Advancing safety & economics in global AMMONIA trade

A focus on open sea terminals and floating storage

Philippe LAVAGNA

Product Account Manager - New Energies Terminals

SBM OFFSHORE / IMODCO

Gastech

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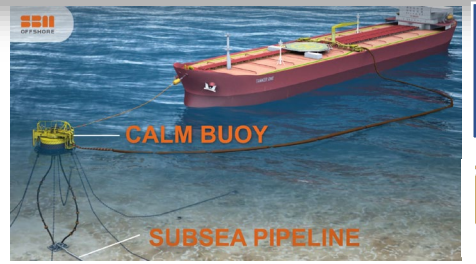
SBM OFFSHORE - Track Record of Innovation & Risk Management

Risk management of high pressure, explosive, toxic or cryogenic products:
from Technology qualification to Offshore Operations



Over 80 world firsts in the offshore industry

Imodco
Part of the SBM Offshore® Group

SBM OFFSHORE pioneered offshore systems.

Committed to **SAFETY** & **COST EFFICIENCY**

From **CALM buoys** [**S**ingle **B**uoy **M**ooring] to **lease & operate** of large & complex **FPSOs** [Floating Production Storage Offloading], our current core business.

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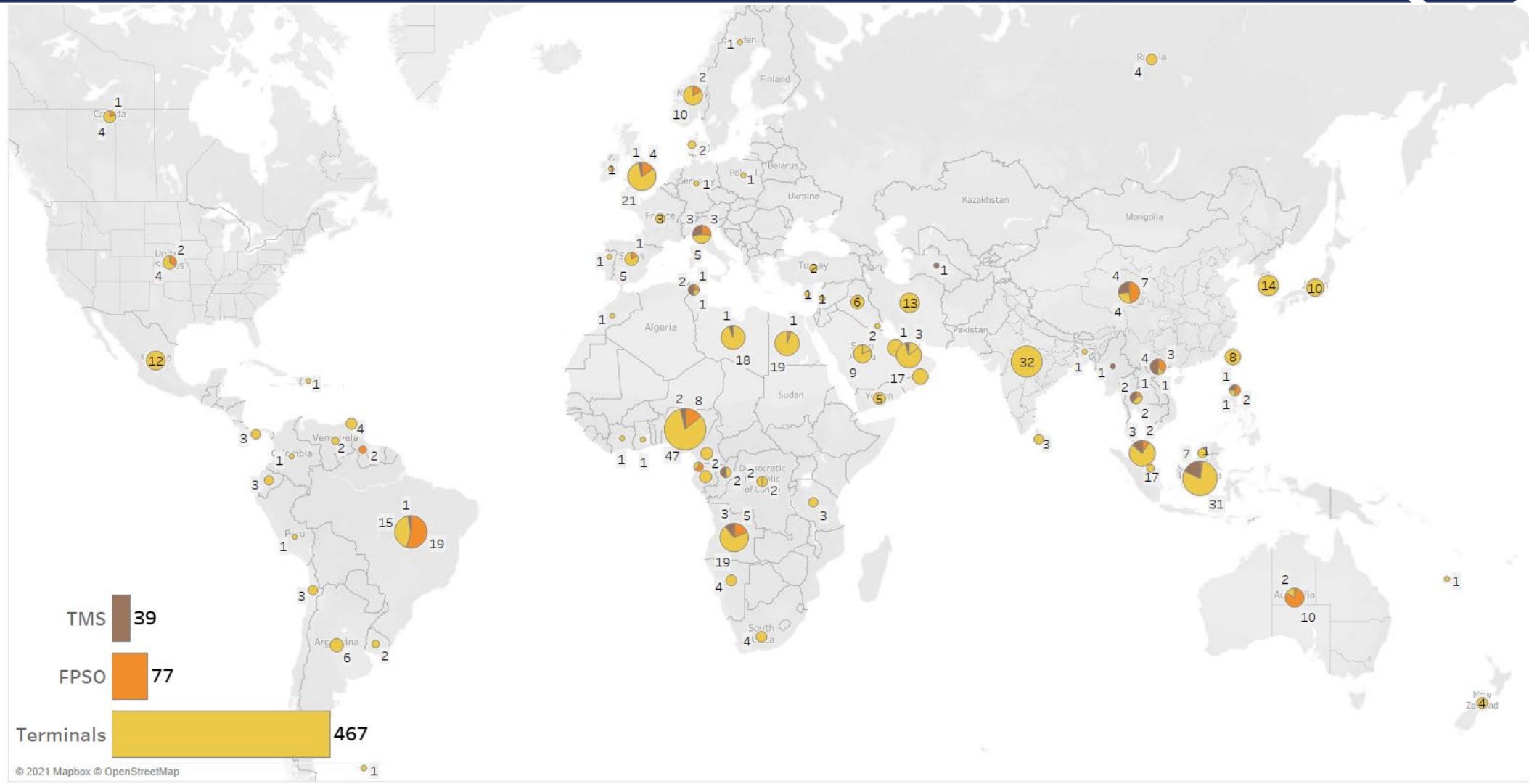
SBM OFFSHORE – Jetty-less Terminals: From Pioneer to World Leader since 1958



SBM OFFSHORE - Offshore Industry Experience

What concept optimizes the project NPV?

Jetty-less concepts often lead to **best CAPEX / OPEX / uptime combinations**

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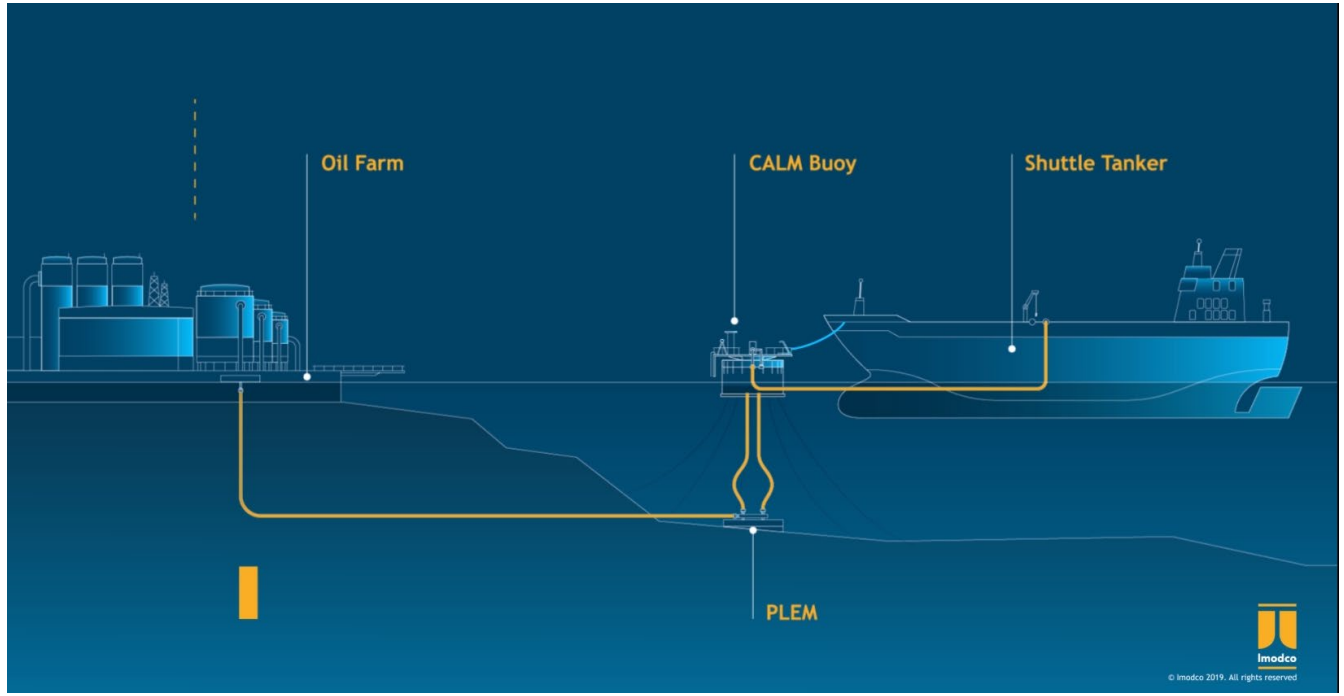
SBM OFFSHORE - CALM Operations

Edition: 3rd Edition **Year:** 2015 **Author:** OCIMF

Single Point Mooring Maintenance and Operations Guide (SMOG)

3rd Edition

Single Point Mooring Maintenance and Operations Guide (SMOG) is an industry guide with technical recommendations and guidance for the operation and maintenance of single point moorings (SPM).



Over **65 years of experience** of operating SPM terminals (CALM)

- summarized in OCIMF SMOG
- illustrated in these videos

- CALM Buoy Operation I Imodco on Vimeo [2 min]
- Catenary Anchor Leg Mooring (CALM) Terminal on Vimeo [4 min]

Scan to watch the video of our CALM buoy operations!

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SBM OFFSHORE - New Energies Terminals

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1. Our mission
2. Safety pitch
3. Qualification status
4. Various concepts

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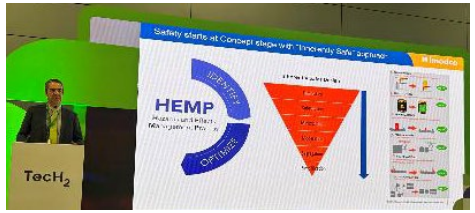
SBM OFFSHORE - Our Contribution: a Better & Safer World

Ensuring safe ammonia transfers

AWARENESS

advocate for jetty-less terminals for large & frequent transfer (white paper & conferences)




Shipping of Ammonia: What is new ?
Rev. 2.0 – Jan-24
Philippe Lavagna
New Energies Terminals
Product Account Manager
Mauro Bedini
Terminals
Engineering Manager
Imodco, the Terminals Product Line of SBM Offshore
Imodco
SBM OFFSHORE
TRUE. BLUE. TRANSITION.

AMMONIA ENERGY ASSOCIATION

ARISE
Ammonia Response In Sea Emergencies

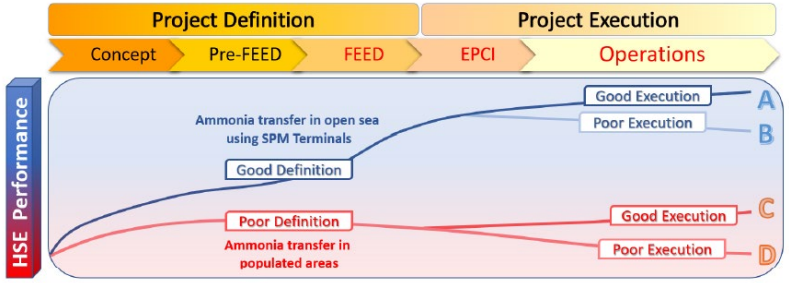
QUALIFICATION

set 'good practices' for ammonia jetty-less solutions

DNV · ABS · SIGTTO · OCIMF · EXMAR · Vopak · BUREAU VERITAS · LR · ADVARIO · ClassNK

SUPPORT TO FIRST MOVERS

strong support to frontline developers



Crystalize best practices into reality from first projects for large ammonia export / import projects

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SBM OFFSHORE - Optimization of Transport KPI - 'Virtual Pipeline' Tariff

PRODUCTION → **TRANSPORT** → **CONSUMPTION**

virtual 'pipeline tariff' optimization considering the **full value chain**

Compare CAPEX & OPEX from ammonia production [excluded] to consumption [excluded]

EXPORT terminal with **onshore storage**:
new jetty [$$$ to $$$$] vs **jetty-less [$$]**

IMPORT terminal with **onshore storage**:
quay side [if possible] vs **jetty-less [if relevant]**

off-the-shore **F**loating **S**torage **O**ffloading [FSO] **option** for export or import terminals: [can optimize overall tariff]

- typically leased by carrier owners / operators
- **Jetty-less FSO <=> permanent mooring system in shallow waters** [close to shore]

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Main Risk with Ammonia Export / Import

NH^3 toxicity largely depends on:

1. **concentration** [ppm],
2. **duration of exposure** and
3. **individual sensitivity**.

However, generally, ammonia levels:

from 2 ppm	*unique & bad smell - good point for safety [H^2 has no smell]*
> 25 ppm	*irritating to eyes & respiratory system*
> 50 ppm	*prolonged exposure can lead to more severe health issues incl. lung damage or respiratory problems*
> 300 ppm	*[longer exposure] dangerous to health & even life*

Substance	Health	Flammability	Reactivity
Ammonia	3	1	0
Hydrogen	0	4	0
Gasoline	1	3	0
LPG	1	4	0
Natural Gas	1	4	0
Methanol	1	3	0

0=No hazard, 4=Severe hazards

Toxic cloud may be the consequence of large, accidental releases:

- **Unplanned rupture of transfer system connections** [loading arm / jumper, release coupling, flanges,..]. At large flow rates, the release can be significant [~ 50 T in 2 min in Chile - see picture].
- **Collision between vessels** could lead to even larger releases.

Exhaustive studies of various plume scenarios are a must, especially if close to busy (SIMOPS) or populated areas.

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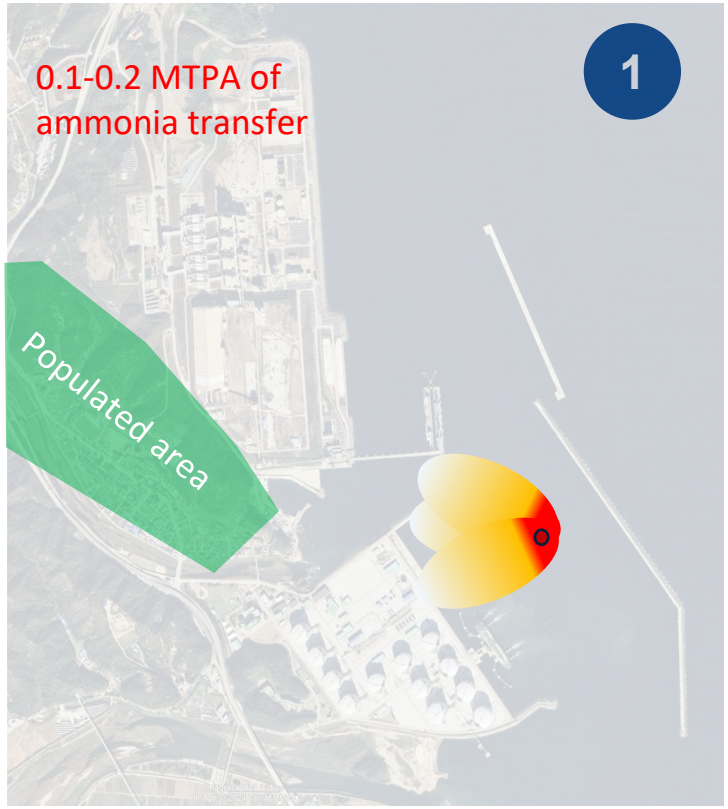
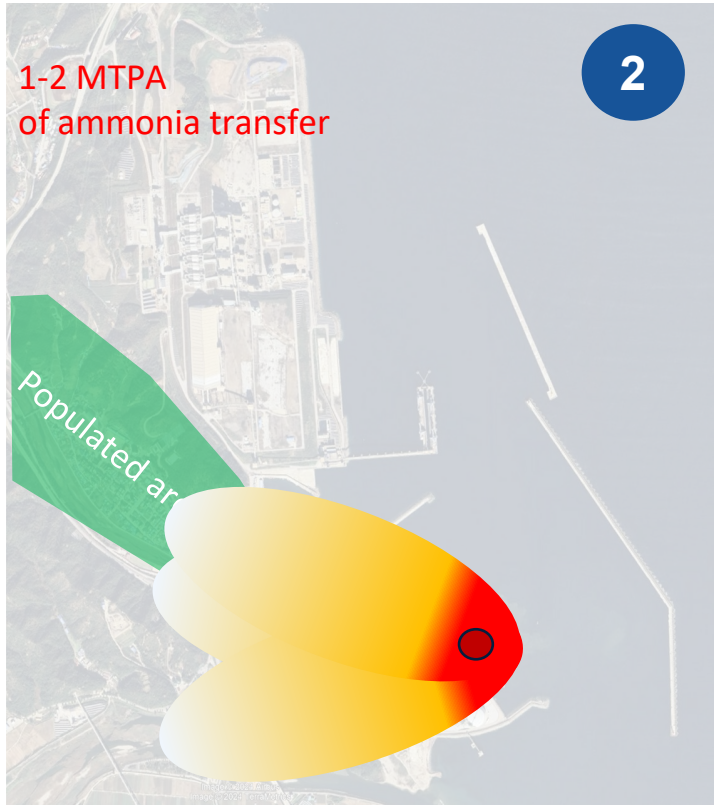
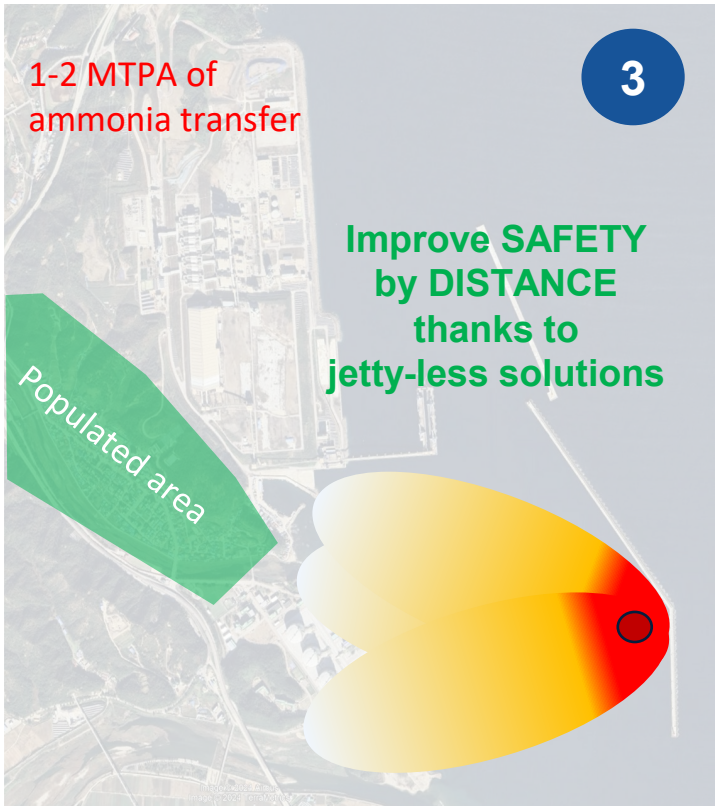
Larger Flow & Higher Frequency IMPACT on QRA (Quantitative Risk Assessment)







- larger **flow rate** -> large release potential -> larger toxic cloud
- higher **frequency** -> larger overall safety radius [more scenarios to consider]

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SBM OFFSHORE - Ongoing Qualification Works for Ammonia Applications

- CALM qualification will cover all open sea solutions [including FSU]
- Ammonia SPM operating manual HAZOP with value chain stakeholders

Ready to Market in H2 2025

Statement no. P42646-3

APPROVAL IN PRINCIPLE

This is to state that the design principles of the

Imodco Ammonia CALM Terminal

Have been assessed by DNV AS and found to comply with current rules of this Society.

The design principles, specified in /1/, /2/ and /3/ have been assessed for compliance with the following class notations:

⊕OI Floating Offshore Installation, [Ammonia Loading Buoy], Field(qualifier), POSMOOR(Near), UWILD

Subject to satisfactory detailed design verification, taking into account the limitations below, and surveillance during construction, installation and commissioning, DNV considers that a Class Certificate with the requested Class Notations can be issued for the Floating Injection Unit.

Project owner: **Imodco Terminals S.A.**

Limitations: This statement does not constitute classification of the design to DNV Rules for Classification, however DNV have no major comments to the received documentation. General comments to the design as well as relevant assumptions are stated in the associated Report on Approval in Principle/1/.

Reference documents:
/1/ Report on Approval in Principle No. P42646-1,
/2/ DNV-RU-OU-0103, "Floating LNG/ LPG production, storage and loading units" July- 2022
/3/ DNV-OS-E403, "Offshore loading and infrastructure buoys", July 2022

Høvik, 2022-08-29
for DNV AS

Inger-Helene Hals
Head of Section

Barros, Pedro
Pedro Barros
Project Manager

DNV AS . Veritasveien 1, N-1322 Høvik, Norway. Tel: +47 67 57 99 00

Electronically published by ABS London, Reference: ES307571, dated 21 Oct 2022

APPROVAL IN PRINCIPLE ABS

as requested by:
Imodco Terminals SA

Date of Issuance: 21 Oct 2022
Certificate Number: T2307571

ABS

APPROVAL IN PRINCIPLE

as requested by:
Imodco Terminals SA (444609)

Date of Issuance: 16 Sep 2024
Certificate Number: WOT0006905

ABS has reviewed the documentation as specified in the ABS letter dated 1 Aug 2024 (Task No. WOT0006905) and considers that the conceptual engineering as proposed is feasible for the intended application, and the facility as presented is, in principle, in compliance with the applicable requirements of the ABS Rules for Building and Classing Single Point Moorings (2024), (Ref. to 1-1-2/1.5 Unconventional Designs), ABS Rules for Conditions of Classification – Offshore Units and Structures 2024, Part 1B, Chapter 1, Section 4, (9 Alternatives, 11 Novel Features, 13 Risk Evaluations for Alternative Arrangements and Novel Features).

FACILITY: SPM Jetty-less Terminals

DESCRIPTION: Concept of a TLU, CALM buoy, CALM Soft Yoke for the transfer of Ammonia, Carbon Dioxide

NEW TECHNOLOGY MATURITY LEVEL: Terminal for transfer of Ammonia / Carbon Dioxide (TLU, CALM buoy, CALM Soft Yoke) – Concept Feasible Stage

To achieve final class approval of the subject design, the conditions and requirements as specified in the review letters [ref. to WOT0006905] must be satisfied.

Steve Brincat
Manager, Engineering, ABS

Note: This certificate evidences compliance with one or more of the Rules, Guides, standards or other criteria of American Bureau of Shipping or a statutory, industrial or manufacturer's standards and is issued solely for the use of the Bureau, its committees, its clients or other authorized entities. Any significant changes to the aforementioned product without ABS approval will result in this certificate becoming void. This certificate is governed by the terms and conditions in the ABS Rules.

ENG-ATT-00307 Revision 1 Page 1 of 1

ClassNK
NIPPON KAIJI KYOKAI

Document No. 24HE01841
Date: 26 December 2024

APPROVAL IN PRINCIPLE

CALM Terminal for Ammonia Application
developed by
Imodco Terminals S.A.

THIS IS TO CERTIFY THAT Approval in Principle is granted to Imodco Terminals S.A.

The AIP is for the design concept of the CALM Terminal for Ammonia Application, and it is based on the *"Guidelines for Technology Qualification (Ver. 1.0)"*.

The documents/drawings specified in the annex to this letter have been reviewed and it is verified that the conceptual design of the system is feasible for the intended application.

Conditions on this AIP are set out in the Annex to letter 24HE01841.
For the final qualification of the system, a complete set of documentation is to be examined by the Society in accordance with relevant class rules/guidelines.

(Akio Usami)
General Manager of Hull Department
NIPPON KAIJI KYOKAI

Form CLS (21.01)

Approval in Principle
Level 1

IMODCO
Jetty-less solutions for Ammonia and/or Natural Gas and LNG

P25-015
May 2025

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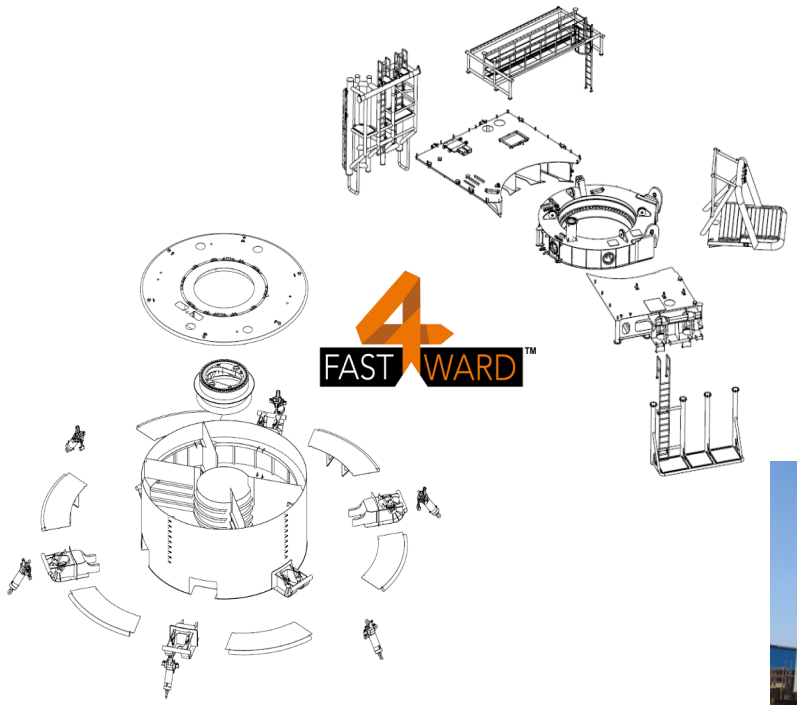
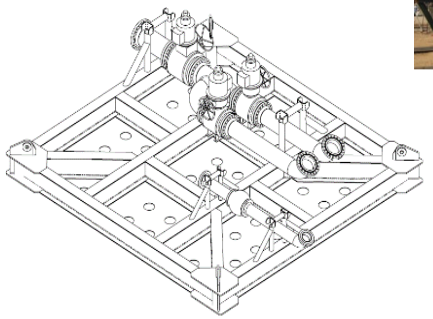
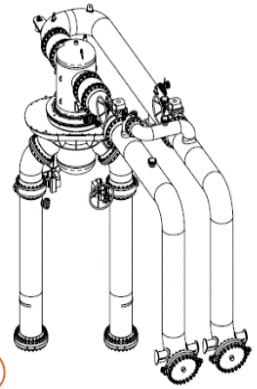
End of 2022

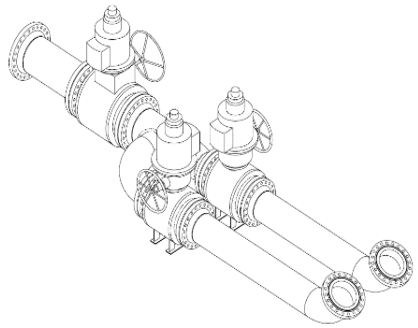
SBM OFFSHORE - NH3 Buoy & Fast4Ward





NH3





Only the components in contact with ammonia need qualification.

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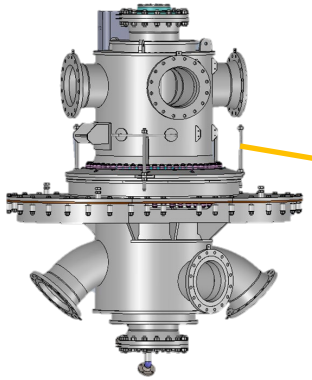
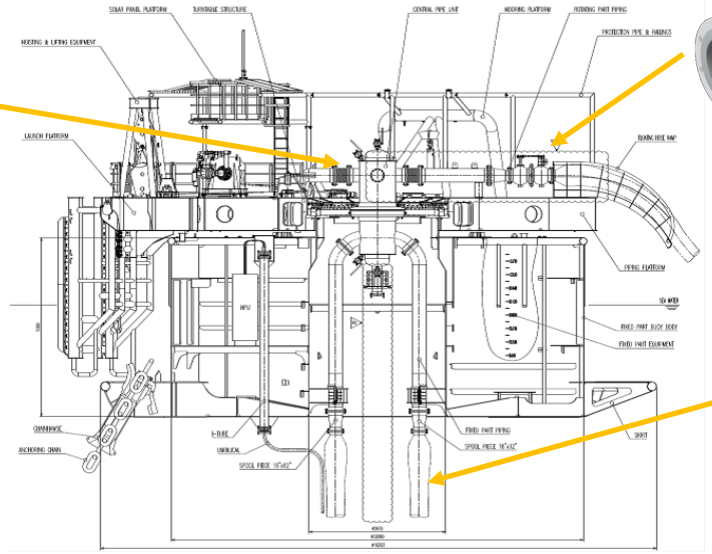
NH3 Developments - Target TRL4 (using API 17N TRL Scale 1-7)

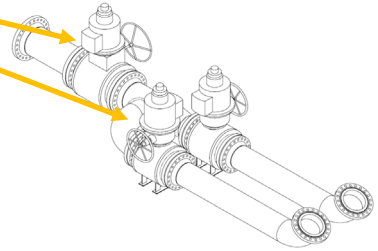
TRL4 [Q3-2024]
Why important:
2 extremes:
- **cold liquid** flow
- ambient T° **vapor** (between loading)

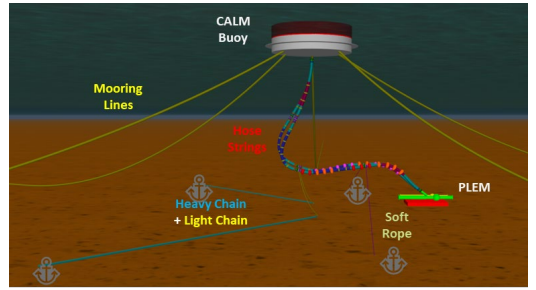




TRL7

TRL4 [Aug-2025]
Why important:
Safety critical element
First time subsea





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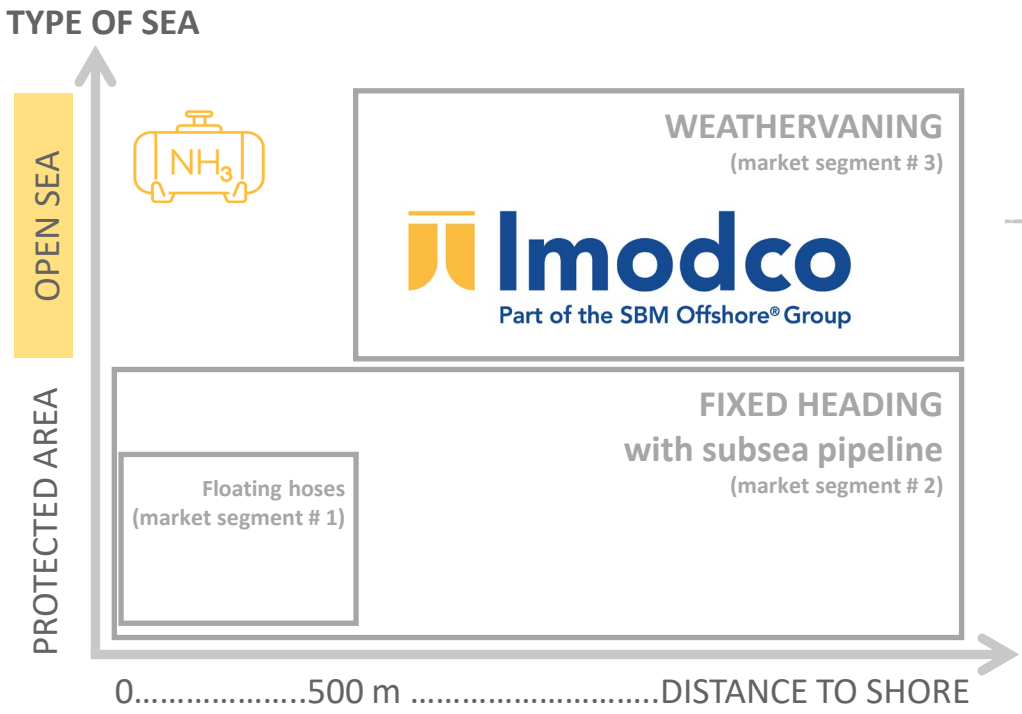
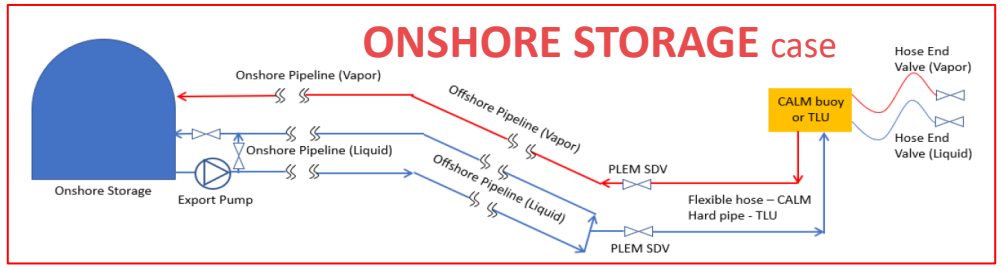
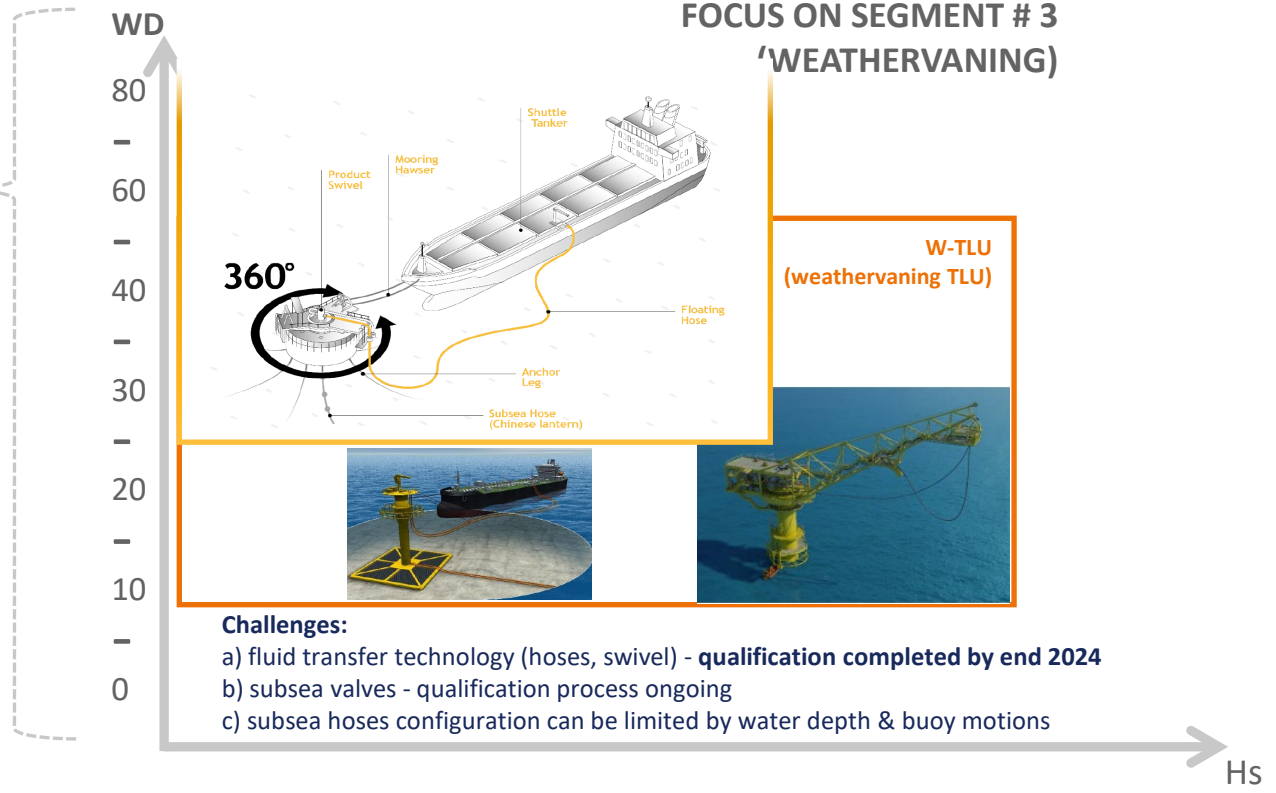
Jetty-less Terminals for Ammonia - Technical Segmentation







Challenges:

a) fluid transfer technology (hoses, swivel) - **qualification completed by end 2024**

b) subsea valves - qualification process ongoing

c) subsea hoses configuration can be limited by water depth & buoy motions

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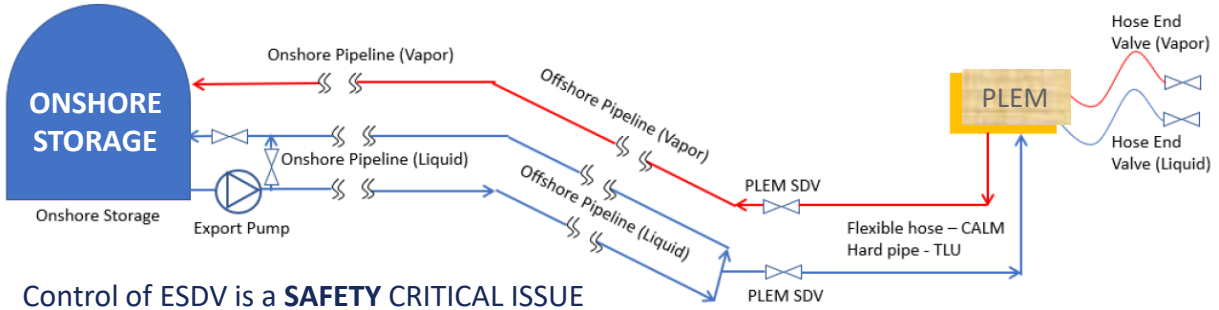
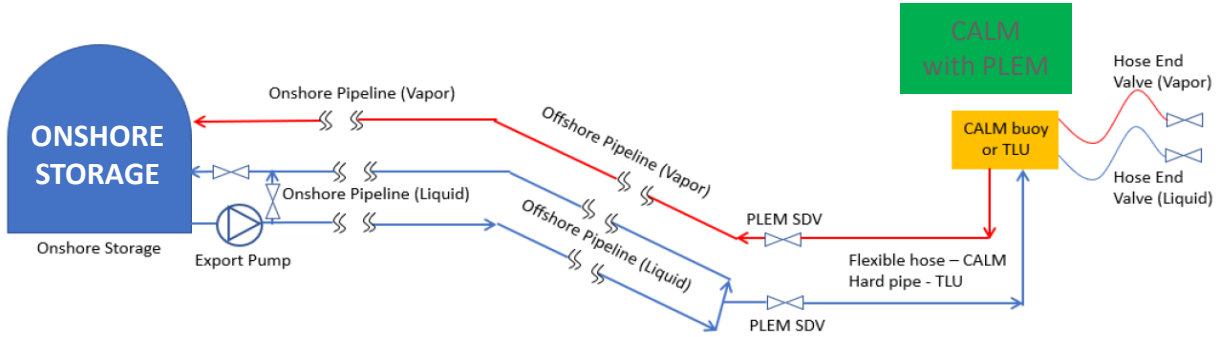
Conceptual Comparison & Battery Limit for ‘tariff’ Comparison

CBM Case (Conventional Buoy Mooring – *fixed heading*)



Control of ESDV is a **SAFETY** CRITICAL ISSUE
[potential blocking operational permit or project insurance]

CALM Case (recommended concept – *SPM* ⇔ *weather-vaning*)



Same pipeline system - similar PLEM location

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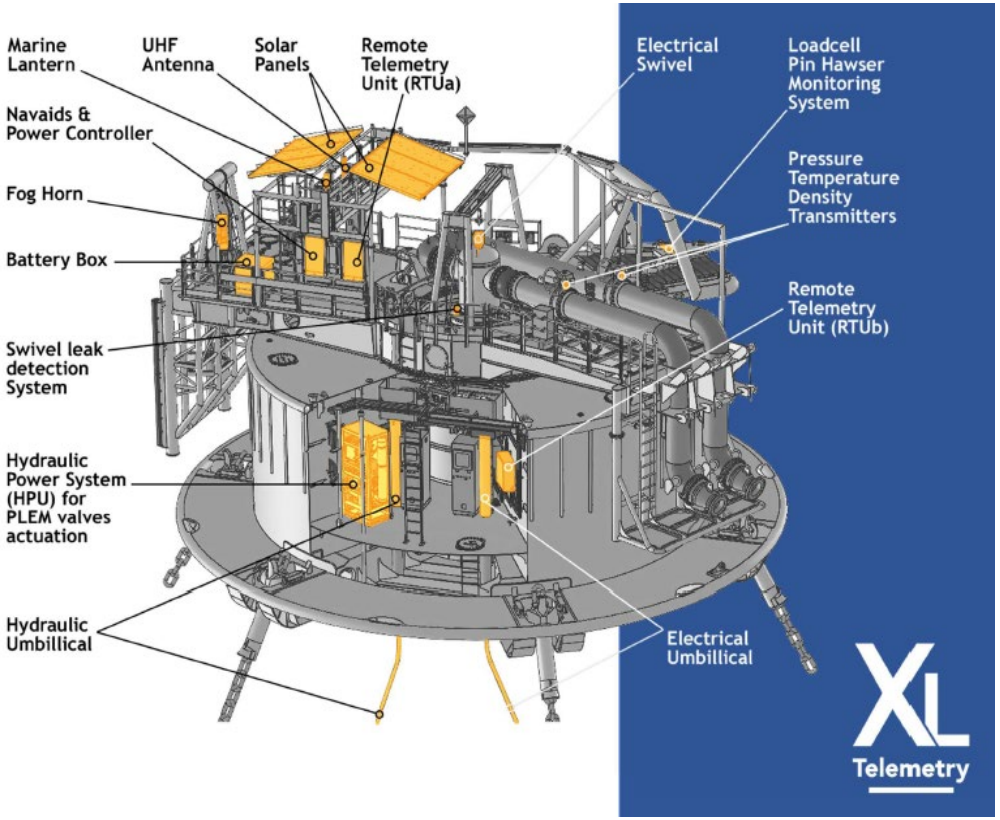
Safety Issue - Control of PLEM ESDV

CALM Case

ESDV controlled from buoy with **high integrity** telemetry & HPU

Functional capabilities of Telemetry XL:

- Remote control of PLEM subsea valves and OPEN/CLOSE status monitoring with process shutdown sequence possible from MTU and PTU
- Product pressure and temperature transmitters to monitor offloading process
- Hawser load monitoring to control tension of the tanker while moored to the buoy
- Swivel leak detection to monitor Product Swivel seals integrity
- Flashing beacon alarms (red, amber) and sounder to alert operator of any event detected by Telemetry equipment
- Fog horn remote activation from PTU to ensure buoy visibility in case of fog
- Marine Lantern healthy status to monitor key navigation aid integrity
- Power system control to monitor electrical system integrity
- Radio system monitoring and transmission diagnostic data
- Subsea valves HPU monitoring



CBM Case

2 options with **lower integrity** level [i.e. more risk of downtime]

1. ***Hydraulic tubing clamped on subsea pipeline***:
   - supply & installation costs to be accounted for
   - longer response time => risk of larger leak / consequence
     Will operational permit be granted? Will insurers cover for this?
   - fail safe system required [risk of downtime] eg damage on clamped tubing
2. ***Dedicated vessel mobilized to control ESDV***:

   will this be realistic or accepted by insurer or for permit ?

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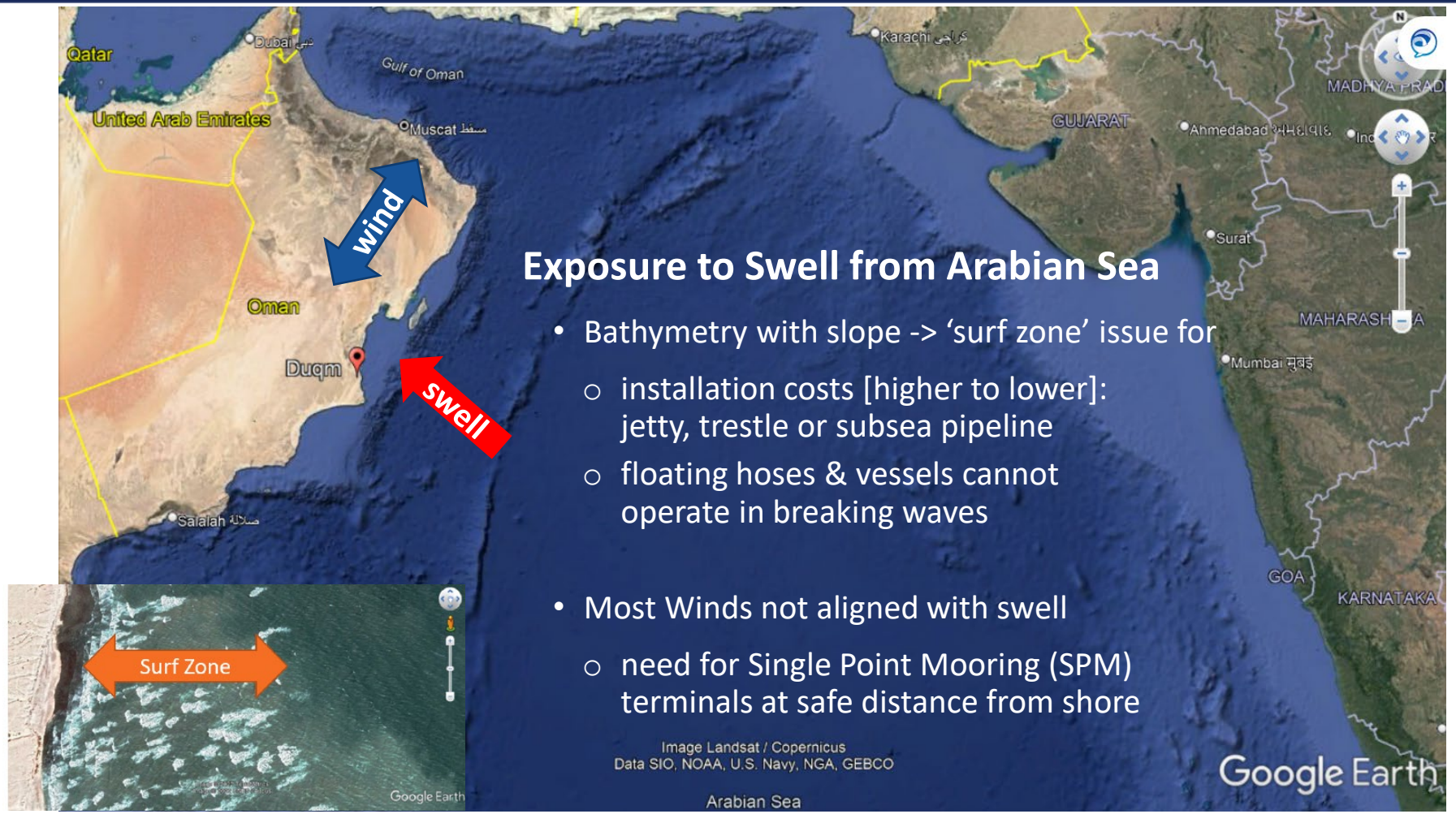
Export Concept Selection Criteria for Oman Case



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CBM vs CALM

CAPEX:

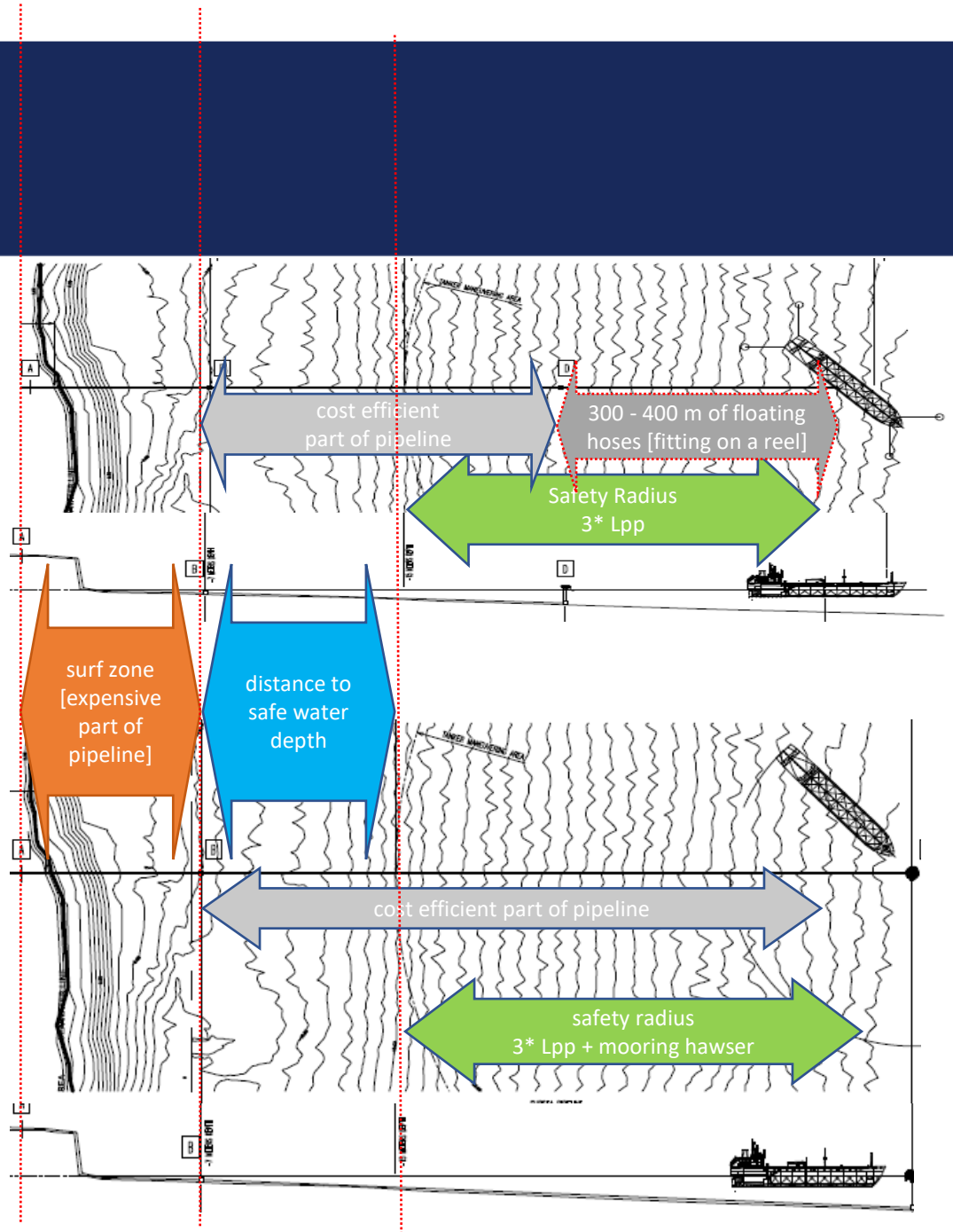
- pipeline cost driven by:
  - **landfall**
  - **surf zone**
- **delta cost is small**

OPEX:

- driven by marine hoses & number of tugs
  - 2 off ASD tugs required for CBM
  - local tug / boat enough for CALM

Uptime in Oman:

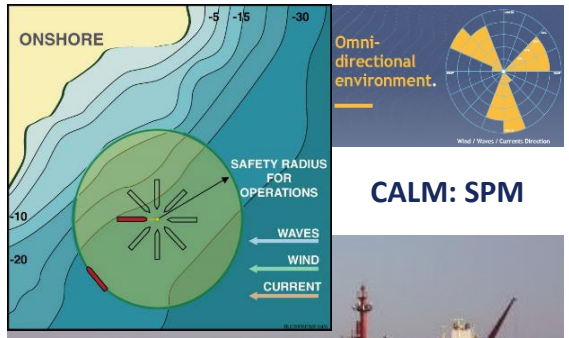
- 100 % for CALM
- downtime for CBM is likely in June-July-August (Khareef season)



CONVENTIONAL BUOY MOORING (CBM)

- Floating buoy used to moor a vessel during fluids transfer
- Transfer of fluids is achieved by a subsea hose connected to a Pipeline End Manifold (PLEM)

CBM: Fixed Heading



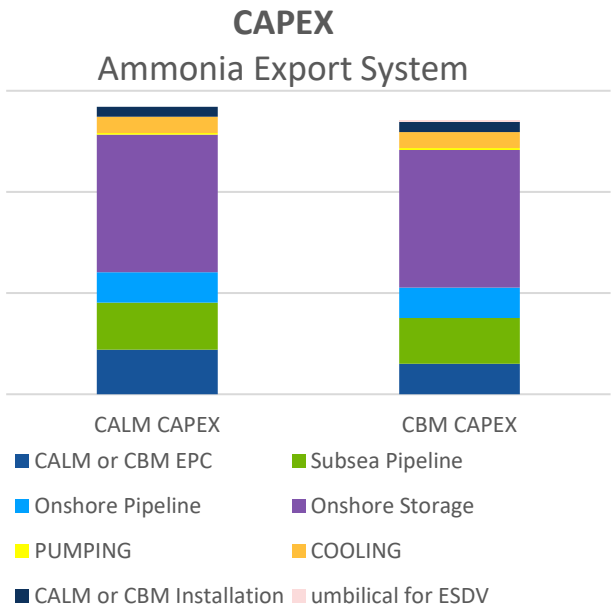
CALM: SPM

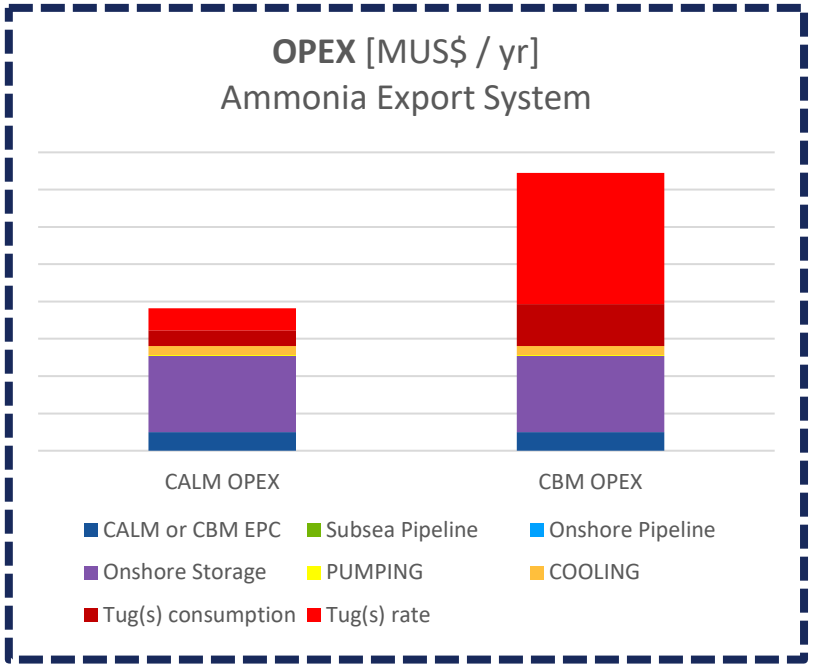
Jetty-less Ammonia Export in Oman - Objectives & Conclusions

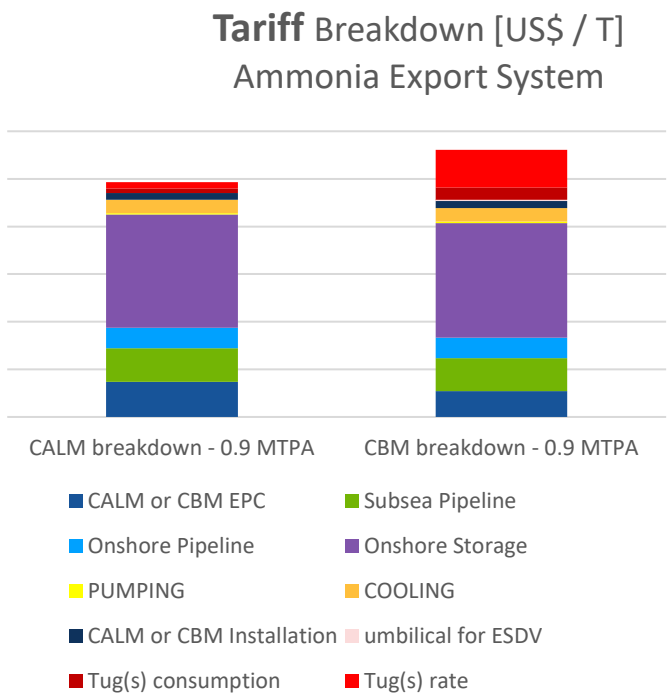
Objectives: preliminary sizing for the '**best jetty-less concept for typical project**'
selection based on '**apple-to-apple**' tariff comparison [safety ⇔ insurers]

Conclusions: for study battery limit from NH^3 production [excluded] to off-taker carriers [excluded],
the 'CALM' is 'best for project' in Oman: best economics ['tariff' in US$ / T of NH^3].

The **lower OPEX** compensates small CAPEX delta [< 5 % of overall CAPEX].







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LPG FSO - Relevant Track Record for Ammonia FSO

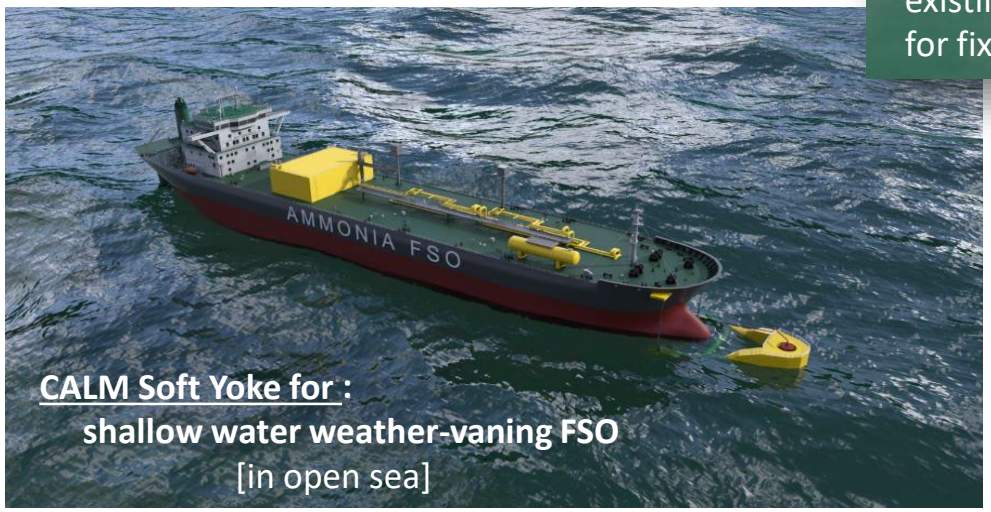
Nkossa II, Congo

Sanha LPG FPSO, Angola

These LPG FSO are in deep water to collect associated gas from oil field development.

Ammonia FSO will be in **shallow waters** (to minimize pipeline length):

- use of CALM Soft Yoke in open waters
- use of SFBM for protected sites (**S**hort **F**ootprint **B**uoy **M**ooring)



CALM Soft Yoke for :
shallow water weather-vaning FSO
[in open sea]

SFBM for :
very shallow water short footprint FSO
[within lee side of existing breakwater allowing for fixed heading]

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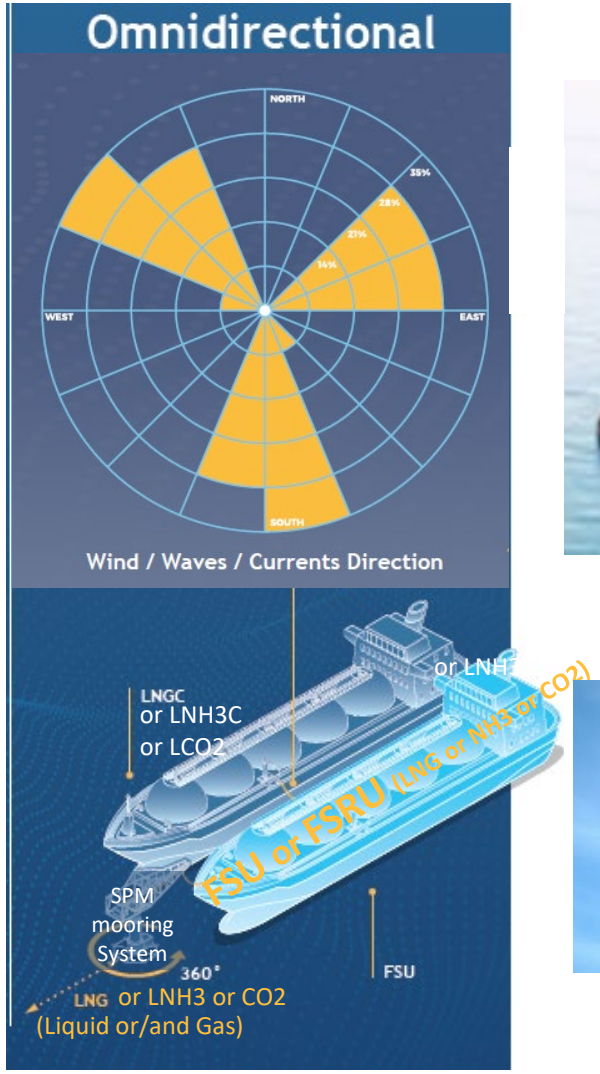
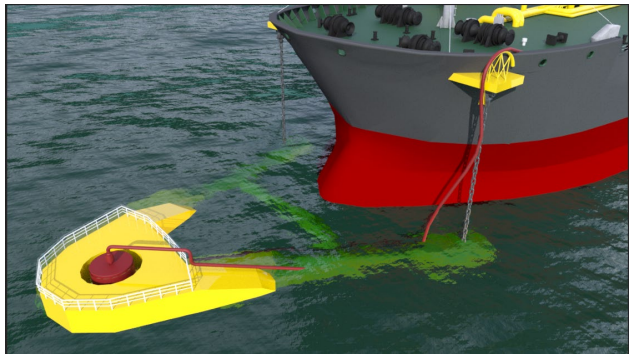
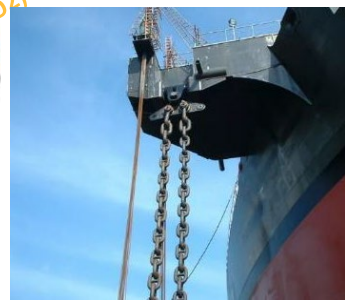
FSU or FSRU ⇔ Permanent Mooring Systems



REFERENCE LIST

UNIT	MOORING SYSTEM SCOPE	FIRST OIL or CONTRACT AWARD (CA)	CLIENT	FIELD	COUNTRY	LAST OIL
FPSO Chi Linh	New Build	1985	Vietsovpetro	White Tiger	Vietnam	-
FSO Licorne Pacifique	New Build	1988	Elf Angola	Palanca	Angola	1992
FSO Chi Lang	New Build	1992	Vietsovpetro	White Tiger	Vietnam	2000
FPSO Ba VI	New Build	1994	Vietsovpetro	Dragon	Vietnam	2008





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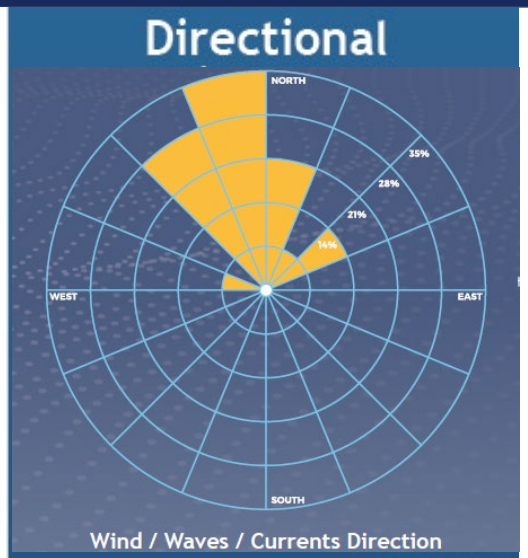
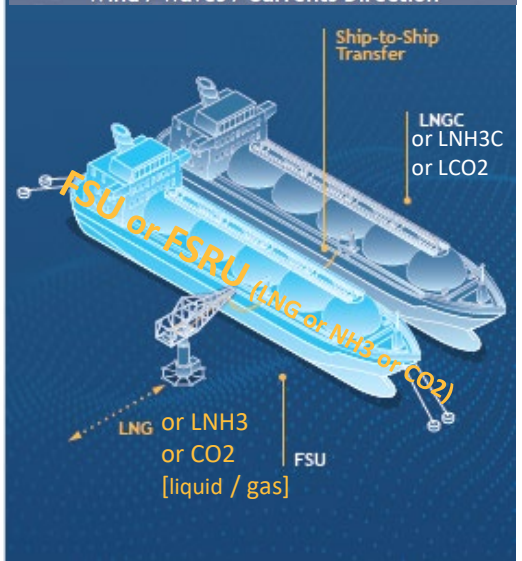
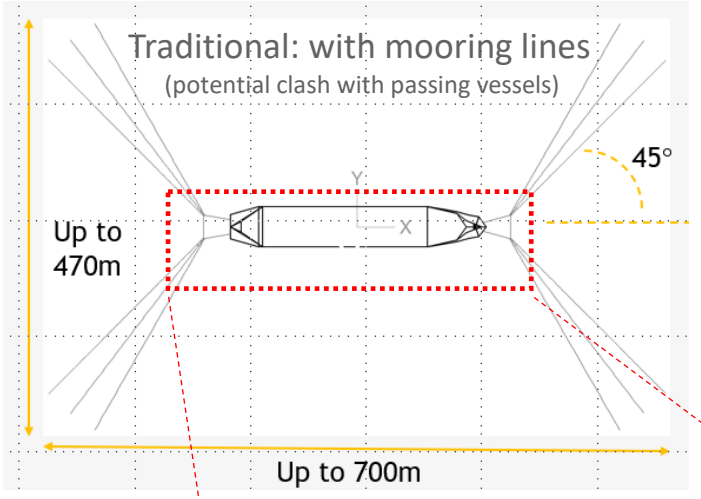
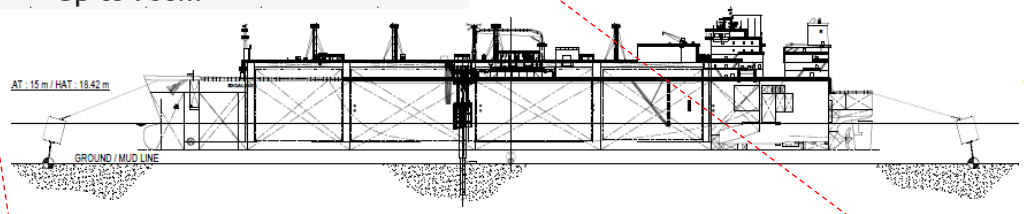
FSO or FSRU - Permanent Mooring Systems

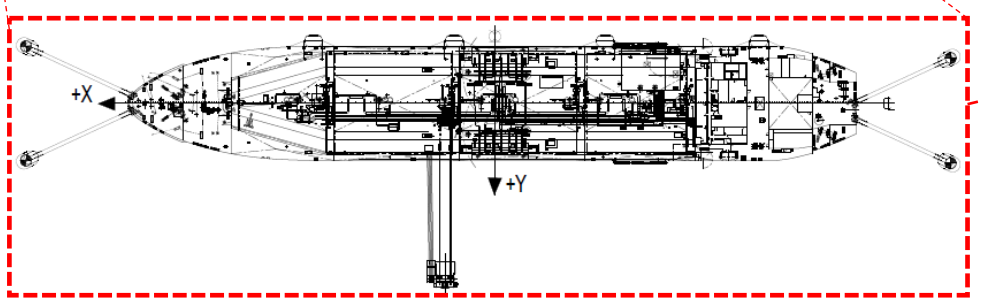




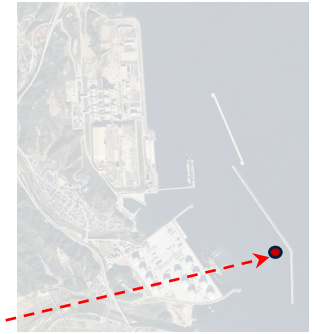




SFBM: Short Footprint Buoy Mooring
(no more clash with passing vessels)



Patent Pending



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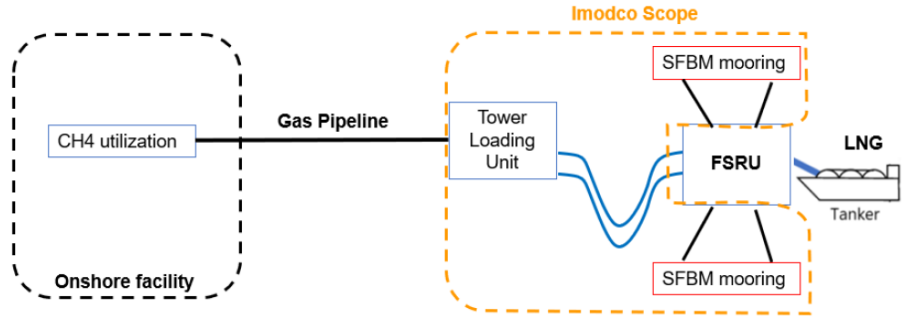
IMODCO Solution for Congested Areas - Reduced Footprint

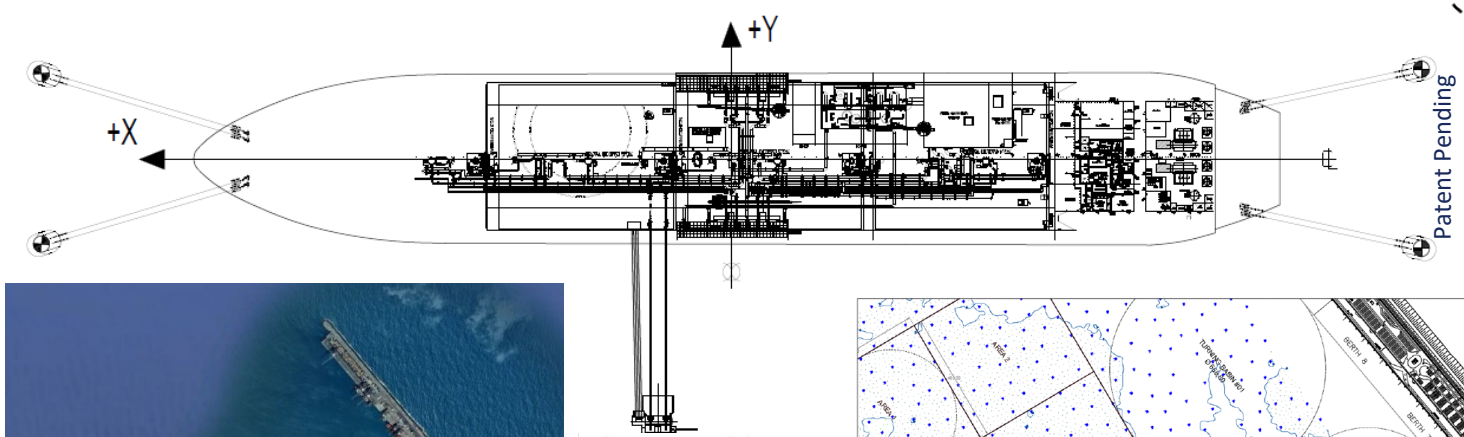
FSRU / FSO moored with a **Short Footprint Buoy Mooring** [SFBM] system

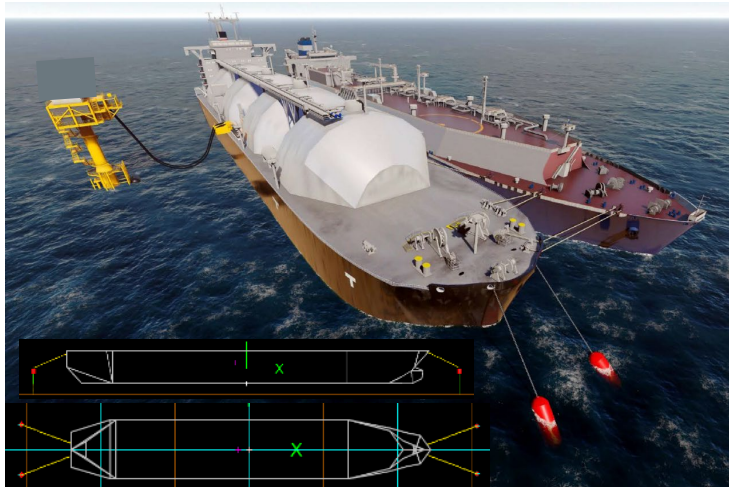
- 4 mooring legs with buoyancy module

IMODCO TLU solution for gas export / import

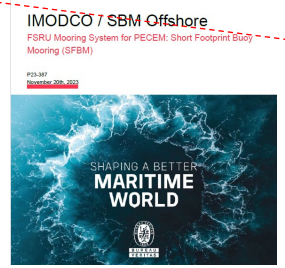
- 2 aerial jumpers for gas export & 4 power cables

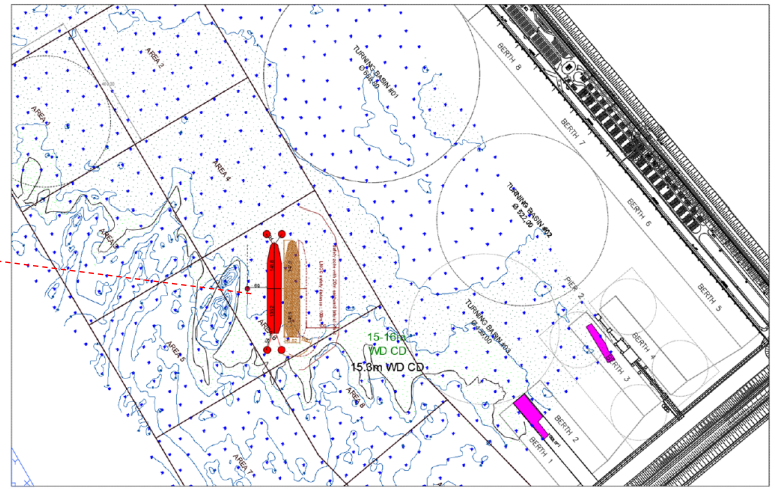






Approval in Principle





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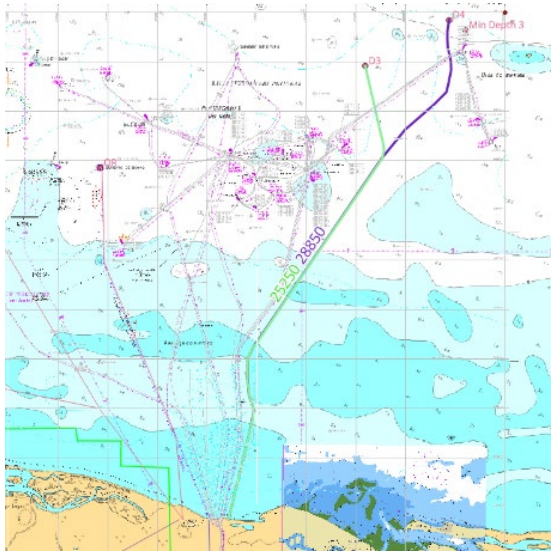
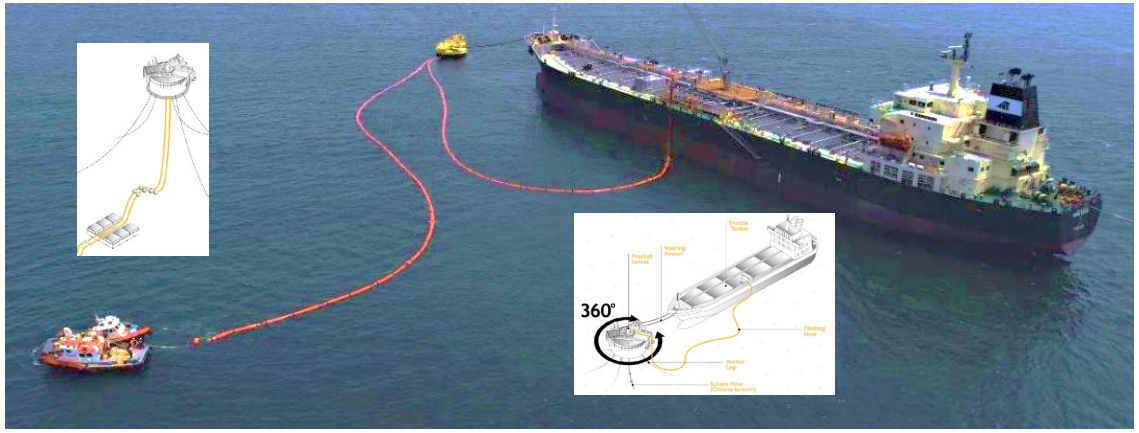
Case Study - Long Pipeline Length [Due to Flat Bathymetry]



	Minimum Water depth for draft clearance [m]				
	min WD [m]	approaching	leaving	resulting min WD [m]	Resulting subsea pipeline [length + 5 km onshore]
FSO	20	12	15	20	29 km [D4 PLEM location]
CALM	20	12	15	20	29 km [D4 PLEM location]
TLU		12	15	15	25 km [D3 PLEM location]

> Need **to compare economics** of **onshore** storage [with CALM] vs **floating** storage [FSO]



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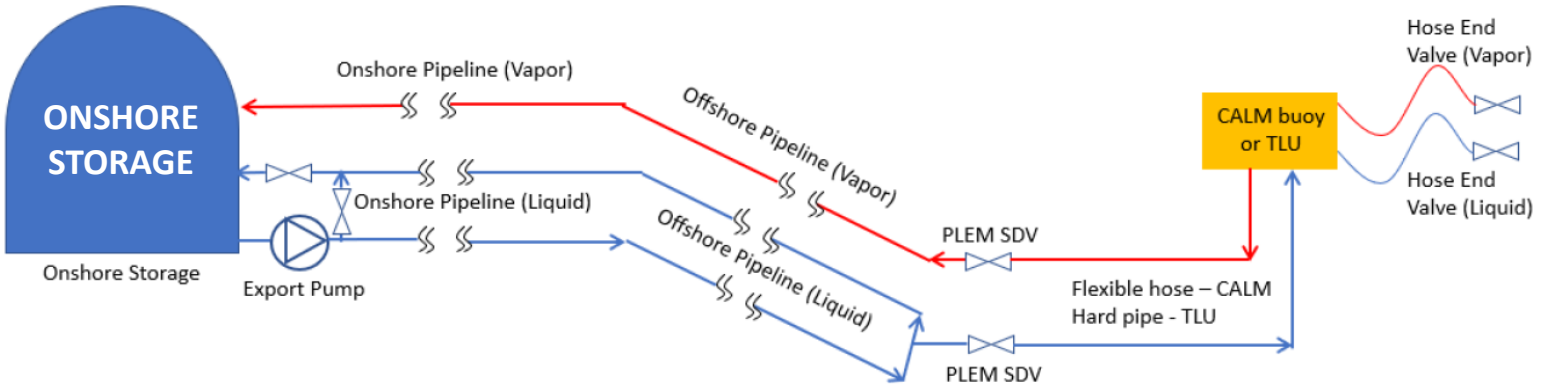
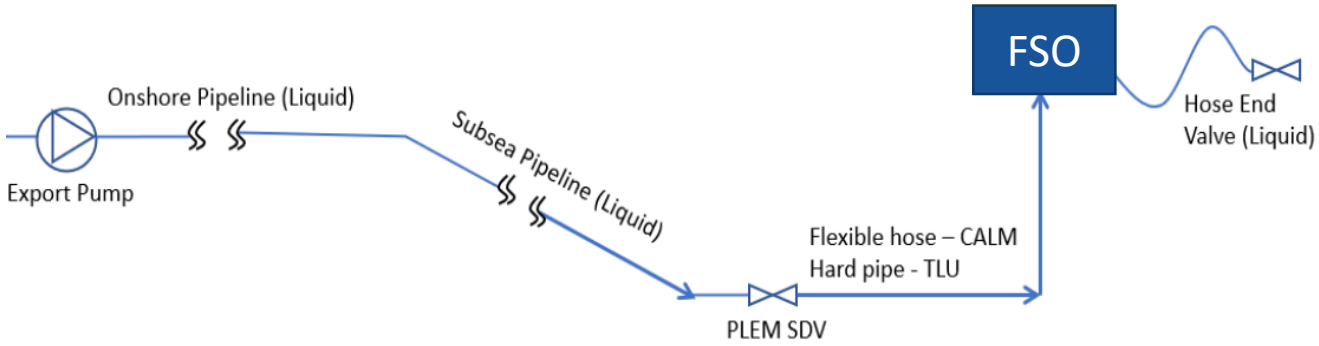
Conceptual Comparison & Battery Limit for NPV Comparison



1,250 T / hr on a 30 kms >> 2 x 18" pipeline loop
~~**expensive**~~ **insulation** ~~+ possibly 10" vapor return~~

55,000 m^3 storage for 38,000 m^3 carriers

Subcooling => no vapor return pipeline



70 T / hr - continuous flow
1 x 8" pipeline **non-insulated**

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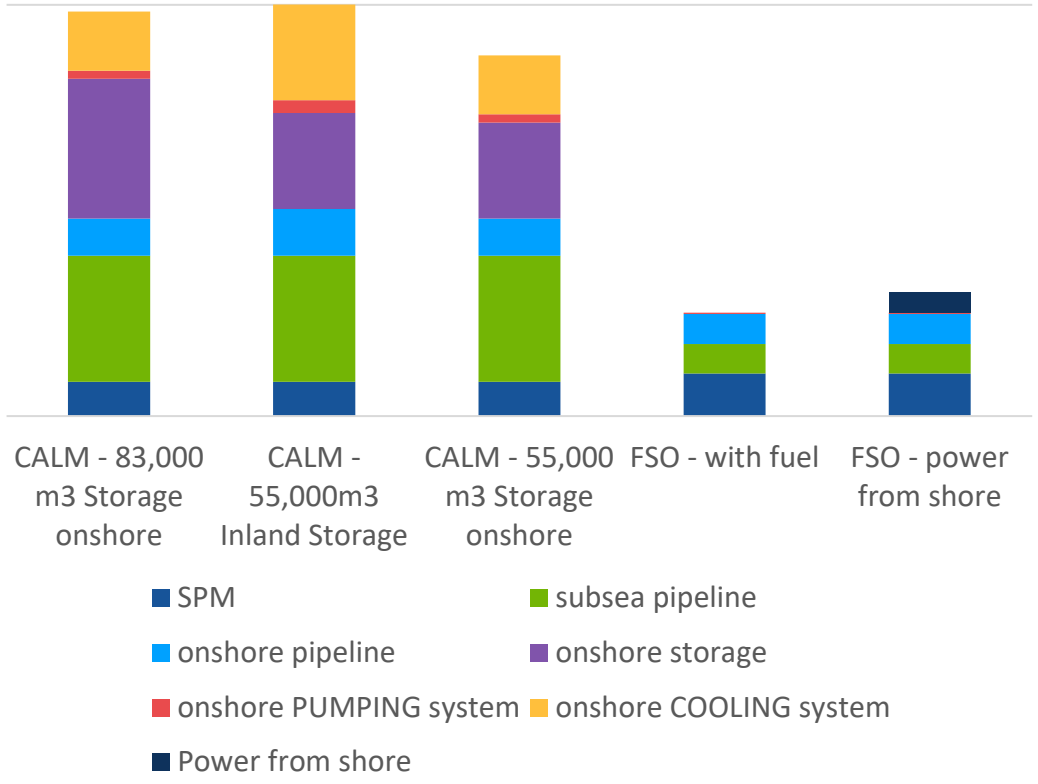
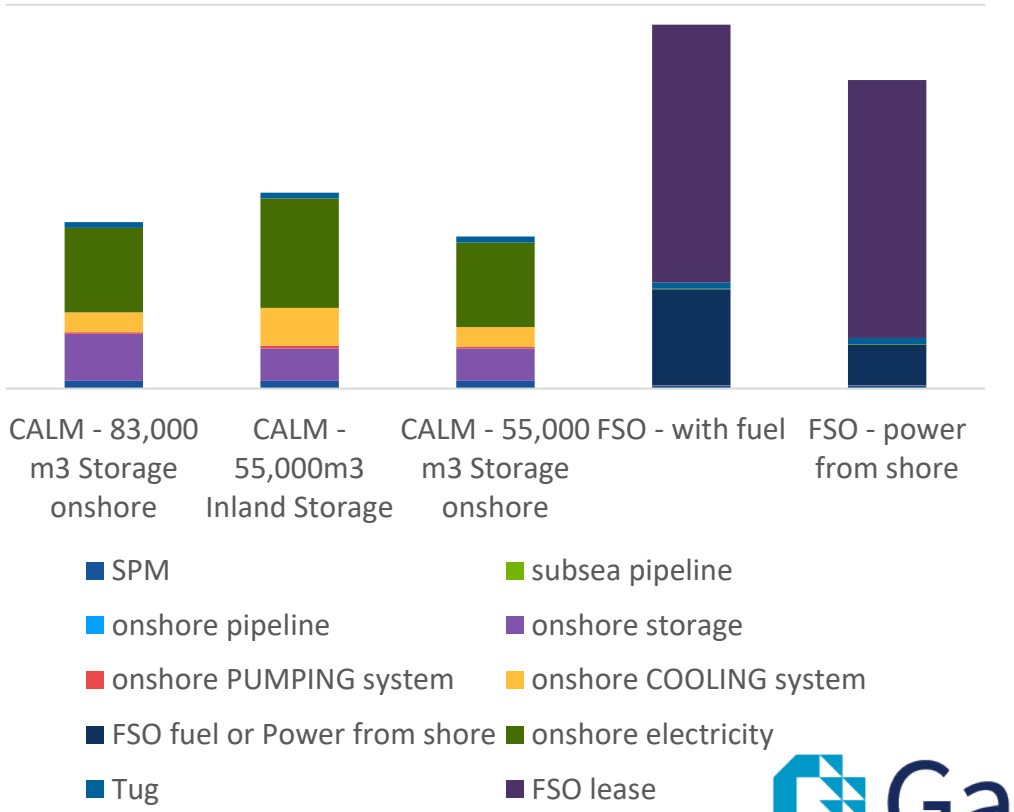
CAPEX & OPEX Comparison

CAPEX (29 km pipeline - 0.6 MTPA)



OPEX (29 km pipeline - 0.6 MTPA)



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CAPEX & OPEX Comparison

CAPEX & OPEX create cost part of cash flow

'**tariff * through put** [MTPA]' creates revenue part of cash flow

IRR [cash flow] is targeted at x %: **tariff is tuned until target IRR is reached**

IRR is closely related to NPV, the net present value function. The rate of return calculated by IRR is the interest rate corresponding to a 0 (zero) net present value.

IRR function in Microsoft Excel.

Description

Returns the internal rate of return for a series of cash flows represented by the numbers in values. These cash flows do not have to be even, as they would be for an annuity. However, the cash flows must occur at regular intervals, such as monthly or annually. The internal rate of return is the interest rate received for an investment consisting of payments (negative values) and income (positive values) that occur at regular periods.

IMPORTANT NOTE:

These tariff estimates are:

- **not accurate enough as absolute value**
- **mainly used for comparing economics**

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29 km Pipeline [Ammonia Export] Concept Comparison Conclusion

CALM:

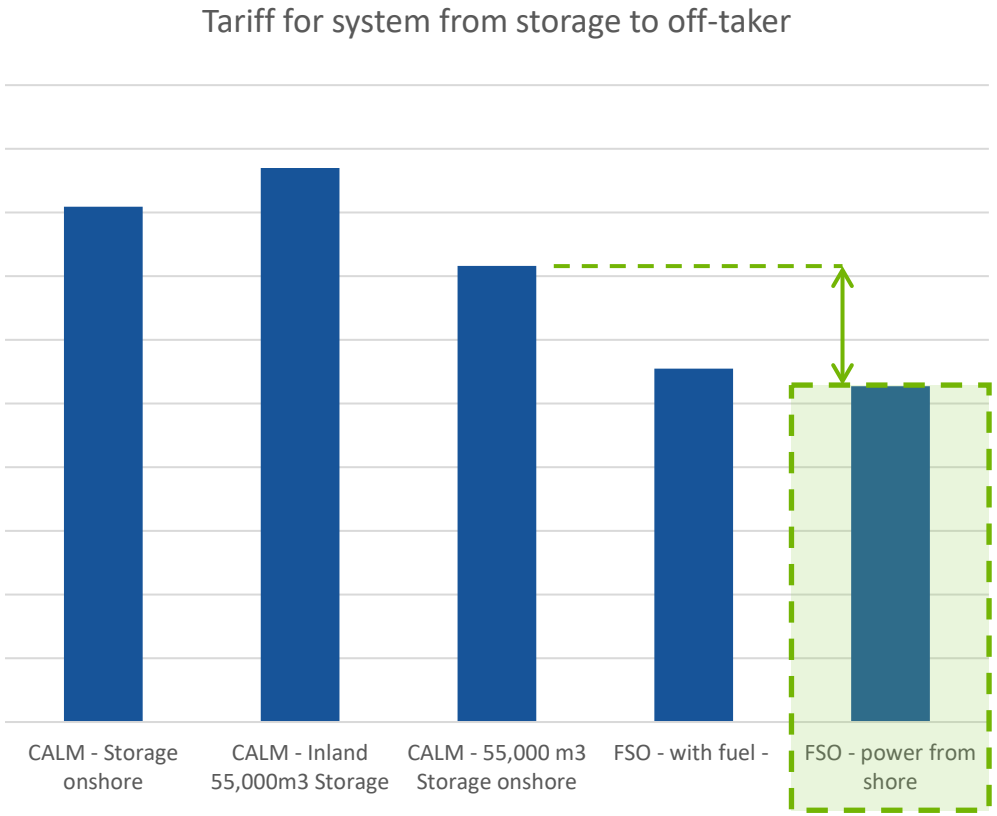
- do not oversize storage: 55,000 m^3 enough
- storage close to shore more cost effective than inland
- 50% increase though put reduce tariff by 1/3

FSO:

- power from shore gives lower tariff & less CO^2
- 50% increase though put reduce tariff by 1/3
- same uptime [tandem offloading is based on 40-year experience in North Sea in high operational sea states]

FSO tariff is lower than CALM by 1/4

Sensitivities illustrate robustness of this conclusion.



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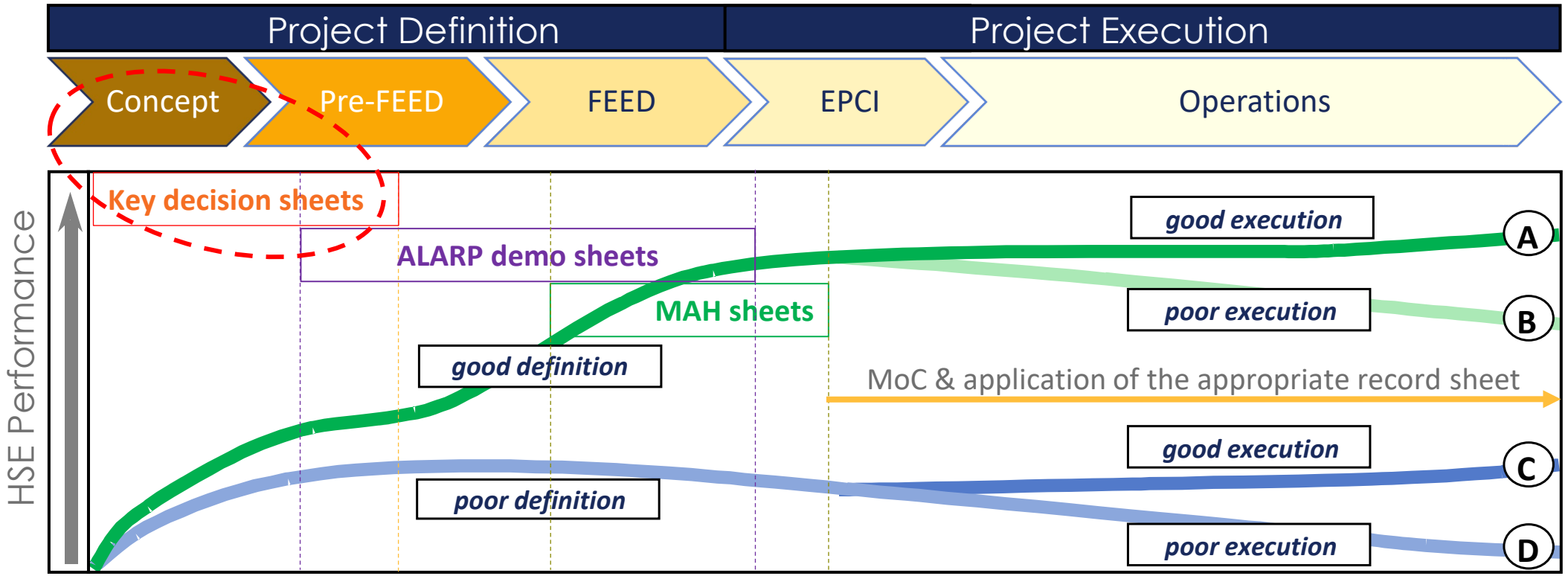
Conclusion: Safety & Cost Efficiency Start at Concept Stage



Safety & Life Cycle Cost Efficiency start at Concept stage

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