g. FRAMO system. The hydraulic power pack prime movers can be electric motors or diesel engines.[26] According to Framo, a combination of electric motor and diesel engine prime movers allows the ship's generators to be designed for the relatively low power requirement in sea-going mode rather than the considerably higher requirement during cargo unloading. The ship's auxiliary engines can therefore operate with an economic load while at sea where the majority of running hours will be. The diesel hydraulic power packs will provide any additional power needed for a high capacity/high head cargo discharge. The potential configurations are shown below.

If diesel engines are used as the prime mover, they are deemed as "auxiliary engines" by CARB. As such, the emission must be controlled according to CARB at-berth regulation. For the tankers using such a configuration, the potential actions to mitigate the risk of out-of-compliances are:

- Convert the hydraulic power pack to use electric motors which draw power from the main switchboard, i.e., from the ship's service diesel generators
- Alternatively, the exhaust from the hydraulic power pack diesel engine(s) must be treated with the capture and control technology which may be too costly for such a relatively small emission source.
- .

[26] Framo, Cargo pumping system brochure

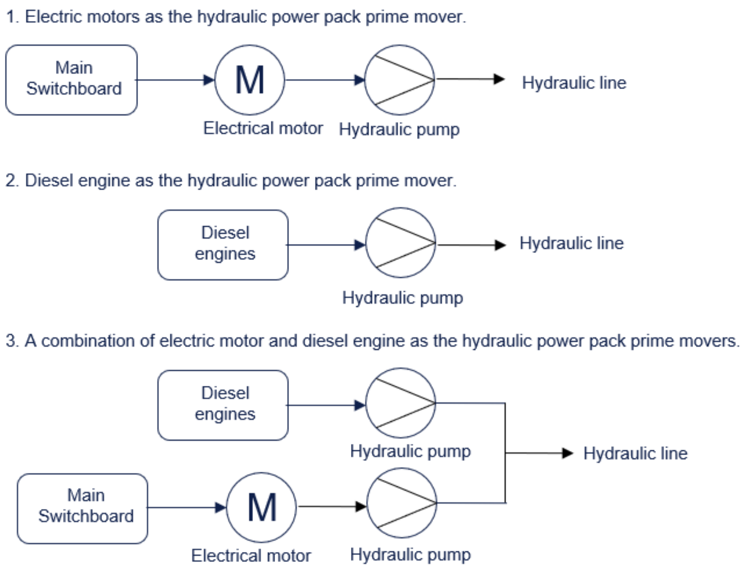



**Figure 6-24 Potential configurations of the hydraulic power pack**

#### 6.3.2.5 HAZOP 10 – Potential fire or explosion from high voltage connection ignited by vapor dispersion in the event of an oil spill

For tankers, oil spillage is a very relevant hazard. It may be caused by leakage from piping or tank, broken couples, unexpected disconnected/damaged loading arm. The vapor dispersion may result in an area having a higher risk of ignition.

It is recommended to:

- Developing the ship shore power emergency response procedure including emergency shutdown with the consideration of the cargo type, potential spillage location, and amount;
- Incorporating the operation of shore power into the terminal's spillage response procedure.

#### 6.3.2.6 HAZOP 12 – Lack of compliance with CARB at-berth regulation towards boiler emissions

During the stakeholder engagement, some stakeholders have expressed concerns that steam-driven cargo pumps' emissions may be out of compliance.

According to the CARB at-berth regulation, "for tanker vessels with steam-driven pumps, **unless the tanker is using shore power to reduce emissions from auxiliary engines**, a person must demonstrate that the CAECS achieves emission rates less than 0.4 g/kW-hr for NOx, 0.03 g/kW-hr for PM 2.5, and 0.02 g/kW-hr for ROG for tanker auxiliary boilers. Default emission rates of tanker auxiliary boilers on ocean-going vessels are 2.0 g/kW-hr for NOx, 0.17 g/kW-hr for PM 2.5, and 0.11 g/kW-hr for ROG."

Therefore, if shore power is used, the emissions from steam-driven cargo pumps will not be regulated. This understanding has been confirmed by CARB during the stakeholder engagement. Therefore, this risk is deemed irrelevant.

# 7 TECHNOLOGY ASSESSMENT OF CAPTURE AND CONTROL (C&C) TECHNOLOGY

## 7.1 Qualification basis

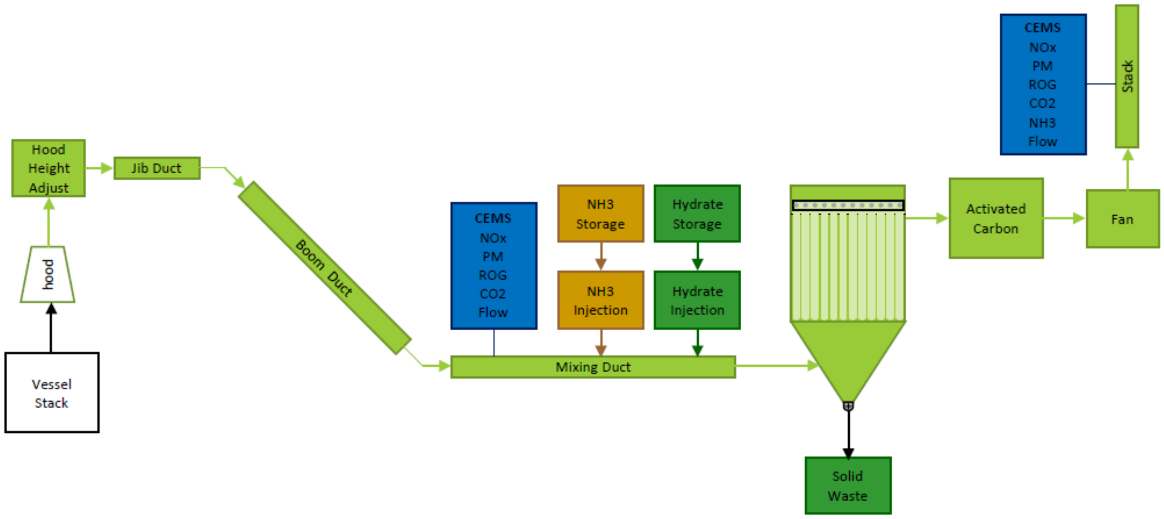
### 7.1.1 Technology Description

According to CARB, **barge-based capture and control systems** involve a capture and control device on a movable barge that is maneuvered alongside or aft of a vessel at berth, to reduce emissions from the vessel while it continues to operate its auxiliary engines and boilers. The current generation of barge-based technologies is designed to control emissions from the vessel's auxiliary engines. Current barge-based technologies are dependent on an external tugboat to move the barge alongside the vessel. Although there is the potential for self-propelled barges to eliminate the need for a tugboat, this technology has not yet been implemented. Once berthed beside or aft of the vessel, a capture boom on the barge lifts a duct/hood up to the top of the vessel's exhaust stack. The current stack hood is being optimized by CAEM and will feature a quick release, failsafe capture system. Then a large fan on the barge extracts the vessel exhaust and excess ambient air through the duct and route it down to the emissions "control" unit on the barge. Existing barge-based systems utilize diesel generators to power both the placement arm and emissions control systems. These systems are dispatched to reduce emissions from specific vessels, typically operated by a third-party system provider. The third-party system provider typically has its own staff on the barge to support this operation. Terminals with wider channels may readily accommodate a barge alongside a vessel at berth, but terminals with narrow channels may not be able to physically fit a barge without blocking navigation in the channel.[27] If the barge is located aft of the vessel, it may not block the navigation in the channel.

According to CARB, **Land-based capture and control systems** are essentially land-based versions of the barge-based systems described above. For a land-based system, the emissions control unit will be built in place near a terminal's wharf or can be mounted on a mobile chassis where the system will be moved along the wharf with a heavy-duty truck. Once the unit is in place on the dock, the system's capture device places the ducting over the vessel stack. The system captures and routes the vessel exhaust emissions from auxiliary engines to the landside control technology.

The boundary of the technology starts at the barge or the shore side installation and stops at the ships' funnel. The process flow is illustrated in the following figure.

[27] CARB, 2019-2020 GRANT SOLICITATION, September 2, 2020




**Comments**

- Solid waste is non-hazardous and goes to landfill.
- System operates at 350 F and all heat is supplied by the vessel engine or boiler.
- Capture efficiency = >90%
- PM, NOx, and ROG capture/destruct is >90%

**Figure 7-1 Process flow diagram of CAEM's emission capture and control technology**

**Figure 7-2 Spud barge example**


**Figure 7-3 Jack-up barge example**

### 7.1.2 Performance Expectations

This section lists the performance expectation on capture and control technology. The details for the same are included under Appendix 7.1.

**Safety for personnel and property**

The technology should provide sufficient safety and security during normal operations and emergencies.

- The technology should be able to operate at defined weather window (tides, wind, currents, waves).
- The technology should be able to operate 24/7 (day and night) during all temperature ranges applicable for the terminal.
- The technology should not increase the risk of fire and explosion.
- The technology should not hinder the tanker requirements of safe evacuation from the berth within 30 minutes.
- The technology shall ensure safe operating environment for working personnel (connection, operations, disconnection, maintenance etc.) both during normal operations as well as emergency scenarios.
- The technology shall not adversely affect the vessel, its machinery or operations. (overloading the stacks, mooring entanglement etc.)

The design and construction of the technology shall ensure a safe environment for the personnel connecting, operating, and maintaining the technology. Further, the safety aspects of the technology shall consider relevant safeguards in terms of operational procedures and training.

**Suitable for tanker and oil terminals**

The technology should be able to be deployed and operated for the visiting tankers considering the factors including:

- The technology should be compatible with different sizes of tankers and their berthing configuration relative to the terminal.
- The technology should be compatible with different stack configurations including number, shape, and height.
- The technology shall ensure reachability towards stack in good time.
- The technology should be able to handle and treat the expected maximum exhaust gas flowrate from multiple sources when a tanker is at-berth
- The technology should be able to withstand the variable temperature from exhaust gas sources
- The technology should be compatible with the variation of tankers' draft and tide.
- The technology should comply with the relevant hazardous zones' requirement for tankers where applicable.

The technology should be able to be deployed and operated for the marine oil terminals considering the factors including:

- The technology should comply with the relevant hazardous zones' requirement of the marine oil terminals where applicable.
- Wharves should be able to carry the weight of the shore-based capture and control technology.
- The wharves should have sufficient space for the installation, operation and maintenance of the barge-based capture and control technology.
- The technology shall limit operational interference such as interference with mooring, cargo or other operations
- The barge-based capture and control technology shall enable safe stowage when not in use.

**Reliability & performance**

- The technology shall perform with acceptable failure rates ensuring little downtime over its lifetime
- The technology shall enable safe inspection, testing and maintenance regime
- The barge-based capture and control technology shall enable sufficient maneuverability in the terminals' environment.

## 7.1.3 Applicable Regulations and Standards

The capture and control technology should comply with and not impact the compliance of the existing relevant rules, regulations, industry standards and guidelines that are applicable to tankers and marine oil terminals.

The following regulations and standards are relevant to tankers and marine oil terminals.

**Table 7-1 Relevant regulations and standards**

| Category | Tanker and Terminal Regulations, Rules, Standards, and Guidelines |
|---|---|
| **Safety: Design and operation** | **IMO Regulation**<br>Safety of Life at Seas (SOLAS) Chapter II-1, Part D |
| | **California State Lands Commission Regulation**<br>Marine Oil Terminal Engineering & Maintenance Standards (MOTEMS) |
| | **Classification Society Rules** |
| | **Maritime Industry Guidelines**<br>OCIMF's Marine Terminal Operator Competence and Training Guide<br>International Safety Guide for Oil Tankers and Terminals<br>The World Association for Waterborne Transport Infrastructure (PIANC) - Safety Aspects of Berthing Operations of Oil and Gas Tankers |
| **Safety: Personnel** | Standards of Training, Certification, and Watchkeeping (STCW) |
| **Environmental protection** | **IMO Regulation**<br>IMO MARPOL Annex VI |
| | US Environmental Protection Agency - ECA requirements (SOX, NOX, PM) |
| | California Air Resources Board's (CARB) ocean-going vessels at berth regulation |

**Figure 7-4 Regulation and standards for tanker and terminals**

In addition to the above, the following CARB requirements are seen to be relevant:

CARB - Control Measure For Ocean-Going Vessel At Berth
Section: 93130.7 (e)(1): At least seven calendar days before arrival, the vessel operator shall communicate in writing with the terminal operator and operator of the CAECS to coordinate the use of a CAECS, and shall do all of the following:

(A) Request use of a CAECS; and

(B) Supply the terminal operator and the operator of the CAECS with information about the compatibility of the vessel with the intended CAECS.

## 7.1.4 Critical Parameters

During the technology assessment workshop on June 24, 2021, the following critical parameters have been identified for the capture and control technology. The dimensioning loads and operational parameters are to be included in a list to be used to check that these have been considered and addressed in the qualification tests, and that any change to these parameters is reflected in the qualification activities. The details of the same are included under Appendix 7.1.

**Table 7-2 Critical parameters for using capture and control technology on tankers [28]**

| |
|---|
| **Fuel composition limitations**<br>**Marine distillate fuel with ≤ 0.1% sulfur content** |
| **Maximum SCR (Selective Catalyst Reduction) inlet temperature**<br>450 °C |
| **Static pressure**<br>Minimum of -2 mm $H_20$ at the hood |
| **Connection** |

[28] https://www.arb.ca.gov/sites/default/files/2020-04/coverletter-ab-15-02_ADA.pdf

| | |
|---|---|
| Direct connect system with seal per specifications | |

**Auxiliary Engine load (kW)**
typically, VLCC = 2 x 1,200kW aframax = 2 x 750kW

**Allowable operation range**
500-1700 kW, current allowable range of the CAEM METS-1 system, could be scaled up

**Exhaust flow rate that can be treated (standard cubic feet per minute (scfm))**
1400 to 6500 scfm of engine exhaust; The CAEM METS-1 system is currently capable of treating up to 6500 scfm of exhaust, might be scaled for tanker applications, upto two engines may be simultaneously controlled

**Ammonia slip emission**
Not to exceed 5 ppmdv, averaged over 60 minutes

**Vertical and horizontal stack position**
Vertical stack position shall consider draft and tidal variations while horizontal position shall consider both starboard and portside mooring.

**Time for connection**
A maximum and minimum time interval for connection to stack shall be defined.

**Treatment capacity**
The technology shall be able to treat exhausts from auxiliary engine, boilers as well as combined exhaust quantities. Minimum and maximum quantities to be specified.

**Temperature of exhaust gas**
The technology shall be able to accommodate a range of temperature of exhaust gas. Minimum and maximum to be specified.

**Operational impact**
The technology shall limit interference of the normal operations such as mooring, cargo operations, traffic etc.

**Other relevant parameters as described under performance expectations**
The critical parameters shall be developed from the performance expectations as seen relevant.

## 7.2 Technology assessment

The purpose of technology assessment is to determine which elements require technology qualification and identify their key challenges and uncertainties. The technology qualification basis forms the input to the technology assessment. The output is an inventory of the novel technology elements, and their main challenges and uncertainties. The technology assessment shall include the following steps:

— Technology composition analysis

— Assessing the technology elements with respect to novelty

To fully understand the novel elements of compound technology, as well as provide common understanding and terminology between people from different technical disciplines, the technology composition shall be analyzed. This is a top-down assessment that starts with the system-level functions and proceeds with decomposing the technology into elements including interfaces.

The emissions capture and control technology supplier Clean Air Engineering-Maritime, Inc.[29] (CAEM) has been developing and operating systems that are capable of capturing and controlling emissions from the auxiliary engines and boilers of ocean-going vessels while at berth or anchor. CAEM currently holds a CARB-approved emissions capture and control technology used for compliance with the airborne toxic control measure for auxiliary diesel engines operated on ocean-going vessels at-berth in a California port: Marine Exhaust Treatment System-1 (METS-1).[30]

The technology assessment is performed largely based on the design concept that CAEM is currently developing for tankers.

The technology composition analysis was conducted together with other industry stakeholders and subject matter experts during the workshop on June 24, 2021. The result is given in the table below.

**Table 7-3 Emissions capture and control technology composition analysis**

| ID | Subsystem | Major Components | Main Function |
|---|---|---|---|
| 1 | Emission capture unit | Crane / placement boom | Bring the flexible duct to the vessel stack |
| | | Stack adaptor / hood | Work as the interface between relevant exhaust stack and flexible duct |
| | | Flexible duct | Transport the exhaust from the stack to the treatment unit |
| 2 | Emission control unit | Inlet | Connection of flexible duct to the treatment system |
| | | Treatment system | Perform treatment of the exhaust |
| | | Exhaust fan | Create vacuum for exhaust flow |
| | | Power supply | Provide power to the treatment system and exhaust fan |
| | | Control panel | Control the treatment system |
| | | Outlet | Release the treated exhaust into the atmosphere |
| 4 | Basis | Land-based (Mobile chassis/stationary)<br>Barge-based | Transport and store the emission capture unit and or the emission control unit |

[29] https://caemaritime.com/

[30] State of California Air Resources Board, Executive Order AB-15-01, June 2015

Novel technologies typically evolve from existing proven technologies. Normally, only some elements of the technology are novel. Uncertainty is associated mainly with novel elements. In order to focus on where uncertainty is greatest, the novelty categorization shown in Table 7-4 can be used. Both the novelty of the technology itself and its application area affect the uncertainty associated with the technology.

Elements categorized as novel (category 2, 3 and 4) shall be taken forward to the next step for further assessment.

Only knowledge and experience that is documented, traceable and accessible to the qualification team should be used to reduce the degree of novelty.

**Table 7-4 Categorization according to DNV Recommended Practice**

| **Application area** | **Degree of the novelty of the technology** | | |
|---|---|---|---|
| | **Proven** | **Limited field history** | **New or unproven** |
| **Known** | 1 | 2 | 3 |
| **Limited knowledge** | 2 | 3 | 4 |
| **New** | 3 | 4 | 4 |

This categorization indicates the following:

- **Category 1:** No new technical uncertainties (proven technology).
- **Category 2:** New technical uncertainties.
- **Category 3:** New technical challenges.
- **Category 4:** Demanding new technical challenges.

Technology in Category 1 is proven technology where proven methods for qualification, tests, load and structural analysis can be used to document margins to failure. It is assumed that acceptable margins to failure for these items are achieved through the regular project activities in order to ensure a reliable qualification process for the components in this technology category.

Technology defined as Category 2, 3, or 4 is defined as new technology and requires qualification. Components assigned to these categories will later be subject to the threat assessment, i.e., FMECA and HAZOP. For sub-components that fall into Category 2, 3, or 4, further subdivision of these components may be necessary based on the risk ranking and complexity of the sub-components.

The components and functions were assessed with the industry stakeholders and subject matter experts during the workshop. DNV has reviewed the response from the workshop participants and developed the novelty categorization as below. Some high-level challenges/uncertainties which are relevant to using the components onto tanker and oil terminals discussed during the workshop are also listed in the table below. Detailed risk assessments have been performed and presented in Section 6.3 and also under Appendix 7.2.

**Table 7-5 Components and categories**

| **System** | **Category** | **Challenge/uncertainty** |
|---|---|---|
| Emission capture unit | 4 | - The placement boom cannot cover the wide range of tanker sizes.<br>- The stack adaptor cannot accommodate the different stack configurations of tankers.<br>- The duct is not able to transfer volume and heat of emission over a wide range of emission flow rates |
| Emission control unit | 3 | - The treatment system does not have enough capacity to treat the amount of emission from tankers. |
| Basis | 4 | - The location of the basis interferences with the normal operation of the tankers.<br>- Disconnecting the technology increases the evacuation time of the tankers. |

## 7.3 Threat assessment

A group workshop with the participants as included under Appendix 7 has been facilitated by DNV on June 24, 2021 and July 09, 2021 virtually via Microsoft Teams. The critical risks which are **unique** for the technology's application onto tankers are discussed in this section. The detailed results of FMECA and HAZOP are given in the Appendix 7.3 & 7.4 respectively.

The risk assessment has been focusing on analyzing:

- the applicability/difference of the identified risks of shore-based emissions capture and control
- the additional or difference in risks from using a barge based capture and control technology

### 7.3.1 FMECA

The FMECA focused on potential failure modes and their effects for the operation of the land-based & shore-based capture and control systems. During the workshop, failure modes from perspective of applicability towards all vessel types were considered and later categorized/filtered to identify the failure modes that would be more relevant specifically for tankers. Ranking of the failure modes are captured in the Figure 7-5 below with risk ids denoted with a # followed by number that relates to type of failure mode considered. Also refer to Appendix 7.

| CONSEQUENCE \ PROBABILITY | | | | |
|---|---|---|---|---|
| | | | | |
| | #3.2, #3.5, #3.14 | #1.17, #1.20 #2.4 | #1.15, #1.21 | |
| | | #2.5 #3.6, #3.12, #3.16, #3.19 | #3.17 | |
| | #3.13 | | #1.6 #3.10, #3.11 | |
| | | #1.22 #3.9, #3.15 | | |

**Figure 7-5 Risk ranking for FMECA**

The overall risk ranking indicted 55 risks in total. Out of the 55 risks identified, 21 of them were found more relevant for tankers. These are indicated in the risk ranking figure above. Out of the 21 risks identified, 6 x risks were high risks, 12 x risks were medium risks, and 3 x risks were low risks. This section describes the details of all the risks relevant for tankers when it comes to utilizing the land-based & shore-based capture and control systems. The details for the same are provided under Appendix 7.3.

#### 7.3.1.1 FMECA 1.6 - Potential operation of 'hazardous zone' non-compliant displacement boom within hazardous zone

As mentioned in 6.3.1.3, the tankers and marine oil terminals have hazardous zones defined. Electrical equipment working inside these areas must comply with the relevant standards, rules, and codes' requirements. As informed by CAEM, during the transportation, the placement boom will be in the stowed position. In the normal operation, the placement boom should approach the stack at the stern of the tankers which is out of the main hazardous zone around the cargo hold areas and the manifold. However, it may still run into the localized hazardous zone around the battery room, paint store, chemical room, etc.

To mitigate this risk, the following recommendations have been identified during the workshop:

- Collect the hazardous zone arrangement from the terminal and also visiting tankers via pre-arrival questionnaire
- Define the route of placement boom operation accordingly to avoid the operation in the hazardous zones
- All vessels might not mitigate this risk the same way so mitigation will be vessel specific

CAEM uses a Vessel Mooring Treatment Plan (VMTP) to collect vessel information and prepare for C&C operations, this document will be updated for tanker use.

#### 7.3.1.2 FMECA 3.10 – Lack of sufficient station keeping in the event of strong surge/swell or passing vessel traffic

The current design of barge-based capture and control technology is planned to operate with 2 spuds with the option to install 4 spuds in 6 different locations. In the event of waves generated from swell or surges or passing traffic, there is a risk with regards to loss of station keeping that may impact the operations.

The following recommendations are identified during the workshop to mitigate this risk:

- Evaluate the spud station keeping capacity against the local climatology and implement appropriate changes in the design.

It is noted that a Jack-up barge capable of operating in 30m (98') water depth could be considered as an alternative.

#### 7.3.1.3 FMECA 3.11 – Potential risk of collision between tanker and barge induced due to channel motions from passing vessel traffic

When using the barge-based capture and control technology, the passing vessel in the channel may cause movement of the tanker. If there is not sufficient clearance between the barge and the tanker, it may induce hull collision.

According to Marine Oil Terminal Engineering & Maintenance Standards (MOTEMS)[31], in general, vessels shall remain in contact with the breasting or fendering system. Vessel motion (sway) of up to 2 feet off the breasting structure may be allowed under the most severe environmental loads, unless greater movement can be justified by an appropriate mooring analysis that accounts for potential dynamic effects. The

[31] Marine Oil Terminal Engineering & Maintenance Standards (MOTEMS) 3105 F.2 Mooring analyses

allowable movement shall be consistent with mooring analysis results, indicating that forces in the mooring lines and their supports are within the allowable safety factors. Also, a check shall be made as to whether the movement is within the limitations of the cargo transfer equipment.

The following recommendations are identified during the workshop to mitigate this risk:

- The safe operating envelope of the barge should be defined with enough clearance between the tanker and the barge-based system will be identified in the mooring and passing vessel analysis for each terminal.
- The maximum clearance that the capture and control technology could provide should be evaluated and compared with the required clearance.
- The barge may also be equipped with a fender system.

#### 7.3.1.4 FMECA 1.22 – Potential electrical short circuit upon contact of stack adaptor to stacks

The capture and control technology is designed to operate the stack adaptor in the non-hazardous zone. However, the metal-to-metal contact between stack adaptor and tanker’s stacks may induce electrical short circuits. It may result in unfavorable sparks, ignition, or fire.

It is recommended to review Marine Oil Terminal Engineering & Maintenance Standards (MOTEMS) to identify the requirements and potentially considering bonding and grounding and ensure compliance.

#### 7.3.1.5 FMECA 3.9 – Potential damage to underground pipelines or cables at port from spud-based solution proposed for barge-based technology

For barge-based capture and control technology, it is planned to use spudding for station keeping. Some terminals have underground pipelines or cables arranged. The spudding activity may cause damage to underground pipelines or cables.

The following recommendations are identified during the workshop to mitigate this risk:

- collect the information about any underground pipelines from the terminal guide and arrange the spudding operation based on the specific terminal arrangement.

It is understood that CAEM has a Vessel Mooring and Treating Plan (VMTP) in place and is assisting terminals with underground evaluations for pipeline and other interferences

#### 7.3.1.6 FMECA 3.15 - The tanker requirements of safe evacuation from the berth within 30 minutes not met in the event of technology being deployed

California Code of Regulations 2 CCR 2340 (c)(28) requires the tank vessel's boilers, main engines, steering machinery and other equipment essential for manoeuvring are maintained in a condition so that the tank vessel has the capability to move away from the berth **within 30 minutes** under its own power. Where the tank vessel does not have such a capability, appropriate tug assistance is available so that the tank vessel can be moved away from the berth within 30 minutes.

To disconnect the capture and control technology from the tanker, it involves the following process:

- lifting the stack adaptor/hood

- stowing the placement boom
- if using the barge-based system, the following activities are additional:
    - lifting the spud
    - starting the engines/propulsion and barge move away from the evacuation route of the tanker

According to CAEM, the process will not need additional support from the tankers' crew. The above process may prolong the evacuation time of the tanker. However, it is understood, based on discussions with port pilots, that this is unlikely.

The following recommendations are identified during the workshop to mitigate this risk:

- Develop an emergency response procedure for such emergency scenarios
- Ensure proper training of the crew including performing scenario drills to evaluate the impact in the event of a real case scenario.

#### 7.3.1.7 FEMCA 3.17 – Potential interference of the technology with normal tanker operations

During the workshop, the possibility of arranging the base unit (fixed or floating platform or barge) at the stern of the tanker on the pier side, as illustrated in Figure 7-6, is also discussed. This will reduce the impact on the passing traffic. However, it will likely interfere with the mooring arrangement of the tankers at the stern as shown in Figure 7-7 and Figure 7-8. This location is generally not recommended for arranging the base unit.

In addition, the tanker will perform deballasting during loading at the berth. If the barge is too close to the deballast discharge point, it may have water onto the system and impact the operation.

To mitigate this risk, it is recommended to:

- Consider the location arrangement of the base unit in terms of normal operation of the tankers to ensure no interference to and from normal operation of tankers


**Figure 7-6 Base unit at the stern of the tanker on the pier side**

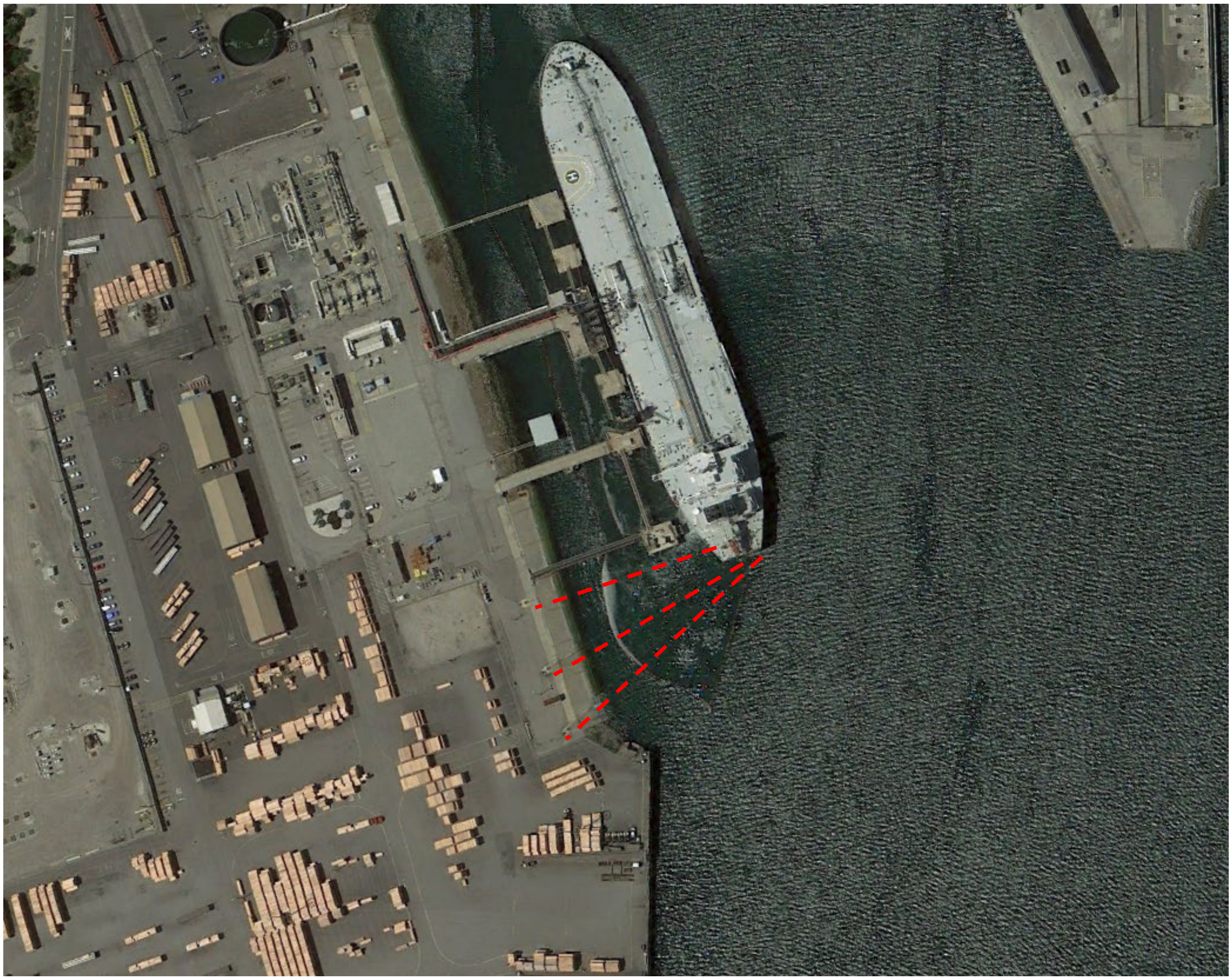


**Figure 7-7 Illustration of mooring lines at the stern of the tanker**

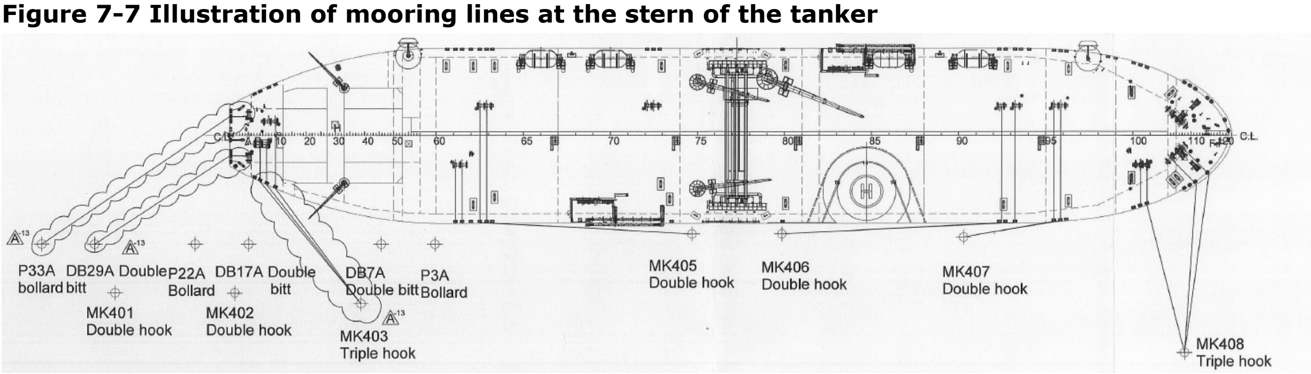



**Figure 7-8 An example of mooring layout of a Suezmax tanker**

#### 7.3.1.8 FMECA 2.5 – Potential operational disruption to boilers/auxiliary engines due to malfunction of technology

The capture and control technology will be equipped with an exhaust fan which provides a minimum of -2 mm $H_20$ at the hood. The fan may malfunction, e.g., overspeed, underspeed, sudden stop due to loss of power. This may cause backpressure buildup or high negative pressure within the tanker's exhaust system. It may cause the boiler fan to stop and incomplete combustion. It may also impact inert gas generation.

The current design concept includes a pressure monitoring system. The stack adaptor is attached to the tanker's stack with openings. If the backpressure is built up, the exhaust gas will escape through the opening. The infrared thermal camera will be capable of recognizing it and sending alarms to the operator.

To further mitigate the risk, the following recommendations are identified during the workshop:

- The capture and control technology supplier will:
    - implement an alarm window of pressure monitoring including both upper and lower limit
    - consider implementing pre-warning alarm regarding differential pressure for crew onboard the tanker to respond ahead
    - ensure fan speed is controlled according to the pressure in the duct
    - evaluate the reliability of the pressure sensor and develop redundancy accordingly
- Establish communication procedure between capture and control supplier, tanker's crew, and terminal operator, including:
    - providing instruction/checklist for tanker's crew to understand the pre-transfer processes, confirmation to proceed, capture and control technology's alarms, emergency procedures etc.
    - capture and control technology service supplier to attend the pre-transfer conference
    - establish VHF communication channel and protocol including pre-warning alarm that alerts the barge crew who can advise the tanker crew via established communications method. Action required by the tanker crew will be included in the instructional description and information package provided prior to connecting.

#### 7.3.1.9 FMECA 3.6 - Incompetent crew impacting the system's reliability and safety of the operation.

The complex navigation condition and operation of the capture and control system requires experience and sufficient qualification of the crew to ensure a safe operation. If the crew onboard the barge is inexperienced or unqualified, it may impact the system's reliability and safety of the operation.

The following recommendations are identified during the workshop to mitigate this risk:

- ensure the crew of the barge is trained properly considering the complexity of the capture and control operation, traffic congestion, etc.
- ensure the crew operating the capture and control technology is familiar with the terminal facility and the local navigation system
- develop operation procedures involving port, terminal, and the capture and control service provider.

### 7.3.1.10 FMECA 3.12 – Potential non-compliance of the terminal with MOTEMS requirements while using capture and control technology

The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) establish minimum engineering, inspection, and maintenance criteria for all marine oil terminals in California, to prevent oil spills and protect public health, safety, and the environment.[32]

The usage of capture and control technology may induce changes in the operation and result in incompliance with MOTEMS requirements. To mitigate this risk, the following recommendations are identified during the workshop:

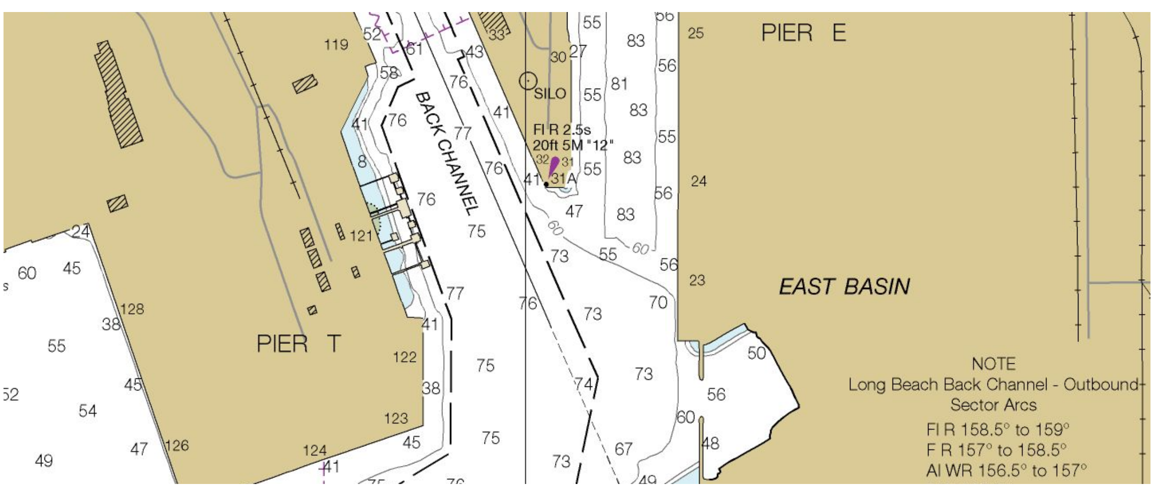
- consider performing Management of Change review before implementation
- monitor marine terminal regulation updates and ensure compliance.

### 7.3.1.11 FMECA 3.16 – Terminal depth (in some cases) not accounted for in the design of the spud for the barge-based capture and control technology.

During the workshop, it is discussed that double banking and mooring involve additional safety risks and is not a preferred way to ensure the station keeping of the barge. Using spuds could potentially be an alternative to provide station-keeping. This is used in CAEM's current design concept for barge-based capture and control technology for tankers. The length spud is currently considered at 75 feet.

If the terminal has relatively deep water, the length of spud may be too short. An example is Port of Long Beach Berth 121 may have the water depth around 76 ~ 77 feet. It is noted that a Jack-up barge capable of operating in 30m (98') water depth could be considered as an alternative. Further, some company's engineering standards do not allow spuds at this great of depth due to safety, reliability and other operational concerns.

It is recommended to review the water depth and perform underground utilities survey for spudded barge applications during the design stage of the barge and adjust the spud length according to the terminal arrangement. A Geotech survey might also be required.

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[32] California State Lands Commission

**Figure 7-9 Water depth at Port of Long Beach Berth 121**

#### 7.3.1.12 FMECA 3.19 – The environmental condition may be too harsh for the barge design.

According to CAEM, the barge-based capture and control technology for tankers will be designed with self-propulsion capability. The maximum speed of the barge will be around 5 knots for operating in Port of Los Angeles and Port of Long Beach. As mentioned earlier, these two ports have enclosed water. The environmental condition (current, wind, wave, tide, etc.) is normally much more benign compared with the Northern California ports. The barge design that is suitable for Port of Los Angeles and Port of Long Beach may not be able to operate safely in the Northern California ports. The propulsion power, stability performance, station keeping capacity of the spuds, etc. may need to be improved accordingly.

It is recommended to:

- Design the barge according to the environmental conditions for the planned operation areas.

#### 7.3.1.13 FMECA 1.15 – Inability of stack adaptor to connect to all emission sources due to compact stack configuration

Some tankers have a compact design of the funnel. In this situation, the limited space may prevent the connection of the stack adaptors to all working stacks. Therefore, some exhaust streams cannot be processed by emission capture and control technology.

To mitigate this risk, the following recommendations are identified during the workshop:

- C&C service supplier to develop pre-arrival communication procedure and understand the stack configuration, the number, and location of operating stacks for the visiting tankers. A bespoken stack adaptor connection method will be developed. The connection method should allow enough room for the necessary adjustment of the location without damaging the vessel's stacks.

If it is found that the stack configuration is too compact for connecting stack adaptors, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. However, it is to be noted that there is a limit in its usage and is listed here as an observation.

#### 7.3.1.14 FMECA 1.21 – Inability of the technology to process all exhaust streams when shifting from one stack to another

While at berth, a tanker may need to shift the usage of auxiliary engines or boilers. In this case, different stacks will need to be connected. As CAEM's current concept of emission capture and control technology for tankers uses only 4 stack adaptors. The emission capture and control technology cannot process all exhaust streams when shifting stack adaptor from one stack to another.

For this risk, the following recommendations are identified during the workshop:

- C&C service supplier to develop pre-arrival communication procedure and communicate the possibility of limiting the shifting of auxiliary engines and boilers while at berth.

If it is found that a tanker needs to shift auxiliary engines or boilers, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. However, it is to be noted that there is a limit in its usage and is listed here as an observation.

#### 7.3.1.15 FMECA 1.17 – Insufficient reach of the placement boom to all emission streams simultaneously due to height and large span of the funnel

The tanker vessel exhaust stacks may be as high as 50 meters above the wharf. The tankers may have two scenarios of berthing orientation, i.e., at the port side or starboard side. The barge-based capture and control technology seems to have a better performance on the flexibility.

In addition, for some tankers, the funnel may have a large span. An example is given by a stakeholder whose ship is using a special double engine room arrangement. Exhaust streams may exist from both the port and starboard sides.

To mitigate this risk, the following recommendations are identified:

- For the shore-based capture and control technology, it should evaluate if it is capable of covering the tankers visiting the terminal considering the size, height of the stack, and berthing orientations.
- For the barge-based capture and control technology, the service supplier shall develop a pre-arrival communication procedure and understand the stack height, configuration, number, and location of operating stacks for the visiting tankers. A bespoken stack adaptor connection method will be developed.

If it is found that the funnel is too wide for the placement boom to reach, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. However, it is to be noted that there is a limit in its usage and is listed here as an observation.

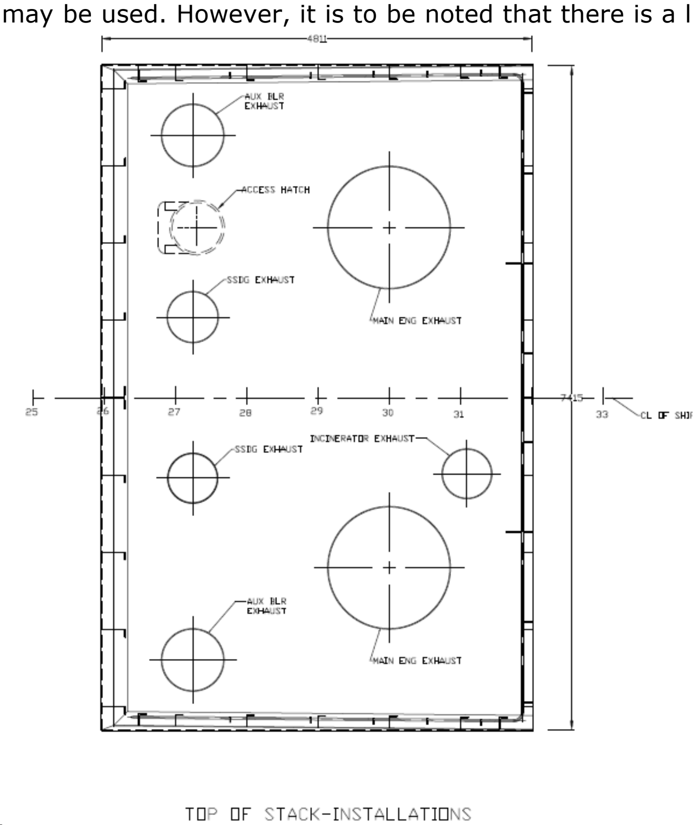



**Figure 7-10 An example of top of stack installation**

#### 7.3.1.16 FMECA 1.20 – Inability of the technology to process all exhaust streams due to higher number of emission sources

Normally, tankers have at least 2 auxiliary engines operating at berth. If the ship has an increased power demand, it is also possible to run 3 auxiliary engines. In addition, commonly 2 boilers may be running at the same time. With the reduced cargo discharge rate at 10 out of 11 berths in LB/LA, it is noted that the common practice is to run 1 generator and 1 boiler.

As a clarification, according to CARB, tankers' inert gas generator emissions are not regulated in the at-berth regulation.

Therefore, there could be up to 4 emission sources to be processed. The total number may also be higher. This is higher than the container vessels which have already been using the emissions capture and control technology.

According to CAEM, the concept for tankers considers using 2 placement booms and each boom has 2 stack adaptors. Therefore, 4 emission streams may be processed at the same time.

The following recommendations were identified during the workshop:

- C&C service supplier to develop pre-arrival communication procedure and understand the number of operating stacks for the visiting tankers.

If it is found that a tanker needs to run more than 4 emission streams, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. However, it is to be noted that there is a limit in its usage and is listed here as an observation.

#### 7.3.1.17 FMECA 2.4 – Inability of the technology to process all exhaust streams due to high exhaust rate from tankers

The currently CARB-approved Marine Exhaust Treatment System-1 (METS-1) system is approved for container vessels with only one auxiliary engine operating at berth. The approved operating conditions are shown in Table 7-2. This system would be too small for tankers considering the total number of exhaust streams from both auxiliary engines and boilers as well as the potential higher power output of auxiliary engines.

During the workshop, CAEM informed that for the design concept to be used on tankers the exhaust flow rate will be increased. It is recommended to review the range of exhaust gas flow rate of the tankers visiting California and increase the treatment capacity of the capture and control system accordingly.

**Table 7-6 Marine Exhaust Treatment System-1 (METS-1) system approved operating conditions[33]**

| Parameter | Value |
|---|---|
| Ocean-going Vessel Type | Container Vessels |
| Ocean-going Vessel Engine Type | One auxiliary engine |
| Fuel composition limitations | Marine distillate fuel with ≤ 0.1% sulfur content |
| Maximum engine MCR [kW] for each engine type | 2500 kW |
| Allowable operating range [kW] | 600 – 1500 kW;<br>Only one auxiliary engine may be controlled per METS-1 system |
| Exhaust flow rate that can be treated [standard cubic | 1020 to 5100 scfm of engine exhaust |

[33] State of California Air Resources Board, Executive Order AB-15-01

feet per minute (sfcm)]

### 7.3.1.18 FMECA 3.13 – If the navigation channel is narrow, the usage of barge-based capture and control technology may block the traffic.

The size of the barge that CAEM currently developing is around 31 meters (102 feet) x 18 meters (60 feet). In addition, clearance is also needed between the tanker and the barge as discussed in Section 7.3.1.3. The water channel close by the terminals can be narrow. According to the engaged experienced pilots, typically 46 meters (150 feet) maneuvering room is needed. If the barge is arranged alongside the tanker, it may block the traffic due to the limited width of the channel. A few illustrations are given below.

Figure 7-11 illustrates that if the barge is berthing alongside an Aframax tanker at Berth 78, it will likely prevent the tanker or bunker barge from passing the channel to leave or call Berth 77 and 76. According to the stakeholder, Berth 77 often has Panamax tankers visiting and Berth 76 frequently has bunker barge visiting. Around Berth 86, there is a turning basin. A detailed evaluation has to be performed to investigate whether the traffic will be impacted if the barge is berthing alongside the tanker.

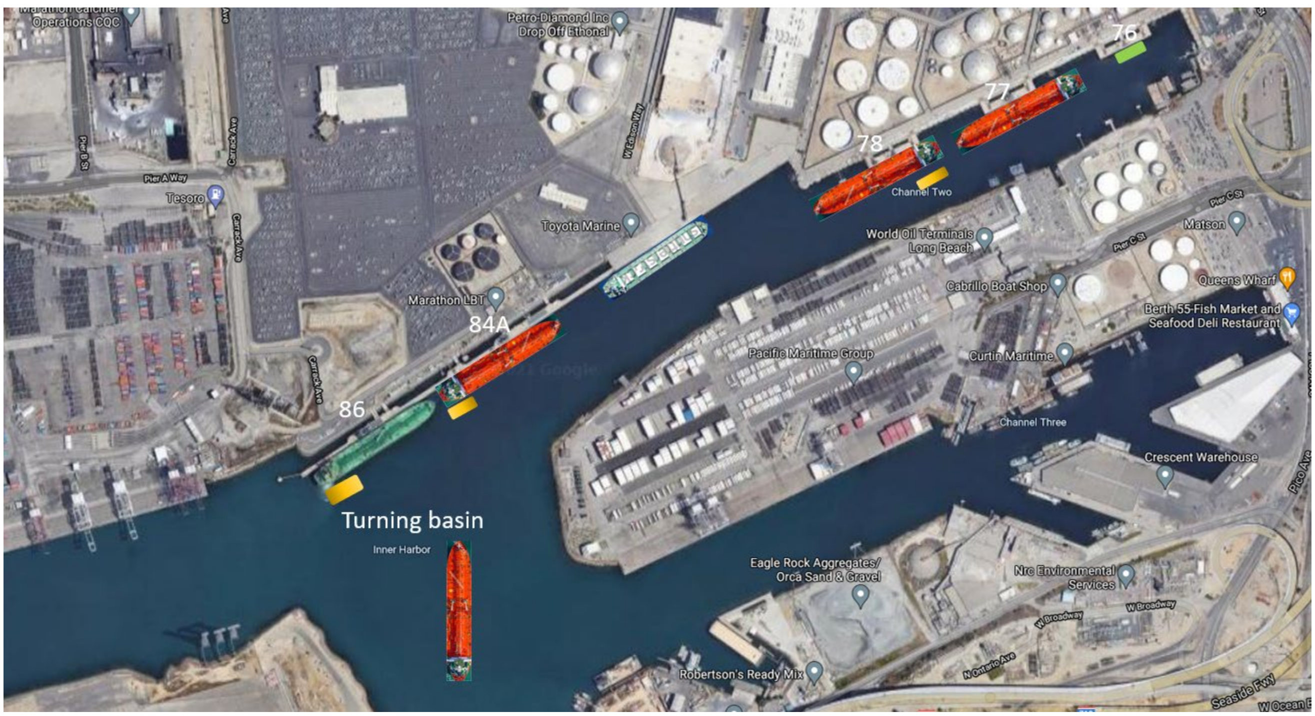



**Figure 7-11 Illustration of the potential impact on the traffic around Port of Long Beach Berth 76 ~ 78, 84A and 86 from the usage of barge-based capture and control technology (The figure is used only for illustration purposes. The measurement is not accurate.)**

On the Carquinez Strait, there are several bridges. The ships must follow a certain route to pass through the bridge. Figure 7-12 illustrates that if the barge is berthing alongside a tanker at marine oil terminals close by the Benicia-Martinez Bridge it may impact the passing traffic on their eastbound way to pass the bridge.


**Figure 7-12 Illustration of the potential impact on the traffic at Carquinez Strait from the usage of barge-based capture and control technology (The figure is used only for illustration purposes. The measurement is not accurate.)**

To mitigate this risk, the following recommendations were identified during the workshop:

- assess the berthing location of barge based on the local traffic and channel navigation system to avoid adverse impact to the passing traffic;
- ensure that the barge is not berthing inside the regulated navigation area;
- consider moving the barge temporary to allow passing traffic following the provision from CARB at-berth regulation regarding removing the capture and control technology temporarily;
- develop real-time communication platform btw all parties (pilot, terminal, capture and control service provider) and install communication and navigation equipment (VHF, GPS, Satellite compass) onboard the barge;
- consider equipping the barge with an automatic identification system (AIS).

#### 7.3.1.19 FMECA 3.2 – Insufficient space at the terminals for installation of shore-based capture and control technology

According to CAEM, the footprint of the technology is around 5.5 meters (18 feet) x 9.1 ~ 15.2 meters (30~50 feet). The height is around 9.8 meters (32 feet).

Similar to the discussion in Section 6.3.1.11, terminals may not have sufficient space for the installation of shore-based capture and control technology. The barge-based capture and control technology could be used as an alternative. Otherwise, a dedicated floating or fixed platform may be needed.

#### 7.3.1.20 FMECA 3.5 – Safety and reliability of operation compromised by improper design and construction of barge

The design and construction of the barge-based capture and control technology needs to consider the different operational profile of the barge given the large variety of terminals it is intended to be deployed. It should also consider the different ship sizes and complexities associated with the potentially complex operations. In case of improper design and construction, this will have an impact on safety and reliability of operations.

If the barge is not operated self-propelled between ports or in open water, but only inside the enclosed area in a port, it may not need to be classed or inspected by US Coast Guard. There are also no industry vetting standards for these barges according to DNV's knowledge.

To mitigate this risk, the following recommendations are identified during the workshop:

- class the barge with a classification society and implement a periodical inspection and maintenance plan
- determine the operating area and clarify with US Coast Guard on the regulatory requirements

#### 7.3.1.21 FMECA 3.14 – Potential encroachment of neighboring property during deployment of capture and control technology

Regarding the potential berthing location of the barge, one possibility is at the stern of the tanker. However, it may involve the risk of encroachment on other's property. An example is given below. It shows that if a tanker is berthing on the port side at Shell Oil Products US Mormon Island Marine Terminal LA Berth, there will be too limited room for berthing the barge in Shell's property. This will involve encroachment on Tinto Minerals' property and impact the ship calling their terminal.

Combining the discussion in Section 7.3.1.18, another possibility is berthing the barge alongside the tanker. It may block the traffic from entering or leaving the channel especially when there is a vessel berthing at Berth 153.

The following recommendations are identified during the workshop to mitigate this risk:

- To review the possibility of berthing the barge at the stern of the tanker, the footprint of the barge should be assessed. Discussion with the neighboring property owner(s) regarding the possibility of using their property may be needed. This should be performed together with the assessment of the local traffic and channel navigation system to identify the feasibility and most preferable berthing location.


**Figure 7-13 Illustration of the property boundary line of terminals (The figure is used only for illustration purposes. The measurement is not accurate.)**

## 7.3.2 HAZOP

The HAZOP workshops identified a total of 12 risks. Out of the 12 risks, 2 risks were seen to be more relevant for tankers. Both the risks identified were medium risks. All the risks relevant for tankers are highlighted in this section and the details can be found under Appendix 7.4. The risk matrix is as indicated in Figure 7-14 below with risk ids denoted with a # followed by number that relates to type of risk considered. Also refer to Appendix 7.

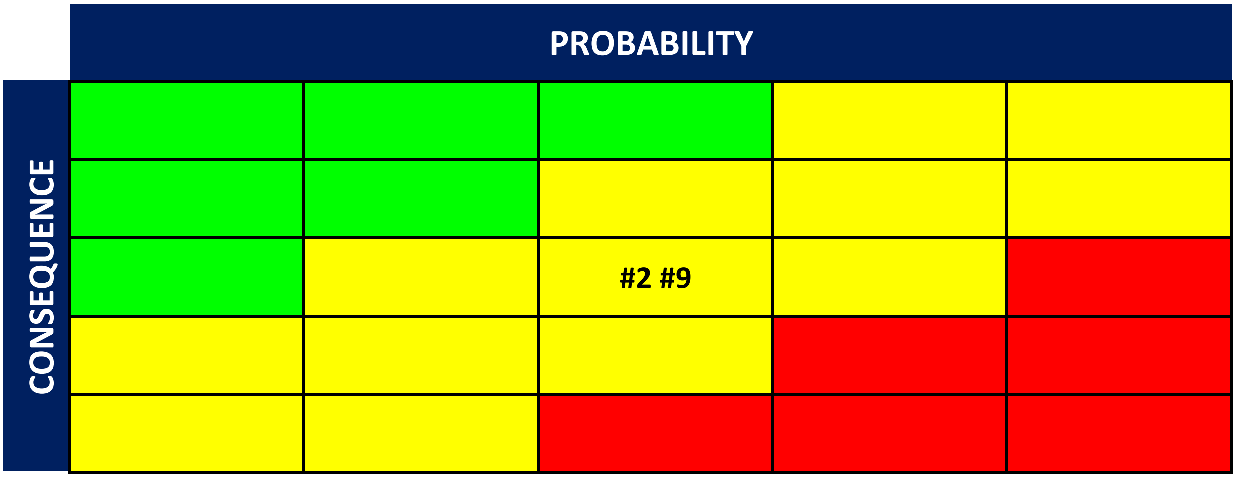



**Figure 7-14 Risk matrix for HAZOP**

#### 7.3.2.1 HAZOP 2 - Safety risk due to human fatigue from long and complex operation of tankers

While at berth, tankers have a relatively complex and long operation. A VLCC may stay in a port for discharging for 3 days. It may cause human fatigue and increase the safety risk.

It is recommended to:

- develop proper training and operation procedures for the whole process including:
  - normal operations such as connection, startup, disconnection, and maintenance
  - emergency response including safety plans
- provide accommodation and ensure proper working conditions for the crew
- develop proper working schedule and shifts for the crew and ensure the proper rest.

#### 7.3.2.2 HAZOP 9 – Potential fire or explosion from the technology in the event of an oil spill

Oil spillage is a highly relevant hazard for tankers. In the event of oil spillage, potential sources of ignition should be eliminated.

It is recommended to:

- Develop a safety/emergency response plan with terminals and ports for oil spill scenarios. The barge will likely need to shut down power and provide shelter (accommodation) for the crew onboard.
- Provide proper procedure and equipment for communication between the emergency response team, tanker, terminal, port, and capture and control service provider.
- Provide necessary PPE during such incidents

# 8 TIMELINE AND COST ESTIMATION

This section will discuss the timelines and costs for the design, permitting, and construction of the technologies assessed to meet the CARB At-Berth regulation as well as an update on the timing of applicable design and operational standards. Estimates are based on available information and input provided by the stakeholders in this project. DNV also used experience and data on the cost and timeline from other projects when considered relevant to this study (e.g., on the shipboard installation and shoreside capital costs). The timeline is a high-level estimation broken down into major milestones at the year/half year granularity. The purpose will be to evaluate a minimum but realistic timeline to implement the technology and comparing it with the timeframe of 2020 At-berth Regulation shown in Table 2-2. A similar approach is used to estimate the capital cost which may include vessel and terminal modifications, procurement of the technologies, etc. The operational cost was analyzed based on the categorized tanker and terminal versions.

DNV recognizes that the technologies reviewed in this report are also evolving. As an example of this, we acknowledge that CARB has granted the South Coast Air Quality Management District (SCAQMD) $10 million dollars to develop a barge-based C&C system. As a result of the work associated with the grant, the hurdles identified in this report may be addressed and result in earlier adoption than determined here. The timelines provided in this section represent DNV's best assessment of the technologies based on their current status. Section 9 also provides a view into the broader energy and fuel transition happening in the maritime industry including the use of environmentally friendly fuels and energy sources to achieve emissions reductions greater than those provided by the technical design and operational measures alone.

## 8.1 Shore Power

The following subsection provides details on the timing of applicable design and operational standards, the timing of permitting, design and construction, and the costs associated with shore power technology.

### 8.1.1 Timing of Applicable Design and Operational Standards

In DNV's opinion, for wide, large-scale implementation of shore power technology, further development of industry standards, regulations, and classification societies rules is required. The gaps in the standards, regulations, or absence of industry guidelines for shore power are likely to delay implementation, increase safety risks, or lead to confusion over technology deployment and investment.

This is especially a concern regarding use of shore power for tankers at berth because the cargo operations involve hazardous products and interfaces with hazardous zones on the terminals and onboard the ship. The explosion and fire risks, as well as personnel risk must be mitigated to be as low as reasonable possible. The global trading pattern of oil and product tankers, the differences in the vessel designs, power needs, and sizes, as well as the lack of standardizations of terminal configurations and shore power cable managements system for tankers needs to be considered. Oil terminal and tanker operations also require specialized crews with relevant training and certifications required during cargo operations. The monitoring, operation, and maintenance of the system and components used when connecting and using shore power will also require planning, training, drills and documentations.

That these concerns are shared were evident from the stakeholders engaged in this technology assessment and risk workshops for this study. To address those concerns, a common framework anchored in industry regulations or guidelines should be developed, but there is currently no timeline for addressing these gaps, and it is unclear who is responsible for initiating these efforts.

In Section 6.1.3, relevant agencies, industry associations, existing regulatory framework, and standards relevant to shore power use for tankers at berth were listed. Of these, DNV, during this technology assessment, has identified standards, agencies, and industry groups that would have a more significant role on the safe implementation of shore power for tankers in California ports and worldwide. Table 8-1 lists the regulations, rules, standards, and guidelines identified from Section 6.

**Table 8-1. Status of regulations, rules, standards, and guidelines**

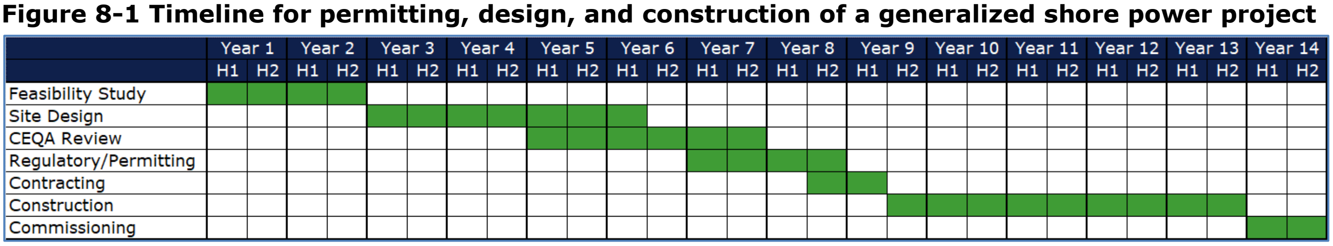
| Regulations, Rules, Standards, and Guidelines | Need | Timeline | Status |
|---|---|---|---|
| **IMO Regulation** Interim Guidelines on safe operation of on-shore power supply (OPS) | Interim guidelines need technical modifications and eventually approved at MSC 105. Focus will be on operational requirement and this is was the comment from the IMO Correspondence group following the draft guideline submitted by China | Interim guideline could be approved at MSC105, May 2022. | Interim guideline refer to IEC/IEEE 80005-1 for design requirements |
| **IACS/ Classification Society Rules** | IACS: recommended practice<br>Class: Tanker specific shore power rules/class notation | 1-2 year | Under discussion |
| **International Standards regarding Interoperability** – IEC / IEEE 80005-1:2019, High voltage shore connection | Lack of<br>IEC/IEEE joint WG need participation from industry to develop tanker specific requirement | 2-3 years | Under discussion |
| **Maritime Industry Guidelines** International Safety Guide for Oil Tankers and Terminals (ISGOTT) | A new edition to include use of shore power during cargo operations | 2 -3 years | Not aware of any ongoing work on updates of these guidelines with a focus on shore power |

## 8.1.2 Timeline for Permitting, Design, and Construction

While each terminal has its own set of unique characteristics that will impact the timeline, a typical shore power project is likely to take around 14 years years making it very unlikely that any ports will be able to comply with the 2020 At-berth Regulation timeline. For larger and more complex terminals, additional time will be required to complete each step due to the larger scale of the engineering, design, and construction effort. This timeline also assumes that the necessary design and operational standards exist, which is discussed in the previous subsection. This section presents generalized durations for the various components of a project: feasibility study, site design, California Environmental Quality Act (CEQA) review, permitting, contracting, construction, and commissioning. Actual timelines may vary depending on the unique challenges associated with each terminal.

Figure 8-1 presents the generalized timeline for a shore power technology installation. These tasks, and their uncertainty, are explained below. Some of these major tasks can be undertaken concurrently to minimize total project timeline; however, some tasks must be completed before the next task can commence.

**Figure 8-1 Timeline for permitting, design, and construction of a generalized shore power project**



**Feasibility study**

The first step for each terminal is to conduct a feasibility study to determine the appropriate, cost-effective technology that can be installed and operated safely. This will inform the site design and ensure a correct layout and structural design to support the necessary equipment. Any feasibility study needs to consider the availability and applicability of internationally accepted standards for interfacing and design. This feasibility study also needs to consider the reliability of power supply given California's recent power generation and transmission issues due to natural disasters. This stage would likely take at least two years to complete in order to properly assess the solution and its alternatives. As part of this stage, the local electricity provider will also need to conduct an assessment of how additional electrical demand will impact the grid, which can take up to a year to complete in conjunction with the site feasibility study. If there are multiple projects in a utility service area, this assessment needs to consider the cumulative impacts of the increased demand.

**Site Design**

The site design cannot commence until a feasibility study is completed to determine the appropriate technology and layout. This site design includes the preliminary and final design and engineering, assessments on utility infrastructure, and siting for egress and safety. The site design may take up to 3.5 years to complete, and depending on the complexity of the site design, could take as long as 5.5 years.

**CEQA Review**

Since any potential project is likely to have a significant effect on the environment, a CEQA review is required. To provide an accurate and stable project description, this review cannot begin until around 60% of the design is completed. This review could require preparation of an Environmental Impact Report (EIR), public comment periods, hearings, and review of the EIR until a final adopted EIR results with specific mitigations for impacts. Based on a review of recent marine projects in California, this is likely to take approximately 3 years. Additional permitting cannot begin until the CEQA review is completed.

**Regulatory/Permitting**

After completing the CEQA environmental review process, projects need to receive permits or regulatory approvals from:

- Local: The local air quality control/management district, local Regional Water Quality Control Board, and building permits and/or coastal development permits from the local city/county
- State: California State Lands Commission, California Department of Fish and Wildlife, and coastal development permits from the California Coastal Commission (if not delegated to the local city/county)
- Regional: San Francisco Bay Conservation and Development Commission (for northern Californian terminals)
- Federal: United States Army Corps of Engineers, U.S. Fish and Wildlife Service (if protected species are affected), National Marine Fisheries Service (where marine mammals may be present), and the United States Coast Guard

Because of the time required to prepare applications across agencies and jurisdictions, time for review and addressing comments, and the potential that requested changes may results in site re-design, this is likely to take about 2 years and potentially longer.

**Contracting**

While the project team is pursuing the appropriate permits, contracting for engineering, contractors, and suppliers can bid. This process includes a bidding (multiple RFPs), selection, and procurement. This can take up to a year or longer to complete.

**Construction**

The shoreside construction phase is largely dependent on the complexity of the site design. This can include crane construction/installation, deck modifications, pilings, new power infrastructure/substation upgrades, cable installation/new ducting, and seismic retrofit. We estimate that this is likely to take about 4.5 years but could range to more than 7 years.

**Commissioning**

After construction is complete, commissioning is required to verify CARB compliance and other federal and state requirements, implement operator training and oversight, and modifications to ensure proper operation to achieve compliance. Newer technologies require longer commissioning durations. We estimate this is likely to take about 1 year to complete.

### 8.1.3 Costs for Vessel Modifications

The installation for shore power technology on tankers will typically be incurred by the vessel owner and will vary depending on a variety of factors. The installation costs are lower for new vessels compared to retrofitting existing vessels.

Depending on the number and location of the connection points, the additional costs, including the equipment costs, for shore power technology on new vessels are estimated to be between $350k and $700k. The capital cost for the equipment is the largest share of the cost, but since the equipment cost and installation expenses are most often included in the total newbuilding cost given by shipyard to the owner, there is a wide range and some uncertainty in the range. However, since the number of the tanker calls at California will be dominated by vessels already in service without the technology installed at the newbuilding phase, the rest of this section will focus on retrofitting existing vessels.

For existing vessels, the cost is dependent on the vessel type, size, vintage, and the need for an onboard transformer. The typical cost for a tanker ranges from about $150,000 to around $1M. For smaller vessels, costs range from about $70,000 to $500,000, and for larger vessels, the costs range from about $500,000 to $1M. If shore power connections are added to both sides of the vessel, costs can be higher. Similarly, if vessels require new electrical cargo pumps/variable frequency drives (VFDs), the cost estimates for vessel modifications can increase to $2-3M.

The key components driving the cost include the distribution system, control panel and junction boxes, cable winch (can also be found on the berth side) and connection unit, and any frequency converters. Table 8-2 shows the typical cost ranges for different size vessels assuming an onboard switchboard connection point and high voltage switchboard updates/additions with the connection point aft of the hazardous zones (no use of safe house midship close to the manifold) .[34] The table illustrates that there are large uncertainties in the cost estimates, and because the technology is still relatively new in the tanker segment and the risk mitigation is even more critical, costs may be higher than what is presented. Additionally, how the retrofit is done, e.g. incremental in steps or during a single shipyard stay can also impact costs significantly (and are not represented in this table). [35]

**Table 8-2. Cost ranges for tanker vessels retrofits**

| | 1,000 – 4,999 GT | 5,000 – 9,999 GT | 10,000-24,999 GT | 25,000 GT - 49,000 GT | 50,000 – 99,000 GT | >=100,000 GT |
|---|---|---|---|---|---|---|
| **Crude Tankers** | $70,000 - $420,000 | $140,000 - $550,000 | $140,000 - $550,000 | $140,000 - $550,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 |
| **Chemical/product tankers** | $70,000 - $420,000 | $140,000 - $550,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 | | |
| **Gas tankers** | $70,000 - $420,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 | $420,000 - $1,040,000 |

These price ranges are consistent with a 2004 shore power cost effectiveness study commissioned by the POLB. The study included an analysis of twelve vessels, including several tankers, and concluded that the average cost to retrofit vessels with shore power technology was $725k (adjusted for 2021 USD).[36]

The above vessel modification costs assume that the shore power connections will be behind the accommodation area and outside the hazardous zones on deck so there is more flexibility to how it will be arranged. In order to connect at the cargo manifold area, connections within the hazardous zone requiring the design and construction of a specialized pressurized and inerted deckhouse (safe room) with an airlock to house the connection point for the shore power is foreseen. The cost of this arrangement would be significantly higher than the retrofit costs in the above table. The deckhouse option also has a safety design challenge since the cable will have to enter the room itself and then the space would have an opening to a hazardous zone.

In May 2019, the California Air Resources Board (CARB) Staff estimated costs for vessel retrofits for the Standardized Regulatory Impact Assessment. Based on a June 2018 survey, CARB assumed an average cost per vessel was $2,256,278 based on a range of $1,612,556 to $2,900,000.[37] Some of the cost estimates include shore power on the second side of the vessel; however, these values are higher than the DNV estimates provided above.

[34] Cost values developed as part of a 2015 study conducted by DNV examining shore power at Norwegian ports. Numbers have been converted to 2021 USD using an average annual inflation rate of 2.42% (US Bureau of Labor Statistics).

[35] Esimated costs for shorepower conversions for tankers around 10 mUSD for vessel with steam driven cargo pumps has been reported, and more than twice that for tanker vessels with electric driven cargo pumps

[36] https://sustainableworldports.org/wp-content/uploads/Long-Beach.pdf

[37] https://ww2.arb.ca.gov/sites/default/files/2020-04/costassumptions_may19_ADA.pdf

### 8.1.4 Costs for Shoreside Modifications

The costs for shoreside modifications vary greatly depending on the unique challenges of each terminal. This results in wide range of costs depending on the space constraints and required distance of electrical runs. Each terminal will require a feasibility study to determine the optimal arrangement and expected costs for modifications. These feasibility studies are not transferable to other terminals because of the unique terminal arrangements and the vessels that they serve. For a typical shoreside modification with limited complexities, the installation of shore power costs between $2.5M – $14M per berth, including interconnections to the grid. Depending on the number of berths, outlets per berth, and supporting infrastructure needs, costs can exceed $20M per terminal. Facilities with multiple berth facilities may have lower capital costs per berth due to economies in design, permitting, and costs of share infrastructure.

The one tanker terminal with existing shore power connections in California is the Marathon Oil Terminal on Pier T (Berth 121) in POLB. The project was completed in 2009 and included a shoreside switchgear and transformer, which was located next to the port substation, and a cable management system platform (crane on ship). The shore power connection was built to serve the Alaska Tanker Company's four oil tankers, and these ships are diesel electric and uses electric driven cargo pumps.

The costs presented in this section provide a typical capital cost range for the main components of the shoreside infrastructure. These modifications typically include costs for main substation, shoreside substation, and berth components. In estimating the capital costs for a specific OPS installation, the costs of extending power from the port's substation to the shoreside substation and, potentially, the costs of increasing the capacity of the substation must be accounted for. These costs only represent the CAPEX costs and do not include O&M or energy costs. Table 8-2 outlines the cost ranges for the main shoreside components. Actual costs may be higher depending on specific berth arrangements. If a terminal does not have sufficient space to accommodate the shoreside infrastructure, there will likely be additional costs associated with expanding the terminal footprint.

**Table 8-3. Shoreside component cost estimates**

| Component | Costs | Notes |
|---|---|---|
| **Substation Upgrade** | $100K - $7M | Includes upgrades to main substation and cabling to shoreside substation. Costs will vary depending on status of main substation and distance to shoreside substation. |
| **Shoreside Substation** | $1M - $3M | Includes shoreside switch gear for feed and isolation of each SPO. |
| **Berth Components** | $500K - $3M | Includes shore power outlet, cable vault, and cable extender. Total cost of berth components dependent on number SPOs and arrangement of cable vault. |

As part of the May 2019 Standardized Regulatory Impact Assessment, CARB staff estimated the cost for shore side modifications using June 2018 survey values at $21,983,333 per tanker berth. These costs ranged from $2,250,000 to $40,000,000 per berth. Costs from container terminal OPS installations also offer insights into expected costs for tanker terminal OPS installations; however, there are some significant differences in the terminal configurations and complexities with tanker interfacing that make OPS more challenging and more expensive. The POLA and POLB developed cost estimates for tanker terminals based on previous shore power construction projects and cost estimates for future shore power work. Using and average cost per SPO of $2,272,609 and $500,000 for a 100-foot cable reel management system, assuming 2 SPOs per berth, the average costs per berth was about $5 million, not including any potential upgrades or connections in the main substation or expansion of the terminal footprint.

## 8.2 Capture and Control Technology

The following subsection provides details on the timing of applicable design and operational standards, the timing of permitting, design and construction, and the costs associated with capture and control technology.

### 8.2.1 Timing of Applicable Design and Operational Standards

To ensure the safe operations of a barge-based or shore-based control system during the transfer of hazardous cargo, there should be international standards and guidelines to accommodate all vessels and vessel interfaces safely. While there are standards for barge construction and operations,[38] there are currently no standards for exhaust capture operations while transferring hazardous cargo at a terminal. The gaps in the standards, regulations, or absence of industry guidelines are likely to delay implementation, increase safety risks, or lead to confusion over technology deployment and investment. Similar to shore power, a common framework anchored in industry regulations or guidelines should be developed, but there is currently no timeline for addressing these gaps, and it is unclear who is responsible for initiating these efforts.

Manufacturers have not yet designed or built capture and control systems that would qualify under the 2020 At-berth Regulation. However, while there is currently no ready to use capture and control technology deployable for tankers, a barge-based system that is currently being designed would likely qualify under the 2020 At-berth Regulation and could be ready for operation by 2025. Shore-based capture and control technology has never been implemented on tankers and needs to be proven that it can be deployed before wide-scale implementation.

### 8.2.2 Timeline for Permitting, Design, and Construction

Based on the infrastructure needs and permitting process, the timeline for a land-based capture and control project will be similar to the that of a shore power project – 14 years. Based on that timeline, a land-based system is currently not a viable option to meet the regulatory deadlines. The earliest that a land-based system can be implemented is 2034. Because of the similarity with shore power infrastructure requirements and the uncertainty around the technology, the rest of this section presents a timeline for a barge-based capture and control project.

The timeline for implementing a barge-based capture and control technology is about 5 years.[39] This timeline also assumes that the necessary design and operational standards exist, which is discussed in the previous subsection. If there is a proven, off-the-shelf technology that was safe for use on tankers and boilers, many of the early steps could be bypassed or the timeline shortened. Figure 8-2 shows a generalized timeline for a barge-based capture and control project. The timeline estimates for preliminary and detailed engineering, construction, and commissioning are based estimates provided by an engineering

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[38] Example: ABS Rules for Building and Classing Steel Barges (2021)

[39] This timeline assumes that there is no need to conduct a CEQA review or any other environmental permitting. If an environmental review of the barge operation is required, this could extend the project timeline 1-2 years.

firm that has already completed a feasibility study and engineering for a Maritime Emissions Treatment System (METS) barge that is expected to available for use by 2025 at Long Beach/Los Angeles terminal. Details of the capacity and specifications of the METS barge for tankers are work in progress.

**Figure 8-2. Timeline for permitting, design, and construction of a generalized barge-based capture and control project**

| | Year 1 | | Year 2 | | Year 3 | | Year 4 | | Year 5 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 | H1 | H2 |
| Preliminary Feasibilty | ■ | ■ | | | | | | | | |
| Preliminary Engineering | | | ■ | | | | | | | |
| Detailed Engineering | | | | ■ | ■ | | | | | |
| Terminal Specific HAZOP | | | | | | ■ | | | | |
| Construction | | | | | | ■ | ■ | ■ | | |
| Commissioning | | | | | | | | | ■ | ■ |

The starting point for a terminal looking at a barge-based capture and control system is the preliminary feasibility study. A feasibility study is needed for each terminal to determine the feasibility of the technology for each terminal. This should include environmental conditions, navigation and ship access, vessel activity, and space restrictions. Barge-based capture and control systems may not be available for all berths such as those in area-restricted ports and within bays that are subject to severe waves and tides.  Any feasibility study must be terminal specific and cannot be used by other terminals; however, terminal feasibility studies need to also consider the cumulative impacts (e.g., limited wharf availability) of multiple barge-based systems at port. Many of the terminal compliance documents for CARB may contain much of this work reducing the total timeline.

At least one vendor has completed the preliminary engineering and has nearly completed the detailed engineering for a barge-based system that is expected to meet CARB requirements, so the key remaining elements in the timeline are a terminal-specific HAZOP and construction. As part of the initial construction phase, the barge must be lofted, and production-level drawings developed. This process can be expedited for simple barges, but it is probably 3 months in total duration. After that is completed the typical construction timeline for self-propelled barge of this nature is likely another 8-14 months. The final step in the timeline is the commissioning phase which concludes with an operating permit from CARB.

### 8.2.3 Costs for Capture and Control Technology

Since no capture and control systems are currently deployed on tankers, there are is still a lot of uncertainty the costs estimate. For land-based systems, CARB estimated costs, as part of the Standardized Regulatory Impact Assessment,[40] at about $16.5 million per berth in capital expenses. This includes $4.5 million for piping infrastructure from the berth to the land-side emission control system, $5 million for the emission controls system, and $7 million for each loading crane. These costs are highly variable based on the existing berth arrangement and available wharf space, but the values are a reasonable estimate for the total capital costs.

For barge-based systems, the capital costs make up a smaller portion of the total costs due to higher operating and administrative costs. However, there are other advantages to barge-based systems including

[40] https://ww2.arb.ca.gov/sites/default/files/2020-04/costassumptions_may19_ADA.pdf

their ability to move and support multiple berths. The CARB estimates of $4.9 million for the barge construction[41] understate to total capital costs required. Costs will be even higher for terminals further north due complications around wind and currents. Any system should be designed in a way that does not require vessel modifications, so all of the capital costs will be on the terminal side. In addition to the capital costs, there will also be leasing/port fees, fuel costs, labor costs, and maintenance costs.

[41] https://ww2.arb.ca.gov/sites/default/files/2020-04/costassumptions_may19_ADA.pdf

# 9 ENERGY AND FUEL TRANSITION IN SHIPPING

Globally, there is increasing demand for solutions to reduce emissions from the maritime industry with the use of cleaner energy sources. More stringent emission regulations have driven the demand for more use of environmentally friendly fuels and energy sources to achieve emissions reductions greater than those provided by the technical design and operational measures alone. This trend is being accelerated as the IMO implements its strategy for the reduction in greenhouse gas emissions from international shipping and shipowners face the prospect of stricter requirements on the carbon intensity of their operations, moving towards the eventual goal of eliminating shipping greenhouse gas emissions in this century.

This development, driven both by global and regional regulations and policies, as well as other maritime stakeholders, e.g., the finance institutions, shippers, and cargo owners, will drive a transition from the traditional fuels and energy sources currently used by ocean-going vessels. Additionally, energy efficiency improvements and innovative technologies will also need further development to achieve the targets set by the maritime industry.

This transition is already underway with rapid growth in the newbuilding orderbook of new ships, especially during the last year, including tankers, are being ordered with alternative fuels, like LNG, LPG, methanol, biofuels as well as early designs based on ammonia as a fuel. The new fleet and fuel mix of the future will also affect the air emissions when at berth, and there might be less need or different needs for reducing the at-berth emissions.

## 9.1 Regulatory Drivers

The International Maritime Organization (IMO) is the main regulatory body for commercial ships trading in international waters. Its policies drive important environmental and safety standards that push the implementation of measures for reduction of emissions in the industry. In 2018, the IMO adopted a resolution on an Initial Strategy to reduce GHG emissions, with ambitions for reducing total emissions from shipping at least by 50% in 2050, and to reduce the average carbon intensity by 40% in 2030, compared to 2008.

The IMO has not yet decided on specific pathways for GHG emission reductions but has committed in its initial strategy to implement an escalating series of measures. Short-term measures focused on improving the energy efficiency (EEXI) and carbon intensity (Carbon Intensity Index or CII) of the existing fleet are to enter into force in 2023 as decided at the Marine Environmental Protection Committee Meeting (MEPC 76) in June 2021. The IMO is also scheduled to review the Initial Strategy in 2023, at which point the focus is expected to shift to mid-term measures which may include requirements to implement alternative fuels, global $CO_2$ pricing measures, or a carbon content limit on fuels permitted for use by international shipping, alongside tightening of existing design and operational measures.

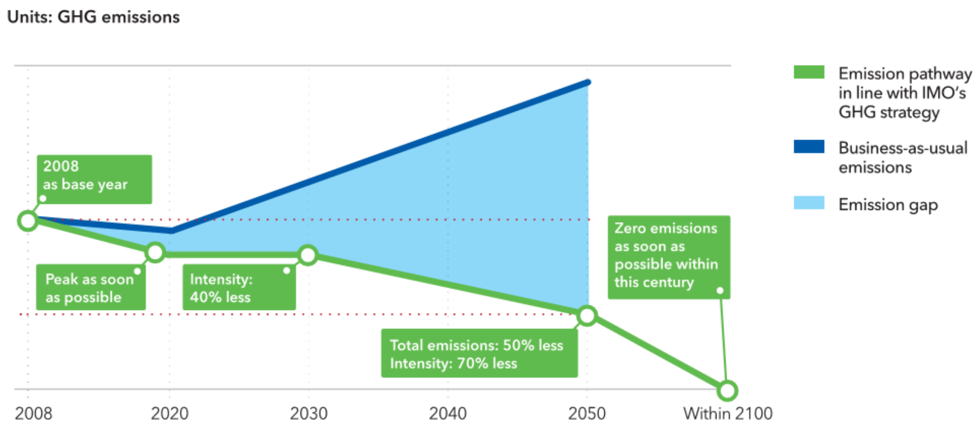



**Figure 9-1 Indicative world fleet GHG emissions pathway to meet IMO ambitions**

While the IMO vision and strategy has been submitted to the United Nations Climate Change Conference process and is widely seen as compatible with Paris Agreement goals, it is of course possible that a growing international sense of urgency may force a significant acceleration of the IMO's plan. Taking for example a scenario where deep decarbonization (e.g. significantly more than 50% reduction by 2040) became a goal then earlier adoption of carbon-neutral fuels would be required, in addition to stricter design, operational, and market-based measures.

## 9.2 Decarbonization of shipping

DNV has since 2017 produced an Energy Transition Outlook (ETO) report to help energy stakeholders and decision-makers responding to a changing energy landscape. The maritime part of the ETO is called the "Maritime Forecast to 2050" (MF2050). MF2050 provides an independent outlook on the maritime energy future, including marine vessel fuel use. The 2019 version of MF2050 focused on the challenges facing the maritime industry in meeting the IMO GHG reduction targets, and the potential implications for maritime stakeholders. It concluded that new fuels, alongside energy efficiency, will play a key role in meeting the IMO GHG targets for 2030 and 2050.

MF2050 includes a model of the different scenarios to reduce the GHG emission from shipping that will meet or even exceed the IMO stated ambitions. Figure 9-2 Uptake of Alternative Fuels – Forecast scenario to meet IMO ambitions with focus on design requirements is taken from the 2019 MF2050 and shows one forecast scenario for energy use and projected fuel mix 2018–2050, assuming a regulatory environment in line with current IMO ambitions and with most measures focused on design requirements for new ships.

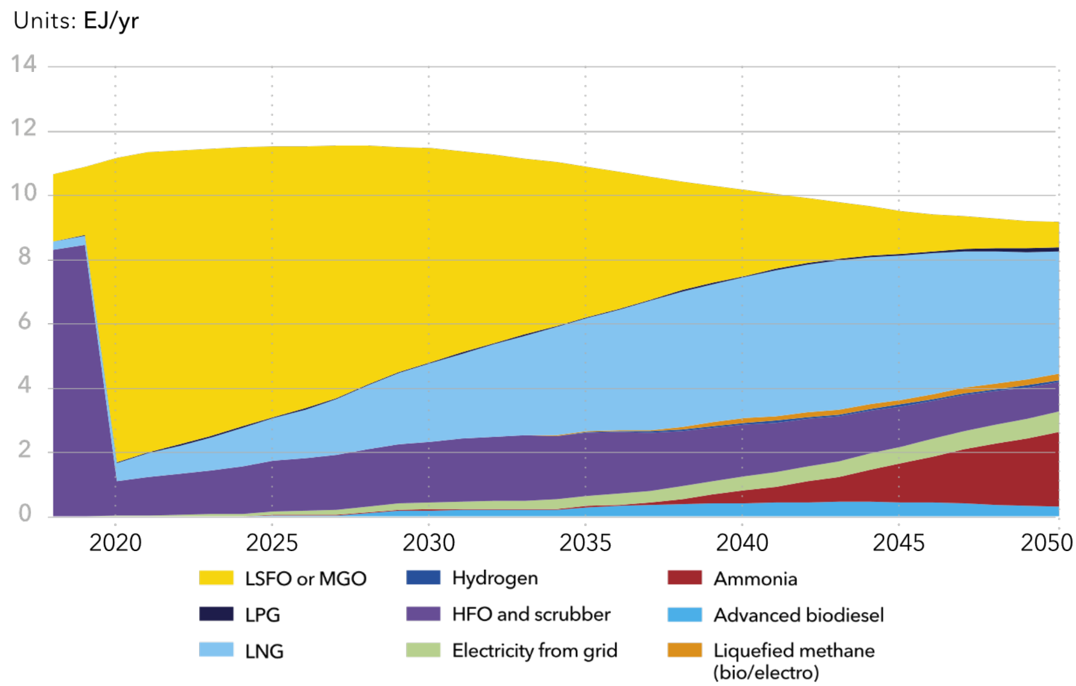
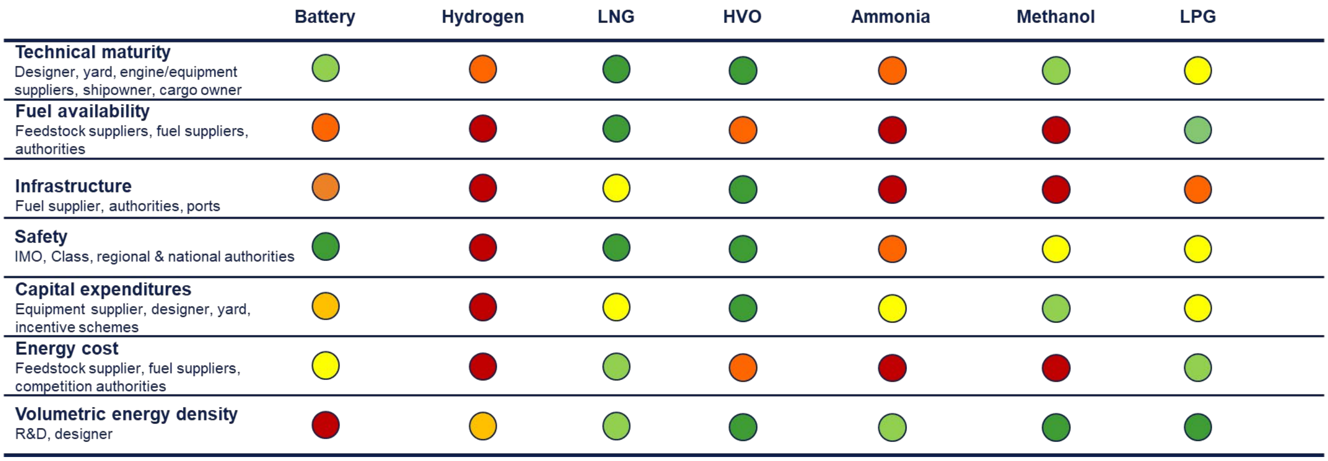



**Figure 9-2 Uptake of Alternative Fuels – Forecast scenario to meet IMO ambitions with focus on design requirements**

It is noted that the actual fuel mix in the future will depend on many factors.

The use of shore power or Onshore Power Supply (OPS) while a ship is in port, rather than the use of the ship's auxiliary engines is also considered as a measure to reduce the environmental impact of shipping and to improve the air quality in the ports. Major ports in Europe, the North-East and West coasts of North America, and now increasingly in Asia have installed OPS facilities. There are shore power facilities for ocean-going vessels in at least 13 North American ports, with several others currently under development. An important consideration for a feasibility assessment is to focus on the operational, economic, and business aspects of shore power. Several jurisdictions, beyond California, have implemented or are considering regulatory requirements or incentives for the use of OPS for ships during port stays.

As the pressure for reducing emissions even further, owners are also looking for other fuels that could help to achieve these targets. Currently, many fuels are being considered as a possible solution for tackling emissions in the maritime industry, with different sources and levels of maturity, but with common issues: availability, cost of production, safe storage, and others.




Technical maturity – refers to technical maturity level for engine technology and systems
Fuel availability – refers to today's availability of the fuel, future production plants, and long-term availability.
Infrastructure – refers to available infrastructure for bunkering
Safety – refers to rules and guidelines related to the design and safety requirements for the ship and onboard systems.
Capital expenditures – cost above baseline (conventional fuel-oil system) for LNG and carbon-neutral fuels, i.e. engine and fuel-system cost.
Energy cost – reflects fuel competitiveness compared with MGO, taking into account conversion efficiency.
Volumetric energy density – refers to the amount of energy stored per volume unit compared with MGO, taking into account the volume of the storage solution.

**Figure 9-3 Alternative Fuels - Barriers in 2020 (source: MF2050)**

A brief description of some alternatives is given here:

**Energy Storage Systems** – Energy is stored onboard in battery cells used to provide power for hotel loads, specific consumers, and/or propulsion. While the technology is consolidated and available globally. These batteries can be charged when the vessel is at port or while sailing through other renewable sources onboard. While the technology is consolidated and available globally, the biggest challenge is the very low energy density, which allows for use only in smaller vessels sailing short routes. New technologies are under development for increasing storage capacity.

**LNG -** The must technical mature and viable alternative fuel currently, natural gas from LNG is the cleanest fossil fuel available today. There are no SOX emissions related to it, particle emissions are very low, the $NO_X$ emissions are lower than those of MGO or HFO, and other emissions such as HC, CO or formaldehyde from gas engines are low and can be mitigated by exhaust gas after-treatment if necessary. Nevertheless, methane releases must be considered when evaluating the CHG reduction potential of LNG as ship fuel, as well as the overall well-to wake GHG emissions. The use of Bio-LNG and e-LNG, as well as renewable diesel fuels are options to reduce the GHG emissions from dual fuel engines.

**Hydrogen** – With an energy density 2.6 times greater than LNG (140MJ/kg versus 53MJ/kg), hydrogen is seen as a good candidate, but it also brings safety concerns for storage at port and onboard. Burning Hydrogen does not produce GHG gasses, but the generation of clean hydrogen with no carbon footprint requires higher amounts of energy and comes at higher costs. Due to its low specific gravity, it's only feasible if stored in compressed ($CGH_2$) or liquid forms ($LH_2$). While the latter has the highest volumetric energy density (10 MJ/l), it must be stored at very low temperatures (-252ºC) leading to additional challenges for transportation and storage onboard.

**HVO** – Hydrogenation-derived renewable diesel (HVO / HDRD) is the product of fats or vegetable oils - alone or blended with petroleum - refined by a hydrotreating process known as fatty acids-to-hydrocarbon hydrotreatment. Diesel produced using this process is called renewable diesel to differentiate it from biodiesel, for example, FAME. $CO_2$ emissions are significantly lower with this fuel and replace diesel without significant changes onboard. Main challenges are the high cost of production and limited availability globally.

**Methanol:** The main upside for methanol is the relatively good performance on applicability, being able to utilize existing engine and low tank costs, which further translates into low capital costs. On the other side, a major downside to methanol as an alternative fuel is its environmental performance if produced from fossil sources. Fossil based Methanol is priced close to, or higher than MGO in today's market. Bio-methanol and e-methanol can offer very low GHG emissions on a lifecycle basis but with higher cost, but availability and infrastructure is very limited currently.

**Ammonia** – Like Hydrogen, the combustion of Ammonia as a fuel does not result in any direct carbon emission. Both gases present similar challenges for use onboard, but Ammonia has a slight advantage as it does not requires extremely low temperatures and has volumetric energy density slightly higher than hydrogen and about half as that of MGO. The main concern for ammonia is safety, as exposure can happen not only through inhalation but also through contact, causing severe health effects.

**LPG -** Low energy cost (close to LNG) and low capital costs make a compelling economic case for LPG. However, operational experience is limited, thus the maturity level is medium. In addition, the lack of bunkering infrastructure is a barrier for using LPG as an alternative marine fuel. Moreover, a major downside to LPG as an alternative fuel is its environmental performance when produced from fossil sources.

# APPENDICES

# Appendix 1 – List of Engaged Stakeholders

| Category | Role | Entity |
|---|---|---|
| **Regulator** | State | CARB |
| **Regulator** | Federal | USCG |
| **Regulator** | Local | South Coast AQMD |
| **Regulator** | Local | Bay area AQMD |
| **Regulator** | International | EMSA |
| **Technology supplier** | Capture and control | Clean Air Engineering-Maritime (CAEM) |
| **Technology supplier** | Capture and control | STAX Engineering |
| **Technology supplier** | Shore power | ABB |
| **Technology supplier** | Shore power | Cavotec |
| **Associations** | Associations | WSPA |
| **Associations** | Associations-Ship | OCIMF |
| **Associations** | Associations-Ship | INTERTANKO |
| **Associations** | Associations-Pilot | Pilot Associations |
| **Terminal** | Terminal-SFO, LB/LA | Chevron |
| **Terminal** | Terminal-LA | Shell |
| **Terminal** | Terminal-SFO, LB/LA | Valero |
| **Terminal** | Terminal-LA | PBF Energy |
| **Terminal** | Terminal-LA | Marathon |
| **Terminal** | Terminal-SFO, LB/LA | Phillips 66 Company |
| **Terminal** | Terminal-LB/LA | PBF |
| **Port** | Port | Port of LB |
| **Port** | Port | Port of LA |
| **Tanker owner/ operator** | Tanker owner/ operator | Chevron shipping |
| **Tanker owner/ operator** | Tanker owner/ operator | Polar tanker/ConocoPhillips |
| **Subject matter expert** | SME-Tankers in general | DNV |
| **Subject matter expert** | SME-Electrification | DNV |
| **Subject matter expert** | Risk assessment | DNV |
| **Subject matter expert** | SME-Engine manufacture | Wartsila |
| **Others** | Construction | AECOM |

## Appendix 2 - List of Workshop Participants May 20 2021

## Shore Power Workshop #1- Technology composition analysis

| Full Name | Company |
|---|---|
| **Andrew Eydt** | ABB |
| **Ronald Jansen** | ABB |
| **Luca Imperiali** | ABB |
| **David Shore** | ABB |
| **Teemu Pajala** | ABB |
| **GLA - Douglas Lang** | ANGLOEASTERN |
| **Storelli, Nicholas** | CARB |
| **Soriano, Bonnie** | CARB |
| **Melgoza, Elizabeth** | CARB |
| **Csondes, Angela** | CARB |
| **Jay Garrett** | CAVOTEC |
| **Filippo Ninotti** | CAVOTEC |
| **Singh, Gurpreet** | CHEVRON |
| **Fields, Laura** | CHEVRON |
| **Boven, Karen L (KBOV)** | CHEVRON |
| **Yang, Steven** | CHEVRON |
| **McIsaac, Andrew F** | CONOCOPHILLIPS |
| **Hartmann, Thomas** | DNV |
| **Wang, Yanran** | DNV |
| **Andersen, Jan Hagen** | DNV |
| **Vestereng, Catrine** | DNV |
| **Istad, Erik** | DNV |
| **Rodrigues, Eduardo** | DNV |
| **BATISTA Ricardo (EMSA)** | EMSA |
| **Dragos Rauta** | INTERTANKO |
| **McDonald, Brian** | MARATHONPETROLEUM |

| Full Name | Company |
|---|---|
| **Tomlinson, Jim** | MARATHONPETROLEUM |
| **Panos Deligiannis** | NEDAMARITIME |
| **Ricardo Martinez** | OCIMF |
| **Ivan Zgaljic** | CURIC TECH |
| **Crabbs, William** | PHILLIPS 66 COMPANY |
| **Mathur, Roy** | PBFENERGY |
| **Williams, Jennifer** | POLB |
| **Farren, Glenn** | POLB |
| **Stone, William** | POLB |
| **Caswell, Morgan** | POLB |
| **Pisano, Teresa** | PORTLA |
| **Coluso, Amber** | PORTLA |
| **Aboulhosn, Shaouki** | PORTLA |
| **Caris, Eric** | PORTLA |
| **McFarlane, Duncan** | SHELL |
| **Flanagan, Christopher** | SHELL |
| **Jordan, Carlton R** | SHELL |
| **Menon, Unni U** | SHELL |
| **Powers, Katy K** | SHELL |
| **Jordan, Carlton R SPLC-STO/824** | SHELL |
| **Sean Marchant - Valero (Guest)"** | VALERO |
| **sanjeet (Valero) (Guest)** | VALERO |
| **Tia Youk (Guest)** | |
| **Steve Brett (Guest)** | PBF Energy (Torrance Logistics LLC) |
| **Taryn Wier (Guest)** | |

# Appendix 3 – List of Workshop Participants June 7-8 2021

## Shore Power Workshop #2 - Risk assessment

| Full Name | Company |
|---|---|
| **Andrew Eydt** | ABB |
| **David Shore** | ABB |
| **Luca Imperiali** | ABB |
| **GLA - Douglas Lang** | ANGLOEASTERN |
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| **Fabio Abbattista** | CAVOTEC |
| **Filippo Ninotti** | CAVOTEC |
| **Jay Garrett** | CAVOTEC |
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| **Fields, Laura** | CHEVRON |
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| **Singh, Gurpreet** | CHEVRON |
| **Yang, Steven** | CHEVRON |
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| **Herring, Stephen G** | CONOCOPHILLIPS |
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| **Payne, Lee** | CONOCOPHILLIPS |
| **Kamat, Sanjeet** | CSUM |
| **Ivan Zgaljic** | CURIC TECH |
| **Andersen, Jan Hagen** | DNV |
| **Hartmann, Thomas** | DNV |
| **Istad, Erik** | DNV |
| **Kvale, Jørgen** | DNV |
| **Rodrigues, Eduardo** | DNV |
| **Vestereng, Catrine** | DNV |
| **Wang, Yanran** | DNV |
| **BATISTA Ricardo** | EMSA |
| **Dragos Rauta** | INTERTANKO |
| **GilYong Han** | INTERTANKO |

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|---|---|
| **Patrick Keffler** | INTERTANKO |
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| **Ricardo Martinez** | OCIMF |
| **Hornsby, Joe** | PBF ENERGY |
| **Mathur, Roy** | PBF ENERGY |
| **Shih, Rick** | PBF ENERGY |
| **Strzepa, Gail** | PBF ENERGY |
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| **Baird, Scott** | POLA |
| **Caris, Eric** | POLA |
| **Coluso, Amber** | POLA |
| **DeMoss, Tim** | POLA |
| **Hoang, Dac** | POLA |
| **Pisano, Teresa** | POLA |
| **Caswell, Morgan** | POLB |
| **Farren, Glenn** | POLB |
| **Stone, William** | POLB |
| **Williams, Jennifer** | POLP |
| **Flanagan, Christopher** | SHELL |
| **McFarlane, Duncan** | SHELL |
| **Powers, Katy K** | SHELL |
| **Cynthia Znati** | USCG |
| **Sanjeet _Valero** | VALERO |
| **Sean Marchant** | VALERO |
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| **Tia Youk** | |

# Appendix 4 – List of Workshop Participants June 24 2021

## Emission Capture and Control Workshop #1 - Technology Composition Analysis

| Full Name | Company |
|---|---|
| **Kenneth Gillespie** | ALBA-MARINE |
| **Nielsen, Mark H** | ANDEAVOR |
| **GLA - Douglas Lang** | ANGLOEASTERN |
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| **Csondes, Angela** | CARB |
| **Foster, Jonathan** | CARB |
| **Light Densberger, Nicole** | CARB |
| **Soriano, Bonnie** | CARB |
| **Storelli, Nicholas** | CARB |
| **Kelsey Hoshide** | CAEMARITIME |
| **Rod Gravley** | CAEMARITIME |
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| **Justin L. Avril** | CHEMOIL |
| **Lawrence Martinez** | CHEMOIL |
| **Zaw Aung** | CHEMOIL |
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| **Fields, Laura** | CHEVRON |
| **Singh, Gurpreet** | CHEVRON |
| **Yang, Steven** | CHEVRON |
| **Bulera, Christopher J** | CONOCOPHILLIPS |
| **Clanton, Wes** | CONOCOPHILLIPS |
| **Gibson, Joe F** | CONOCOPHILLIPS |
| **Hayes, Robert M** | CONOCOPHILLIPS |
| **McDill, Christopher M** | CONOCOPHILLIPS |
| **Payne, Lee** | CONOCOPHILLIPS |
| **Wright, John K.** | CONOCOPHILLIPS |

| Full Name | Company |
| --- | --- |
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| **Istad, Erik** | DNV |
| **Raj, Sarath** | DNV |
| **Wang, Yanran** | DNV |
| **BATISTA Ricardo (EMSA)** | EMSA |
| **Dragos Rauta** | INTERTANKO |
| **GilYong Han** | INTERTANKO |
| **Garcia, Carmen** | KINDERMORGAN |
| **Ndiangang, Magnus** | KINDERMORGAN |
| **Ririe, John** | KINDERMORGAN |
| **Smith, Cinnamon** | KINDERMORGAN |
| **Tomlinson, Jim** | MARATHONPETROLEUM |
| **Panos Deligiannis** | NEDAMARITIME |
| **Pavlos Zouridis** | NEDAMARITIME |
| **Ricardo Martinez** | OCIMF |
| **Brett, Steve** | PBF ENERGY |
| **Mathur, Roy** | PBF ENERGY |
| **Stone, William** | POLB |
| **Williams, Jennifer** | POLB |
| **Coluso, Amber** | PORTLA |
| **Pisano, Teresa** | PORTLA |
| **Flanagan, Christopher** | SHELL |
| **McFarlane, Duncan** | SHELL |
| **Menon, Unni U** | SHELL |
| **Bill Johns** | |
| **Capt. Mahesh Bedre** | |
| **Jimmy Fox** | |
| **sanjeet (Valero)** | VALERO |
| **Steve Brett** | PBF Energy (Torrance Logistics LLC) |
| **Tia Youk (VLO Benicia)** | |

# Appendix 5 – List of Workshop Participants July 9 2021

## Emission Capture and Control Workshop #2 – Risk Assessment

| Full Name | Company |
|---|---|
| **Luca Imperiali** | ABB |
| **Ronald Jansen** | ABB |
| **Goebel, Heidi** | AECOM |
| **Kenneth Gillespie** | ALBA-MARINE |
| **Brett, Steve** | PBF Energy (Torrance Logistics LLC) |
| **Mei Wang** | AQMD |
| **Rod Gravley** | CAEMARITIME |
| **Csondes, Angela@ARB** | CARB |
| **Foster, Jonathan@ARB** | CARB |
| **Light Densberger, Nicole@ARB** | CARB |
| **Storelli, Nicholas@ARB** | CARB |
| **Filippo Ninotti** | CAVOTEC |
| **Jay Garrett** | CAVOTEC |
| **Zaw Aung** | CHEMOIL |
| **Boven, Karen L (KBOV)** | CHEVRON |
| **Fields, Laura** | CHEVRON |
| **Wallace, Amanda** | CHEVRON |
| **Gibson, Joe F** | CONOCOPHILLIPS |
| **Hayes, Robert M** | CONOCOPHILLIPS |
| **McDill, Christopher M** | CONOCOPHILLIPS |
| **McIsaac, Andrew F** | CONOCOPHILLIPS |
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| **Andersen, Jan Hagen** | DNV |
| **Wang, Yanran** | DNV |
| **Madhuri Bedre** | GMB MARINE SERVICES |
| **Vahik Haddadian** | H3SOLUTIONS |
| **GilYong Han** | INTERTANKO |

| Full Name | Company |
|---|---|
| **Garcia, Carmen** | KINDERMORGAN |
| **Ndiangang, Magnus** | KINDERMORGAN |
| **Tomlinson, Jim** | MARATHONPETROLEUM |
| **Panos Deligiannis** | NEDAMARITIME |
| **Ricardo Martinez** | OCIMF |
| **Crabbs, William** | PHILLIPS 66 COMPANY |
| **Mathur, Roy** | PBFENERGY |
| **Stone, William** | POLB |
| **Williams, Jennifer** | POLB |
| **Baird, Scott** | PORTLA |
| **Coluso, Amber** | PORTLA |
| **Flinn, David** | PORTLA |
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| **Anne McIntyre** | SFBARPILOTS |
| **Flanagan, Christopher** | SHELL |
| **McFarlane, Duncan** | SHELL |
| **Cindy Znati** | USCG |
| **Cynthia Woodlock** | USCG |
| **Capt. Mahesh Bedre** | |
| **John Strong** | |
| **Nelson** | |
| **Sherman Hampton** | |
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# Appendix 6 – Threat Assessment - Shore Power

## 5.1 FMECA Results – Shore power

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 | Power source | Electrical failure - power shortage | The electrical grid is not be able to provide sufficient power supply. | The shipboard instrument will not receive stable power source. | | 5 | 3 | H | | -The energy agencies, ports, and their electrical utility companies (such as Southern California Edison, Pacific Gas and Electric Company, etc.) will need to be involved to review the feasibility and planning of providing the additional power load with the consideration of hot weather when significant demand and strain have been put on California's energy grid. | Described |
| 0.2 | Power source | Quality of electricity (voltage variation, voltage and current transient, harmonic distortion) | During starting of the cargo pumps, voltage may decrease momentarily. When calculating power demand based on fuel (energy) consumption the result will be an averaged based power figure. This may not be sufficient to cope with | | | 5 | 2 | M | | Each ship type will have a different peak factor which should be considered when designing shore-power infrastructure. During the design stage, the decision is recommended to be taken together with tanker operators whether to design for average power demand, peak power demand, or any design point in between. | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | momentary or short-termed peak consumption. | | | | | | | | |
| 0.3 | Power source | Electrical failure - high inrush current | High inrush current may happen when starting a high capacity consumer, e.g. electrical driven cargo oil pumps | Voltage dip | | 3 | 2 | M | | It is recommended to:<br>- sizing the transformer according to the terminal's traffic and potential peak load from the visiting tankers;<br>- establishing a communication procedure beforehand between the ship and terminal about if there are load restrictions from the shore power system and the ship's required average and peak load;<br>- performing the start-up of electrical machinery onboard the tankers in a manner that will limit the peak currents, e.g. using a soft start or frequency-controlled motor. | Described |
| 0.4 | Power source | Electrical failure | Lighting strike | Damage of the consumers onboard the ship | | 4 | 1 | M | | Insulation has to be in place for overvoltage protection. Ensure the design and installation of shore power system are following the relevant local standards and codes. | Not unique to tankers |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Main incoming station | Electrical failure | Shipboard electrical frequency and voltage may not be compatible with the shore power. | | | 4 | 2 | M | | -Voltage step down transformers and frequency converter to be installed when needed | Described |
| 1.2 | Main incoming station | Electrical failure - overheatin g | The extreme environmental temperature may induce overheating of the main incoming station. | | | 3 | 2 | M | | Consider implementing climate control for the main incoming station | Not unique to tankers |
| 1.3 | Main incoming station | Electrical failure - fail to start | Fault in the control system. | Unable to supply power to the tankers | Ship will continue to use auxiliary engines to provide power. | 2 | 3 | M | This situation will be registered as a Vessel Incident Event (Vie) / Terminal Incident Event (Tie). | | Not unique to tankers |
| 1.4 | Main incoming station | Electrical failure - fail to stop | Fault in the control system. | Cannot disconnect the shore power when it has power on. | | 2 | 3 | M | | -Incorporate a mechanical tripping of the circuit breaker for bypassing the main incoming station control system | Not unique to tankers |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.1 | Power cable | Mechanical failure - structural failure | The strength of the pier may not be sufficient to carry the extra load from the power cable. | Structural damage of the pier | | 5 | 2 | M | | -A structural evaluation, including seismic analysis, shall be performed following MOTEMS to evaluate if upgrades of the structural system of the causeway and terminal is needed. | Described |
| 2.2 | Power cable | Mechanical failure - Rupture | Cable might be damaged from the traffic on the wharf and earthquake. | | | 3 | 2 | M | | -Perform electrical relay coordination study | Not unique to tankers |
| 2.3 | Power cable | Mechanical failure - Flooding | Flooding in the duct may damage the power cable. | | | 3 | 2 | M | | -Ensure using waterproof typed power cable | Not unique to tankers |
| 3.1 | Onshore installations (excluding CMS) | Electrical failure - Overheating | Switchgear could be overheated in the extreme weather. | | | 3 | 2 | M | | Consider implementing climate control for the switchgear | Not unique to tankers |
| 3.2 | Onshore installations (excluding CMS) | Electrical failure - Fail to start | Fault in the cable, switchgear, etc. at the onshore installation | Unable to supply power to the tankers | Ship will continue to use auxiliary engines to provide power. | 2 | 3 | M | This situation will be registered as a Vessel Incident Event (Vie) / Terminal Incident Event (Tie). | | Not unique to tankers |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.3 | Onshore installations (excluding CMS) | Electrical failure - Fail to stop | Fault in the control system. | Cannot disconnect the shore power when it has power on. | | 2 | 3 | M | | -Incorporate a mechanical tripping of the circuit breaker for bypassing the control system | Not unique to tankers |
| 3.4 | Onshore installations (excluding CMS) | Design challenge | The terminals may not have sufficient space for the shore power installation. | | | - | - | - | -Easy access and minimizing the distance between ship and pier is preferred. | -Evaluate if an upgrade of the terminal is needed for accommodating the pier side shore power equipment. | Described |
| 3.5 | Onshore installations (excluding CMS) | Mechanical damage | Wake from channel, provision loading, vehicle traffic, dropped objects may cause damage. | | | 3 | 2 | M | | -Review the traffic design to introduce safety barriers, e.g. armor, at the high risk locations | Not unique to tankers |
| 3.6 | Onshore installations (excluding CMS) | Electrical failure - Internal short circuit or arc | Internal short circuit or arc | Injury of personnel during operation. | | 3 | 4 | M | | -Perform an arc splash study and internal arc test<br>-Following the local code to identify the design requirements, e.g. use arc-proof switchgear. The code may include:<br>1. National Fire Protection Association (NFPA) 70 - National Electrical Code (NEC) and<br>2. NFPA 70E - Standards for electrical Safety in the Workplace | Not unique to tankers |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 | Cable management system | | Wide range of tankers' length and two scenarios of berthing orientations | Some tankers cannot be covered by the reach of cable management system. | | 5 | 3 | H | Scenario: installation of the connection point at the stern out of hazardous zone, which is closer to the consumers. | -An industry standardized solution on the installation location of the Shore power connection location is recommended. if the connection location is agreed to be arranged in the non-hazardous area, e.g. stern of the tanker, a cost-effective cable management system that is complying with the standards to accommodate the existing portfolio of tankers is recommended to be developed. the solutions or design changes will need to be reviewed for compliance with the existing technical standards.<br>-Before An industry standardized solution is available, the Shore power connection locations will need to be investigated closely for each terminal based on the terminal configuration and the portfolio of visiting tankers. | Described |
| 4.2 | Cable management system | | Lifting heavy materials | Injury of personnel during operation. | | 3 | 3 | M | | -Locate/ install a suitable crane for handling the cables. | Described |
| 4.3 | Cable management system | | Handling high voltage cables | Injury of personnel during operation. | | 3 | 3 | M | | -Ensure the shore power design and installation follow relevant standards, e.g. IEC standards and Class society standards.<br>-Provide high-voltage operation and shore power usage safety trainings for the relevant personnel | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.4 | Cable management system | | Unawareness of the potential conflicts during the design and operation | Interference the normal operation of tankers and marine oil terminal, e.g. cargo discharging, provision loading, etc. | | 3 | 1 | L | | -Perform traffic study and develop an operation procedure to avoid conflictions | Not unique to tankers |
| 5.1 | Shipboard installation | Electrical failure - ignition from sparks and/or over-temperature | Electrical equipment's spark and/or over-temperature | Fire or explosion during the transfer of hazardous cargo. | | 5 | 3 | H | -Currently, there is no ex-proof certified marine use high voltage components such as cable, plug, socket<br>-Current standards do not recommend electrical installation in the hazardous areas. | -Consider the possibility of using pressurized electrical house in the hazardous area, however the possibility high voltage cable running through hazardous area still seems not feasible with the current availability of ex-proof marine use equipment and current status of industry standards.<br>-Implement measures to avoid sparks and over-temperature | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.2 | Shipboard installation | Electrical failure | In-compatibility between the connections at different ports due to the lack of developed design standards | The usage of shore power technology is limited. | | 5 | 2 | M | Currently there are no unified standards for shore power especially the plugs and sockets while tankers typically have a worldwide operation profile. | -Before the tankers' arrival, it is recommended to confirm the compatibility of the shore power system with the terminal.<br>-Standardization of the shore power design for tankers including a unified design of safety and physical design of the plugs and sockets through e.g. IEC/IEEE 80005-1:20199 Annex F Additional requirements for tankers with contribution from the industry stakeholders is recommended. | Described |
| 5.3 | Shipboard installation | Electrical failure - ignition | If the shore power connection point is arranged at the bow out of hazardous zone, the installation connection may enter the berth hazardous zone during slipped mooring. | | | 4 | 1 | M | Scenario: installation of the connection point at the foreship | -Develop procedure for de-energize the shore power system during the emergency situation of slipped mooring. | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.4 | Shipboard installation | | Install the shore power connection on an elevated platform at the midship | Blockage of visibility and impact on stability | | 3 | 1 | L | Scenario: installation of the connection point at an elevated location at midship (Benefit is that the location of manifold area is relatively fixed. It makes the terminal capable of accommodating more ship sizes.) The height of hazardous zone from deck depends on the location of PV valves and natural ventilation. | -If a platform is installed for arranging the shore power connection point, assessment is recommended to ensure it is not impacting the bridge's visibility and ship's stability. | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5.5 | Shipboard installation | | Install the shore power connection on an elevated platform at the midship | The platform is still inside the hazardous zone of the tanker or berth. | | 4 | 3 | M | | -the specific hazardous area arrangement of the visiting tankers and marine oil terminals has to be studied for each terminal. | Described |
| 5.6 | Shipboard installation | Electrical failure - ignition from sparks and over-temperature | There are still openings to the electrical house. The installation may be out of compliance of the current regulations and industry standards. | | | 3 | 2 | M | Scenario: installation of the connection point in an electrical house with airlock and overpressure at the midship. Chemical tankers follow IBC code which has strict requirement on installation of electrical equipment. ISGOTT has strict requirement on electrical requireme | -A thorough examination and potential updates of the existing regulations and industry standards (e.g. SOLAS, IBC code, Class rules, ISGOTT, PIANC standards) for the pressured electrical house concept | Described |

| Id | System | Failure mode | Failure Cause | Effect of failure | Existing Safeguards | Cons. | Prob. | Risk | Comment | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | nt as well. PIANC has requirements on the terminal design. | | |
| 5.7 | Shipboard installation | | The condition of instruments may be unknown after a long term of unuse. | | | 3 | 1 | L | | -Develop a maintenance procedure<br>-Develop an inspection procedure before connection | Not unique to tankers |
| 5.8 | Shipboard installation | Mechanical failure - cable tear and wear | Cable tear and wear, especially with long cable run and exposure to greenwater | Personnel injury, unable to provide power, sparks in the hazardous zone | | 4 | 2 | M | | -Implement protection of the cable and the shore power equipment from tear and greenwater | Not unique to tankers |

## 5.2 HAZOP Results -Shore power

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Emergency (earthquake, tsunami, fire) | Earthquake, tsunami, fire | Release procedure and system design may not be able to meet evacuation requirement (30min requirement from California Land Commission) | -The current terminal design is designed to be compliant with MOTEMS and meeting the requirement on earthquake. | 5 | 1 | M | -Ensure the emergency response button for disconnecting the power is implemented in the design and installation at reasonable locations, e.g. engine control room, local control cabinet at the connection room, shore side control room, etc.;<br>-Implement a breaking signal system and auto-ejection mechanism;<br>-Implement a quick-release / weak-link arrangement using an in-line breakable coupler on the cable. Once the breaking signal system sends the signal for quick releasing, the coupler will be unlatched and allow for breaking;<br>-Implement scheme and devices for handling the loose cables from both shore side and ship side;<br>-Develop an emergency response procedure including handling the shore power connection with a clear definition of responsibility, safety precautions, and necessary operations for the stakeholder including shipboard, terminal, and port teams;<br>-Evaluate the time required for | Described |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | emergency response when connecting to shore power (disconnect shore power, turn on engine power, maneuver away from the berth) and ensure that it is within 30 minutes. | |
| 2 | Blackout of shore power | Sudden electrical grid power loss, fault in the power transmission system | Cargo discharging will be interrupted. The cargo discharge valves and ballast valves may not be able to close due to the loss of hydraulic | -The manifold valves are still operatable as these normally are manual valves.<br>-Shore side shut-down valve may control the cargo discharge/loading (if the whole terminal experiences a | 3 | 2 | M | -Establish a ship and terminal-specific bow tie analysis of shore power blackout and identify the difference with blackout from ship's auxiliary engines (if any), and its consequence;<br>-Develop an emergency response procedure with the consideration of the needed recovery time and establish shore power blackout response procedure;<br>-Incorporate the signal reading of shore power loss into the shore | Described |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| | | | power. The inert gas generation will stop during blackout. | grid power lost, the Shore side discharge valve normally will be closed automatically.) | | | | side discharge/loading valves;<br>-Consider increasing the redundancy into the shore power design with the balance of cost-effectiveness. | |
| 3 | Dropped object | Objects drop (depending on the location of installation, from provision crane at stern, cargo loading arm) onto flexible cable between ship and shore. | It may result in a spark. | | 3 | 2 | M | -Perform traffic analysis of potential simultaneous operations<br>-Consider installation of cable tray/trench to provide protection of flexible cable | Not unique to tankers |
| 4 | Harsh weather | Strong wind, gust, load from passing vessel | The shore power connection (cable, crane operation) may be damaged. | | 3 | 2 | M | -Provide technology supplier the weather envelope (California State Land Commission has specific requirements for weather conditions of cargo operations) and evaluate the shore power's capacity under harsh weather<br>-Develop an operation procedure which considers:<br>--the weather limits, if the weather | Not unique to tankers |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | is too harsh, the shore power may not be connected<br>--monitoring the condition including weather condition, vessel movement due to ballasting/de-ballasting, tidal movement | |
| 5 | Harsh weather/Human error | Connection point becomes damp during harsh weather or misoperation. | Injury of personnel<br>Damage of instrument<br>Delay of connection | | 3 | 2 | M | -Develop an operation procedure to inspect the connection and ensure that it is dry before connection | Not unique to tankers |
| 6 | Wild fire | Dust accumulated onto the electrical instruments. | | | 2 | 1 | L | -IP (ingress protection) protection to be provided | Not unique to tankers |
| 7 | Wild fire | Adverse weather condition from wild fire (haze, high PM) | Adverse effect to workers' effect and may cause delay on delaying shore power. | | 3 | 3 | M | -Provide PPE for the workers | Not unique to tankers |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| 8 | Cybersecurity | Human error, system vulnerabilities, cyberattacks | It may cause a blackout, especially during the cargo operation which is a critical operation. | Currently IEC standard does not require data communication for tanker shore power installation. The current standard requires a monitoring function, but not a control function. | 3 | 3 | M | -If the shore power system is equipped with data communication capability, it is recommended to identifying the vulnerable subsystems (e.g. service interface of switchgear, service interface of cable management system), performing cybersecurity assessment, and ensure air gap is in place. | Described |
| 9 | Ships moving out of the operating envelop | Mooring line breaks, passing traffic impact and ships drift away (as an emergency without announcement). | -Release procedure and system design may not be able to meet evacuation requirement (30min requirement from California Land Commission)<br>-Snap-back of broken | | 3 | 1 | L | -Implement a weak link mechanism<br>-Consider the implementation an active load monitoring system for the mooring line and in cooperation this signal to shore power control<br>-If the shore power installation is located at the stern, the shore power installation has to avoid the mooring installation. | Not unique to tankers |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| | | | mooring line may damage the shore power instrument. This is relevant when the shore power connection is installed at the stern. | | | | | | |
| 10 | Oil spillage | Leakage from piping or tank, broken couples, unexpected disconnected/damaged loading arm | Fire or explosion | -Terminal's existing emergency response procedure | 3 | 1 | L | -Develop the ship shore power emergency response procedure including emergency shutdown with the consideration of the cargo type, potential spillage location, and amount;<br>-Incorporate the operation of shore power into the terminal's spillage response procedure. | Described |
| 11 | Human error | Energized shore power plug became disconnected. | Personnel may be exposed to live cable. | -Shore power safety loop design<br>-Mechanical interlock opening will disconnect the power. | 3 | 1 | L | -Develop shore power operation procedure and perform training of the relevant personnel | Not unique to tankers |
| 12 | Human error | If use shore power technology, boilers' emissions may be out of compliance with | Out of compliance | | - | - | - | If shore power is used, the emissions from steam-driven cargo pumps will not be regulated. Therefore, this risk is deemed | Described |

| ID# | Deviation | Cause | Consequence | Safeguard | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|
| | | CARB at-berth regulation. | | | | | | irrelevant. | |
| 13 | Human error | If use shore power technology, diesel driven power packs' emissions may be out of compliance for CARB at-berth regulation. | Out of compliance | | 4 | 1 | M | -Convert the hydraulic power pack to use electric motors which draw power from the main switchboard, i.e. from the ship's service diesel generators<br>-Alternatively, the exhaust from the hydraulic power pack diesel engine(s) must be treated with the capture and control technology which may be too costly for such a relatively small emission source.<br>-Use the Innovative Concepts (IC) provision given in CARB at-berth regulation as a compliance option to offset the emission from the hydraulic power pack diesel engines and achieve equivalent (or greater) emissions reductions in port. | Described |

# Appendix 7 –Emissions Capture and Control

## 6.1 Performance Expectations

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| **Suitability for tankers** | The technology should be able to be deployed and operated for all tankers visiting the terminal | The technology should be capable of accommodating the difference sizes of tankers | Range of tankers visiting the terminals | - Seawaymax (0-60,000 dwt)<br>-100 m Coastal Tankers at <50,000 DTW and 200 m x 32 m beam | -ULCC (315,000-520,000 dwt)<br>-350m<br>VLCC at 320,000 DTW and 340 m x 60 m beam | What is the maximum number of aux engines and boilers running on the largest vessel during discharging of cargo? | | |
| | | The technology should be able to fit the variable stack configurations | Stack dimensions | 0.4 m, single Aux engine at 600 kW | '1.2 m for a 45 MT/hr steam boiler on a VLCC<br>0.5m for auxiliary engines<br>0.5m for IG vent | Shall fit the stack for the range of visiting tankers to the terminals | | N |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | | Stack numbers | 4<br>Single aux engine operational while vessel is at berth and not offloading cargo or is being loaded. | 6 (2boilers, 3 aux engine, 1inert gas vent line)<br>Single aux engine providing power for vessel operations while at berth.<br>Cargo Operations<br>-Hydraulic Pumps - a second aux engine running to support cargo offloading<br>-Steam Pumps - 1 or 2 boilers operational depending on offload rate. | Typically, while at-berth typically both boilers are running. All 3 aux engines may be running at certain scenario and minimum 2 are running.<br><br>In the port of LA/LB all berths are limited to an unloading rate of less than 10,000 bbls/hour which means only a single aux engine or single boiler will be associated with unloading operations. The one exception is T121 which can offload at rates up to 80,000 bbls/hour | | N |
| | | The technology should be able to reach the stack position | Stack vertical position | 35.4m | 67 m | Ballast 55m for a VLCC, 40m for Aframax | | |
| | | | Stack horizontal position | 30m | 49m | The tanker may be moored on starboard side or | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | | | | | portside. The C&C technology needs to account for both scenarios. | | |
| | | The technology should be able to reach the stack position within a specified time period | Definition of min/max times | 20 min | 60 minutes | Best case, worst case | | |
| | | The technology should be able to treat the exhaust GAS amount from the tanker discharging cargo | Auxiliary engine kW | Single engine at 400 kW operating | typically, VLCC = 2 x 1,200kW<br>AFRA = 2 x 750kW | -7000 kW for T121 terminal | | N |
| | | | Boiler (metric ton/hr steam) | For hydraulic pumping a boiler is not used | VLCC = 2 x 45 Mt/hr steam<br>AFRA = 2 x 25 MT/hr steam | 30,000 kg steam per hour | | N |
| | | | Total exhaust from auxiliary engines and boilers (kg/hr) | Single Aux Engine at 400 kW = 3,000 kg/hr | TBD | It will be calculated based on the auxiliary engine (7.3 kg/kW for Aux Engines) and boilers' emission. 'VLCC = 2 x 10,000 kg/hr (DG) + 2 x 50,000kg/hr (A/B including IG vent)<br>AFRA = 2 x 6,250 | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | | | | | kg/hr (DG) + 2 x 35,000kg/hr (A/B including IG vent ); if independent IGG (or electrical COP) then +10,000kg/hr | | |
| | | The technology should be able to accommodate for changes in vessel draft and tidal variation during the operation | Select a vessel scenario with greatest variation in drafts (light vs loaded condition) | - | VLCC = 22.5 m laden, 11m ballast - AFT DRAFT | Changes of draft and ship movement during operation needs to be accounted for | -Current design for container vessels can accommodate draft change around 10-15feet by boom adjustment. | |
| | | The technology should be able to accommodate the variable temperature of exhaust gas from the sources including aux. engine, boiler, inert gas generator. | Temperature of exhaust gas | 150 °C | 400 °C | | | |
| | | Comply with hazardous zone requirements as relevant for accommodating tankers | - Identify the requirements and ensure compliance as relevant | n/a | Barge will operate outside hazardous zones | -The technology plans for a design without operator at funnel | | Y |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| **Suitability for oil terminals** | The technology should be able to be deployed and operated for all tankers visiting the terminal | Sufficient infrastructure and space available to install the technology (shore-based) | -Site suitability in terms of impact to neighboring infrastructure and potential logistics. | n/a | -Some terminals may require both side berth | 80x20 m footprint | | |
| | | Terminals and wharves existence and should be able to carry the weight of the installation (shore-based) | - Bathymetry/foundation related calculations to ensure site suitability | n/a | Treatment unit located on a floating pontoon moored to the shore and connected to shore power. | | | |
| | | Comply with hazardous zone requirements if relevant | - Establish if this will apply '- If so, ensure compliance | n/a | Floating pontoon to comply with hazardous zone requirement if required. | | | |
| | | Sufficient infrastructure and space available (barge-based) | Sufficient channel width and maneuvering capacity for safe maneuvering and placement of barge | - | - | CAEM Barge is approximately 32m long and breadth of 18m. Highly maneuverable with dual 360-degree rotating thruster propellers with joystick control. | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | | Tug availablility | - | Max wind conditions will be determined, and tugs used to assist where required. | For CAEM's current design for POLA and POLB, the barge will be self-propelled and has a speed around 2-3knots. | | |
| | | Limit interference of the normal operation, e.g. mooring, cargo loading/unloading, traffic | | - | For CAEM's design, the vessel will be spudded. The movement from passing traffic is assumed to be minimal. | | | |
| | | Have space available for barge-based technology storage | | - | CAEM Barge is approximately 32m long and breadth of 18m. Storage space is needed. | | | |
| **Compliance** | The technology shall be in compliance with applicable local, terminal, industry and tanker rules | Technology shall meet applicable rules, regulations, industry standards and guidelines as applicable. | -IMO Regulations | -SOLAS<br>-MARPOL | | | | |
| | | | -California State Lands Commission Regulation | MOTEMS | | | | |
| | | | -Class Society Rules | -Ship rules | | | | |
| | | | -Maritime Industry Guidelines | -OCIMFs Guidelines<br>-PIANC | | | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | and regulations | | -CARB Ocean-going vessels at berth regulation | Should be approved by CARB with the emission reduction limits for the exhaust | | | | |
| **Safety** | The technology should be safe to deploy and operate during normal operations | Safety of personnel should be maintained throughout the operation (connection, operation, disconnection, maintenance) | Training, procedures, design and construction, safeguards | | CAEM's design and construction will be in accordance with ABS Rules. Procedures to include general operation and emergency procedures. Training in the procedures will be developed and performed on a continuous basis. | | -Vetting of the barge to ensure safety | |
| | | Safety of property should be maintained throughout the operation | To be evaluated as part of the HAZID/FMECA | - | - | | | |
| | | Use of the technology should not increase the risk of fire and explosion | To be evaluated as part of the HAZID/FMECA | - | - | | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | The technology should be able to operate safely at defined operational windows | Wind | | 30 knots | MEG 4 environmental criteria ie wind 60kts, current 3.5kts, swell 2.5m | | |
| | | | Current | | 0.75 knot<br>Maybe up to 6 knots for Northern California terminals | | | |
| | | | Waves | | 2.5m swell | -How is the system compensating for relative movements | | |
| | | | Temperature | | | Define operational windows | | |
| | | Should be able to operate safely 24/7 (day and night) | Visibility and illumination should be sufficient for the safe crane operations | | 24-hour operation with lighting and cameras sufficient to perform all operations. | | -Ensure illumination at port | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | Protection requirments | Establish protective barriers as necessary for normal and emergency operations | | The barge will operate outside the normal hazardous area. The pontoon will be built to intrinsically safe standards as required for the zone of operation. | IP, ex-proof | -Identify the hazardous area definition from both tankers and terminals<br>-Identify the equipment of capture and control running potentially in the hazardous zone | |
| | | System not to interfere with machinery combustion parameters and safety matters | treatment system fan suction | | Extraction to be minimum possible and adjustable so as not to interfere with boiler air pressure sensors and do not alter IG oxygen level.<br>Low speed stable flow to be maintained.<br>Treatment system should not apply backpressure to the piping | | | |
| | Securing arrangement for hood on stacks | should not impose any load on the stacks | structural integrity | | | | | |
| | SIMOP - | | mooring tangling | | | Possible catastrophic failure due to | | |

| **Performance Expectations** | **Description** | **Requirements** | **Critical Parameters** | **Requirements/ Acceptance criteria** | | **Comment** | **Action** | **Current product feasibility** |
|---|---|---|---|---|---|---|---|---|
| | | | | **Min** | **Max** | | | |
| | | | | | | mooring wire break. | | |
| | The technology should provide sufficient safety during emergencies | Should not hinder the tanker requirement of safe evacuation from the berth within 30 minutes | Evacuation shall be possible within the specified 30 min limit | as soon as possible | 30 mins | -Disconnection process: boom removing -> stow boom (within 10min), spud lifted, barge sails away with its own power (around 10min) require no interaction from vessel or crew<br><br>-How is the system quickly disconnected? '-Potentially adverse loads on connection?<br>-The plan for complying with California State Lands Commission (CSLC) ruling requiring a 30-minute vessel evacuation from berth -Tugs? Other means? | -Develop emergency disconnection procedure and training of personnel | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| **Reliability & Emission reduction** | Performance | The capture and control technology should perform as expected with acceptable failure rates. | Failure rates/NPT | | 90% available hrs (10% time for maintenance) | -Power generation has redundancy. The rest does not have redundancy currently. | | |
| | Lifetime | The capture and control technology should perform as expected over the lifetime. | Lifetime/ design life | | 15 years before a major overhaul, 10 years operating life after the overhaul | | | |
| | Maintenance | The capture and control technology shall enable safe maintenance as required. 'Flexible pipe and boom should be of suitable material, easy to maintain and easy to inspect/test | Maintainability | | - | | | |
| | | Barge should be capable of maneuvering in the port and sail to different ports. | -Sailing speed | No minimum speed | 5 knots | The barge will be highly maneuverable with dual 360-degree rotating thruster propellers with joystick control. Barge should be able to maintain position and be | | |

| Performance Expectations | Description | Requirements | Critical Parameters | Requirements/ Acceptance criteria | | Comment | Action | Current product feasibility |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | | | |
| | | | | | | safely moored - as required. | | |
| | | | -Sailing range | n/a | Within confines of Port of LA and Port of Long Beach | Passage between other ports to be evaluated on a case-by-case basis. | | |

## 6.2 Technology Assessment

| ID | Description | Application | | | Technology | | | Techn. Class | Main function | Comments |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Known | Limited knowledge | New | Proven | Limited History | New | | | |
| 1 | **Emission capture unit** | | | 1 | | 1 | | 4 | Transport ship exhaust to the treatment system by connecting the ship exhaust stack to the emission control unit via a duct. | -Reach of crane<br>-Stack suitability<br>-Motion compensation<br>-Connection (connection time expected at around 45min to an hour for tankers, |
| 2 | **Emission control unit** | | 1 | | | 1 | | 3 | The emission control unit consists of catalytic ceramic filters (CCF) technology to treat the ship exhaust and remove diesel particulate matter (PM) and NOx. | -Any parts need Ex proofing? |
| 3 | **Shore-based** | | | 1 | | 1 | | 4 | | |
| 4 | **Barge-based** | | | 1 | | 1 | | 4 | | |

# Threat Assessment

## 6.3 FMECA – Capture and control

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.1 | Emission capture unit | Crane / displacement boom | Power outage | -Generator outage<br>-Grid power outage | Not able to lift adaptor | -Barge-based has backup for generator and hydraulic power pack.<br>-Shore-based has diesel generator as a backup power for grid power.<br>-Some terminals may have back up generators. | 2 | 3 | M | -For shore based, request the back-up power from the terminal for removing boom or equip the C&C with back-up power | -If grid has a power outage, the tanker offloading flow will be reduced. | Not unique to tankers |
| 1.2 | Emission capture unit | Crane / displacement boom | Hydraulic failure | Loss of hydraulic pressure | Not able to lift adaptor | Hood has 15m movement capability driven by electric winches. | 2 | 2 | L | | | Not unique to tankers |
| 1.3 | Emission capture unit | Crane / displacement boom | Mechanical failure | Structural damage of crane / displacement boom | Not able to lift adaptor | | 2 | 2 | L | | -Crane for bulk carrier cargo loading is used | Not unique to tankers |
| 1.4 | Emission capture unit | Crane / displacement boom | Mechanical failure | Lack of stability | Emission capture not possible/ damage to vessel(s) being serviced | | 4 | 2 | M | -Perform stability analysis and define the operation envelope of the crane. | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | Emission capture unit | Crane / displacement boom | Mechanical failure | Lack of maintenance | Not able to lift adaptor | | 2 | 2 | L | -Ensure proper access for maintenance and inspection of the crane/boom<br>-Develop maintenance and inspection procedure | | Not unique to tankers |
| 1.6 | Emission capture unit | Crane / displacement boom | Inadvertent operation in hazardous zone | Human error, miscommunication | The displacement boom may accidentally work inside the hazardous zone of the tankers or terminals while it is not compliant with the requirements. | | 4 | 4 | H | -Collect the hazardous zone arrangement from the terminal and also visiting tankers via pre-arrival questionnaire<br>-Define the route of placement boom operation accordingly to avoid the operation in the hazardous zones | | Described |
| 1.7 | Emission capture unit | Crane / displacement boom | Mechanical failure | The crane tips in the high wind condition | Not able to lift adaptor | | 3 | 3 | M | -Develop the safe working criteria (the crane designed for 30knots and the operating limit is defined as 25knots)<br>-Ensure the crane has been analyzed and tested according to the defined criteria | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.8 | Emission capture unit | Flexible duct | Mechanical failure | Flexible duct teared | Emission capture compromised | Flexible duct has coil steel to hold flexible duct. | 2 | 3 | M | | | Not unique to tankers |
| 1.9 | Emission capture unit | Stack adaptor /hood | Adaptor may add on additional load to the stack and cause structural damage. | Improper load distribution | Damage to stack/stack adaptor | Adaptor is not designed to add on weight to the stack in the normal operation. The crane will take the load of the adaptor via 3 winch cables. | 3 | 2 | M | | | Not unique to tankers |
| 1.10 | Emission capture unit | Stack adaptor /hood | Adaptor may damage the spark arrestor. | Improper load distribution | Damage to stack/stack adaptor | | 2 | 2 | L | -Before vessel's arrival, the stack (spark arrestor) configuration and photos need to be understood and the centering cone to be adjusted accordingly. | | Not unique to tankers |
| 1.11 | Emission capture unit | Stack adaptor /hood | Adaptor center cone may be stuck into the stack. | Improper installation or debris on stack | Damage to stack/stack adaptor | | 2 | 2 | L | -Manual operation is needed to remove the adaptor. Safety operation procedure to be developed. | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Co n. | Pr ob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.12 | Emission capture unit | Stack adaptor /hood | Mechanical failure | Winch cable broken<br>If the stack has an angle, e.g. 90°, the adaptor may fall with 1 winch cable broken. | Stack adaptor falls onto/into the stack. | -3 winch cables installed; the hood could be lifted by 2 winch cables.<br>-The adaptor cone is designed to be bigger than the stack diameter. | 4 | 2 | M | -Evaluate the number of winch cable and location to optimise the design | -2 aux (one running, one standing-by), can we use 1 only?<br>-shifting usage of aux. engines. | Not unique to tankers |
| 1.13 | Emission capture unit | Stack adaptor /hood | The stack adaptor cannot adapt to the variable sizes of stacks. | Stack sizes bigger than adaptor | Cannot capture exhaust, leaks, or drawing in ambient air | Pressure monitoring<br>Adaptor attached to stack with an opening and IR monitoring. Pre check of exhaust pipe size and configuration, to select the proper hood and duct to match the vessel | 2 | 4 | M | -Pre-vessel call questionnaire will collect the size, relative location, angle of the stacks. Crew of C&C service supplier will select the adaptor from the inventory accordingly. | Multiple (2) funnels, e.g. Polar Tankers with twin engine room need considerati on | Not unique to tankers |
| 1.14 | Emission capture unit | Stack adaptor /hood | The system cannot process the different exhaust gas rate from different sources. | High volume and flow rate of exhaust | Exhaust not handled appropriately | | 2 | 3 | M | -Exhaust fan is used to ensure negative pressure. IR camera used to adjust the flow rate of exhaust fans. | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.15 | Emission capture unit | Stack adaptor /hood | The stack adaptor conflicts with another when the stacks have a compact configuration. | Misfit between stack and adaptor | Some exhaust streams cannot be processed by the emission capture and control technology. | | 2 | 4 | M | -C&C service supplier to develop pre-arrival communication procedure and understand the stack configuration, the number and location of operating stacks for the visiting tankers. A bespoken stack adaptor connection method will be developed. The connection method should allow enough room for the necessary adjustment of the location without damaging the vessel's stacks.<br>-If it is found that the stack configuration is too compact for connecting stack adaptors, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. | -Use of innovative concept (emission credits)<br>-Each terminal has 5% non-compliance buffer for vessel visit events per terminal, each ship owner has 5% non-compliance buffer for the fleet based on the previous years' operation. | Described |
| 1.16 | Emission capture unit | Crane / displacement boom | Physical interference from shipboard installation | Improper planning and lack of communication | Damage to radar, antennas, etc., boom and hood | | 4 | 3 | M | | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.17 | Emission capture unit | Crane / displacement boom | The boom cannot reach PS and SB stacks when the funnel has a large span, e.g. when a ship is using double engine room arrangement. | Improper planning | Functionality affected | | 2 | 3 | M | -For the shore-based capture and control technology, it should evaluate if it is capable of covering the tankers visiting the terminal considering the size, height of the stack, and berthing orientations.<br>-For the barge-based capture and control technology, the service supplier shall develop a pre-arrival communication procedure and understand the stack height, configuration, number, and location of operating stacks for the visiting tankers. A bespoken stack adaptor connection method will be developed.<br>-If it is found that the funnel is too wide for the placement boom to reach, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.18 | Emission capture unit | Stack adaptor /hood | Structural failure | Centering cone is stainless steel. Fatigue damage may be induced by stack vibration. | Functionality affected | | 3 | 2 | M | -Develop periodical inspection procedure (visual and NDT) of the centering cone structure | | Not unique to tankers |
| 1.19 | Emission capture unit | Stack adaptor /hood | Adaptor may be disconnecting from the tankers' stack. | Poor connection or lack of engagement of the magnet | Adaptor not engaged and functionality affected | Adaptor is attached to the stack via magnetic attachment. | 2 | 3 | M | | | Not unique to tankers |
| 1.20 | Emission capture unit | Stack adaptor /hood | Unable to process all exhaust streams (e.g. 2 auxiliary engines and 2 boilers) | Misfit between stack and adaptor | Some exhaust streams cannot be processed by the emission capture and control technology. | | 2 | 3 | M | -Ensure communication procedure btw C&C service provide and tanker operator about the number and exact stacks for procession | The CAEM's design concept for tankers currently considers 2 booms for normal operation, i.e. capable of processing 4 stacks.Normally, tankers have 2 aux. engines, 2 boilers, and 1 vent line as the emission streams. | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.21 | Emission capture unit | Stack adaptor /hood | Unable to process the exhaust when shifting auxiliary engines/boilers | Too many stacks to handle | Not all exhaust stream processed | | 2 | 4 | M | -C&C service supplier to develop pre-arrival communication procedure and communicate the possibility of limiting the shifting of auxiliary engines and boilers while at berth.<br>-If it is found that a tanker needs to shift auxiliary engines or boilers, Vessel Incident Events (VIE) and Terminal Incident Events (TIE) may be used. | | Described |
| 1.22 | Emission capture unit | Stack adaptor /hood | Inadvertent operation in hazardous zone | Electrical short circuits | sparks, ignition, fire | The adaptor is operating in the non-hazardous zone. | 5 | 3 | H | Review MOTEMS to identify the requirements and potentially considering bonding and grounding. | | Described |
| 1.23 | Emission capture unit | Stack adaptor /hood | Fire or explosion risk | Spark and stack fire in the adaptor | Incidents causing fatalities and/or damage to vessel and terminal | Adaptor made by metal. Flexible duct withstanding temperature up to 1200F. | 4 | 2 | M | | -Technology experienced 2 stack fires and it worked ok. | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.24 | Emission capture unit | Flexible duct | Damage to duct | High temperature | Functionality affected | | 3 | 2 | M | | | Not unique to tankers |
| 1.25 | Emission capture unit | Flexible duct | Leakage | Lack of extraction Structural damage | Unprocessed exhaust gas emits to air | -High-definition camera and IR monitoring at the hood<br>-Boom duct has pressure monitoring | 2 | 2 | L | -Develop procedure about monitoring the leakage, alarm and response (disconnection the C&C) | -Static pressure monitor in the hood to ensure negative pressure on the hood<br>-If fan fails, in procedure to remove adaptor<br>-Open space allowed for gas emission if back pressure built-ip<br>-IR camera monitoring gas leakage | Not unique to tankers |
| 2.1 | Emission control unit | Treatment system | Personnel safety | Leakage of the processing chemical | Human fatality/injury | Secondary containment with leak monitoring in annular space | 4 | 3 | M | -Provide proper training to the workers<br>-Install leakage alarm and develop safety procedure<br>-Ensure vapor control in place | Ammonia is stored /dissolved in water. The tank is stored in a contained area. | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.2 | Emission control unit | Treatment system | Personnel safety | Handling the solid waste (soot) | Human fatality/injury | | 4 | 2 | M | -Develop the system and operating procedure to ensure the solid waste is handled properly (not in the exposed way)<br>-Provide PPE to the crew | | Not unique to tankers |
| 2.3 | Emission control unit | Treatment system | Not able to process the emission exhaust | Low temperature from the exhaust gas | Functionality affected | | 2 | 4 | M | -Reheat the exhaust gas to minimum temperature requirement | | Not unique to tankers |
| 2.4 | Emission control unit | Treatment system | Design failure | High exhaust rate of tankers | The capture and control technology is not capable of processing the exhaust streams according to the at-berth regulation requirement. | | 2 | 3 | M | -Review the range of exhaust gas flow rate of the tankers visiting California and increase the treatment capacity of the capture and control system accordingly. | | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.5 | Emission control unit | Exhaust fan | -Mechanical failure<br>-Power failure | Overspeed of fan, underspeed of fan, sudden stop | Backpressure build-up within the tanker's exhaust system. It may cause fan failure for boilers, incomplete combustion, and inert gas generation. | -Pressure monitoring<br>-Adaptor attached to stack with an opening and IR monitoring | 3 | 3 | M | -The capture and control technology supplier will:<br>--Implement an alarm window of pressure monitoring including both upper and lower limit<br>--Consider implementing pre-warning alarm regarding differential pressure for crew onboard the tanker to respond ahead<br>--Ensure fan speed is controlled according to the pressure in the duct<br>--Evaluate the reliability of the pressure sensor and develop redundancy accordingly<br>-Establish communication procedure between capture and control supplier, tanker's crew, and terminal operator, including:<br>--Providing instruction/checklist for tanker's crew to understand the capture and control technology's alarms<br>--Capture and control technology service supplier to attend the pre-transfer conference<br>--generate VHF communication channel | | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.6 | Emission control unit | | Sensor failure Mechanical failure | Design fault | Loss of control and monitoring | | 2 | 5 | M | Evaluate the reliability of the pressure sensor and develop redundancy accordingly | | Not unique to tankers |
| 2.7 | Emission control unit | Power supply | Component failures | Generator:<br>-Mechanical failure<br>-Electrical failure<br>-Lack of fuel<br>Grid:<br>-Electrical failure | Loss of control and monitoring | | 3 | 3 | M | | -Barge has Li-Titanium oxidized battery bank and redundant generator. Spud motor is electrical driven. Hydraulic power pack redundancy may be needed to remove the boom during failure. | Not unique to tankers |
| 2.8 | Emission control unit | Power supply | Capture and control technology's own emission is not processed. | Design/operational fault | Functionality affected | If movable shore-based technology, Tier IV generator will be used. | 2 | 2 | L | -The exhaust from the generator will also be treated by the C&C technology. | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.9 | Emission control unit | Outlet | The processed gas is discharged out of compliance. | Design/operational fault | Functionality affected | Monitoring system is installed. Non-compliance addressed by CARB executive order | 2 | 2 | L | -Following CARB testing procedure and certification<br>-Develop alarm based on the regulation requirement and the procession efficiency | All exhaust streams combined and treated together | Not unique to tankers |
| 3.1 | Base unit | Shore-based | Unable to transport onto the site during the technology installation | Narrow road on the wharf Insufficient overhead clearance (height of the unit is around 30-50feet) | Delayed installation | | 2 | 2 | L | -Perform transportation analysis<br>-Assemble onsite<br>-Use heavy lift vessel | Assembled in port, moved by barge to terminal | Not unique to tankers |
| 3.2 | Base unit | Shore-based | There is no sufficient space at the terminal for installation. | Poor planning for installation | Delayed installation | | 2 | 2 | L | -Use barge or install a floating/fixed platform as an alternative | -18feet x 30~50 feet footprint overall height 32 feet | Described |
| 3.3 | Base unit | Shore-based | The berth does not have enough strength to withstand the weight and load of the capture and control technology. | Insufficient planning/home work | Damage to berth and functionality affected | -Use barge or install a platform purposely as an alternative | 4 | 1 | M | -Compare the weight limit of the pier with the unit<br>-Utilize engineering solutions to spread the weight of the base unit | -expected total weight 150,000-230,000 lbs<br>-T shaped terminal has a given weight limit for existing pilings | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.4 | Base unit | Barge-based | The movement of barge may cause relative movement btw adaptor and stack. It may add additional load onto the stack. | -Swell, surge, passing traffic | relative movement between crane boom and stack | Flexible duct is used to adapt to the relative movement. | 3 | 2 | M | -Flexible duct length to be adjusted purposely for tankers.<br>-Operator of C&C technology adjusts the angle of place boom accordingly.<br>-Controlling the vacuum and response time with long ducting. | -Gravity spuds are considered for the current design concept for tankers. The vertical position of the barge changes according to the tide.<br>-Suction/magnetic mooring arrangement may be considered. | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.5 | Base unit | Barge-based | The self-propelled barge is constructed without meeting the regulation requirement or constructed with a low quality. | Poor design and construction | Not possible to operate | | 2 | 2 | L | -Class the barge with class society and consider a periodical inspection plan; -Determine the operating area and clarify with US Coast Guard on the regulatory requirements; | CAEM's current concept is designed for use in the enclosed water in POLA/POLB, but not California Bay Area or transit in open water. The preliminary assessment indicates that the barge does not have to be USCG inspected. License are also not required. However, CAEM plans to provide specific training for the crew regarding navigation and operating the capture and control system. | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.6 | Base unit | Barge-based | Low qualification of the crew | Poor management of the barge | Flawed and/or delayed operation | | 3 | 3 | M | -Ensure the crew of the barge is trained properly considering the complexity of the capture and control operation, traffic congestion, etc.;<br>-Ensure the crew operating the capture and control technology is familiar with the terminal facility and the local navigation system;<br>-Develop operation procedures involving port, terminal, and capture and control service provider. | | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.7 | Base unit | Barge-based | Spudding operation is operating without meeting environmental permitting requirement. | Disturbance to the vegetation, marine mammal through spudding | Environmental damage/environmental liabilities | | 3 | 3 | M | -Verify the environment requirement regarding spudding from state agency and if CSL CEQA requirement is needed | Any environmental permitting requirement for spudding?(superfund, sensitive vegetation? marine mammal)Chevron eelgrass POLA vegetation growth start at 15feet depth | Described |
| 3.8 | Base unit | Barge-based | Airborne noise distrubance to the adjacent area | Noisy operations | Noise pollution | | 3 | 3 | M | -Install silencer onto the exhaust of the barge | | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.9 | Base unit | Barge-based | Spudding may damage the underground piping. | Lack of knowledge of underground installations | Domestic utilities or installations affected | | 5 | 3 | H | -Collect the information about any underground pipelines from the terminal guide and arrange the spudding operation based on the specific terminal arrangement. | The barge will have an emergency anchoring system | Described |
| 3.10 | Base unit | Barge-based | The barge may not have sufficient station keeping capacity. | Strong surge/swell Passing traffic | Collision between tanker and barge/ operation hampered | -The current design concept uses 2 spuds. The barge has 6 spuds installed. More spuds may be used to increase the station keeping capacity. | 4 | 4 | H | -Evaluate the spud station keeping capacity against the local climatology. | -SF bay wave height 4-6 times greater than Richmond harbor. | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.11 | Base unit | Barge-based | The tanker and barge move when there is a passing traffic but the barge is well stationed. | Passing traffic | Collision between tanker and barge | | 4 | 4 | H | - The safe operating envelope of the barge should be defined with enough clearance between the tanker and the barge based on the mooring analysis for each terminal;<br>- The maximum clearance that the capture and control technology could provide should be evaluated and compared with the required clearance.<br>- The barge may also be equipped with a fender system. | According to MOTEMS, in general, vessels shall remain in contact with the breasting or fendering system. Vessel motion (sway) of up to 2 feet off the breasting structure may be allowed under the most severe environmental loads, unless greater movement can be justified by an appropriate mooring analysis that accounts for potential dynamic effects. | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.12 | Base unit | Both | Inusfficient operational planning | Modification of the terminal operation induced by using the capture and control technology | Out of MOTEMS compliance. | | 3 | 3 | M | -Consider performing Management of Change review before implementation;<br>-Monitor marine terminal regulation updates and ensure compliance. | | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.13 | Base unit | Barge-based | Traffic in the channel is affected and in a worst-case scenario, collisions | Narrow channel | The usage of barge may block the traffic in the channel. | barge equipped with GPS, VHF radio, and compass | 4 | 2 | M | -Assess the berthing location of barge based on the local traffic and channel navigation system to avoid adverse impact to the passing traffic;<br>-Ensure that the barge is not berthing inside the regulated navigation area;<br>-Consider moving the barge temporary to allow passing traffic following the provision from CARB at-berth regulation regarding removing the capture and control technology temporarily;<br>-Develop communication platform btw all parties (pilot, terminal, capture and control service provider) and install communication and navigation equipment (VHF, GPS, Satellite compass) onboard the barge;<br>-Consider equipping the barge with an automatic identification system (AIS). | | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.14 | Base unit | Barge-based | Large footprint of the barge | The usage of barge may involve encroachment to other's property. | Unable to berth the barge | | 2 | 2 | L | -Assess the footprint of the barge and discuss with the neighbour regarding the possibility of using the property | | Described |
| 3.15 | Base unit | Barge-based | Emergency situations | The capture unit cannot be quickly released. The barge may not be able to move away in time during emergency. | Out of compliance, injuries, damage to property | | 5 | 3 | H | -Develop an emergency response procedure<br>-Perform training of the crew<br>-Potentially perform drills to evaluate the impact in reality | | Described |
| 3.16 | Base unit | Barge-based | Boundary conditions not well-defined during design | Deep water in the terminal; Short spud length | The spud length may not be sufficient for the water depth. | Terminal specific pre-assessment | 3 | 3 | M | -Review the water depth during the design stage of the barge and adjust the spud length according to the terminal arrangement. | | Described |
| 3.17 | Base unit | Barge-based | Vessel operations hampered | The barge may interfere with the normal tanker operation (mooring, deballasting). | Unable to berth the barge or install the floating platform | | 3 | 4 | M | -The location arrangement of the base unit should consider the normal operation of the tankers and ensure it does not interfere and is not interfered by the normal operation of the tankers. | Deballasting normally at the bow of the tankers | Described |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.18 | Base unit | Barge-based | There is no storage space in the port available for the barge when it is not in use. | Insufficient planning/home work | Functionality affected | | 2 | 1 | L | -Consider spud the barge at a storage location as opposed to tied up against the berth and identify the location with Port authority (it may be acceptable for USCG/port to leave the barge attended) | The Port of Long Beach only has 2000 linear feet of wharf space – equivalent to two berths. And all other space is leased out, which means the Port will be limited in its storage capacity of emissions capture and control systems. | Not unique to tankers |

| Id | System | Component | Failure mode(s) | Failure cause(s) | Effect of failure(s) | Existing Safeguards | Con. | Prob. | Risk | Recommendations | Comments | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.19 | Base unit | Barge-based | The operating condition may be too harsh for the barge design. | Harsh environmental condition | The barge cannot be maneuvered as planned or do not have sufficient station keeping capacity. | | 3 | 3 | M | -Purposely design the barge according to the environmental conditions for the planned operation areas. | -The current design is having 3-5knots speed.<br>-Northern California terminals have a harsher environment compared with POLA, POLB. | Described |
| 3.20 | Base unit | Barge-based | The barge does not have sufficient stability. | Poor design and construction | Damage to barge/vessels | | 4 | 2 | M | -Perform stability analysis | | Not unique to tankers |
| 3.21 | Base unit | Barge-based | Safety of personnel | Work at height | Fatality to personnel | | 4 | 2 | M | -Elevator is available | | Not unique to tankers |

## 6.4 HAZOP Results – Capture and control

| ID | Phase | Applicability (Shore, Barge, both) | Hazard / Deviation | Cause | Consequence | Existing safeguards | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Normal Operation | Barge | Operation not possible | Unexpected high traffic | No sufficient capture & control available | | 2 | 3 | M | -Evaluate demand based on historical traffic data<br>-Consider use innovative concepts | Not unique to tankers, more relevant to commercial aspects |
| 2 | Normal Operation | Both | Complex and long operation | Human fatigue | Injuries, damage of the property, accidents | | 3 | 3 | M | -Develop proper training and operation procedures for the whole process including:<br>--normal operations such as connection, start up, disconnection, and maintenance<br>--emergency response including safety plans<br>-Provide accommodation and ensure proper working conditions for the crew<br>-Develop proper working schedule and shifts for the crew and ensure the proper rest. | Described |
| 3 | Normal Operation | Barge | Movement of barge | Inadvertent thruster operation | Collision, relative movement | | 3 | 1 | L | -Lockout procedure to be implemented when spudding | Not unique to tankers |
| 4 | Normal Operation | Both | Extreme movement of the vessel | Surge | The adaptor may cause damage to the funnel or disconnect from the funnel. | | 3 | 3 | M | | Not unique to tankers |

| ID | Phase | Applicability (Shore, Barge, both) | Hazard / Deviation | Cause | Consequence | Existing safeguards | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | Normal Operation | Both | Poor visibility | Darkness<br>Fog<br>Wild fire | Unable to connect | | 2 | 4 | M | -Develop procedure for response in the bad visibility situation<br>-Utilize emission credit | Not unique to tankers |
| 6 | Normal Operation | Shore | Strong wind | Harsh weather | Crane unable to operate | | 3 | 4 | M | -Operating under MOTEMS regulations. Need to develop operational envelop to obtain weather criteria | Not unique to tankers |
| 7 | Normal Operation | Barge | Strong current | Harsh weather | The barge is not able to manoeuvre safely by itself. | | 2 | 2 | L | Using tug? | Northern California ports have a more exposed water. |
| 8 | Normal Operation | Barge | Hull damages | Harsh weather | Larger relative movements between hood and tanker. It may cause damage of the hull. | | 4 | 2 | M | | Not unique to tankers |

| ID | Phase | Applicability (Shore, Barge, both) | Hazard / Deviation | Cause | Consequence | Existing safeguards | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 | Emergency Scenario | Both | Environmental damage/oil spills | Operational impact/emergencies/breach etc. | Emergency evacuation required | | 4 | 3 | M | It is recommended to develop a safety response plan with terminals and ports for oil spillage. The barge will likely need to shut down power and provide shelter (accommodation) with air recirculation for the crew onboard. Proper procedure and equipment for communication between the emergency response team, tanker, terminal, port, and capture and control service provider should be provided. | |
| 10 | Emergency Scenario | Both | Earthquake, tsunami, fire | Natural disasters | Emergency evacuation required | -Current terminal design is designed to be compliant with MOTEMS (for any permanent structures) | 5 | 1 | M | -Evaluate the time required for emergency response when connecting to hood (disconnect hood, disconnect barge, manoeuvre away from berth)<br>-Develop emergency response procedure | |
| 11 | Emergency Scenario | Both | Dropped objects | -Crane failure<br>-Poor maintenance<br>-Human error | -Dropped object on barge<br>-Dropped object on shore<br>-Dropped object on ship | | 3 | 3 | M | -Analyze the hydraulic failure with crane provider | |

| ID | Phase | Applicability (Shore, Barge, both) | Hazard / Deviation | Cause | Consequence | Existing safeguards | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | | | ISPS and MTSA compliance | Opertional issues | Non compliance | | 3 | 2 | M | -Investigate the applicability and ensure compliance | |
| | | Both | Backpressure / Additional pressure from the emission capture and control technology may impact the safe operation of the ship | -Blockage of exhaust flow<br>-High flow of emissions which is the emission treatment is unable to process<br>-Shutdown of capture and control system (i.e. Primary fan failure) | | | | | | Built up pressure needs to be evaluated<br>-Identify alarm interfaces and safeguards that would prevent backpressure build up within the tank vessel exhaust systems<br>-Pressure relief arrangement? | Not used |
| | | | Variation of boiler pressure | | | | | | | | Not used |
| | | | Accumulated heat in the system | | | | | | | | Not used |
| | | | Reverse flow of emissions? | | | | | | | | Not used |
| | | Shore | Blackout on terminal side | | | | | | | | Not used |
| | | Both | Blackout of ship | | | | | | | | Not used |
| | | Both | Hood damaging the funnel | Adverse weather, relative motion control not sufficient | | | | | | | Not used |
| | | Barge | Barge capsizing due | Poor barge maintenance and | -Damage to tanker funnel | | | | | -Maintenance and inspection regime on barge | Not used |

| ID | Phase | Applicability (Shore, Barge, both) | Hazard / Deviation | Cause | Consequence | Existing safeguards | Cons. | Prob. | Risk | Recommendations | Relevance for tanker |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | to adverse stability | quality control | | | | | | | |

## About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline, or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

Driven by its purpose, to safeguard life, property, and the environment, DNV helps tackle the challenges and global transformations facing its customers and the world today and is a trusted voice for many of the world's most successful and forward-thinking companies.