Outlook for Ship -to-Ship (STS) Operations to 203 6

A forward-looking assessment of demand, alternative fuels, operational capability and strategic readiness.

James Fisher Fendercare – Outlook for Ship-to-Ship (STS) Operations to 2036, Project

Coastal Energy Internship Programme | *CREST Project Report*

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Project period	Coastal Energy Internship Programme
Report focus	STS demand, fuel transition, equipment, safety, regulation and 2036 readiness
Prepared	2026

Executive summary

This project examines how ship-to-ship (STS) operations may change between the present day and 2036 as shipping responds to decarbonisation policy, changing energy trade, alternative fuels and increasing operational complexity. The central finding is that STS is unlikely simply to disappear as fossil fuels decline. Instead, the market is likely to become more diversified: conventional oil and petroleum transfers will remain important, LNG and other transitional cargoes may create near- to medium-term opportunities, and ammonia, methanol and potentially hydrogen could create new specialist markets if production, regulation and infrastructure develop at sufficient scale.

The evidence also suggests that the strongest strategic response is not to bet on a single fuel. JF Fendercare should maintain its established STS capability while building a modular readiness model: develop competence and equipment for the fuels with the clearest commercial pathway, monitor emerging fuels through pilot projects, strengthen digital and data capability, and preserve the ability to move equipment and personnel between regions. The most significant risks are uncertainty over the future fuel mix, stranded investment, sanctions and trade disruption, local regulatory permissions, weather and sea-state limitations, and the very different toxicity, cryogenic and flammability hazards associated with new cargoes.

A key recommendation is therefore a phased readiness roadmap rather than a single 2036 forecast. The company should use evidence and trigger points to decide when to scale investment. This reduces the risk of over-investing in equipment for a fuel whose adoption is slower than expected, while ensuring that JF Fendercare is prepared when demand becomes commercially significant.

STS Abbreviations:

AI	Artificial Intelligence
BOG	Boil-Off Gas
CO_2	Carbon Dioxide
CREST	Creativity in Science and Technology
ESD	Emergency Shutdown
ETS/EU ETS	Emissions Trading System
FPSO	Floating Production, Storage and Offloading
GHG	Greenhouse Gas/Gases
GIS	Geographic Information System
HAZOP	Hazard And Operability Study
IMO	International Maritime Organization
JFF/JF Fendercare	James Fisher Fendercare
LH_2	Liquid Hydrogen
LNG	Liquefied Natural Gas
LNGC	Liquefied Natural Gas Carrier
MARPOL	International Convention for the Prevention of Pollution from Ships
MASS	Maritime Autonomous Surface Ships
MEPC	Marine Environment Protection Committee
Mt	Million Tonnes
NH_3	Ammonia
N_2O	Nitrous Oxide
OCIMF	Oil Companies International Marine Forum
POAC	Person in Overall Advisory Control
STS	Ship-to-Ship (Transfers)
STSSI	Ship-to-Ship Superintendent
UCL	University College London (Source)
ULCC	Ultra Large Crude Carrier
VLCC	Very Large Crude Carrier
ESG	Environmental, Social, and Governance (Sustainability)

Glossary:

Alternative Fuels
Fuels used as alternatives to conventional fossil fuels, including LNG, ammonia, methanol, biofuels and hydrogen.

Ammonia (NH_3)
A chemical compound that can be used as a future marine fuel. It is highly toxic and requires specialist handling, equipment and safety procedures during STS operations.

Biofuels
Fuels produced from biological materials such as plants, waste oils or organic matter that may help reduce lifecycle greenhouse gas emissions.

Boil-off Gas (BOG)
Gas created when a cryogenic liquid such as LNG or liquid hydrogen warms and evaporates during storage or transfer.

Bunkering
The process of supplying fuel to a vessel for its own consumption rather than transferring cargo between ships.

Cargo Compatibility
The suitability of equipment, materials and systems for safely handling a specific cargo or fuel.

Coastal State
A country that exercises authority over activities taking place within its territorial waters or exclusive economic zone.

Cryogenic
Extremely low temperatures used to store and transport gases such as LNG and liquid hydrogen in liquid form.

Decarbonisation
The process of reducing greenhouse gas emissions from shipping and other industries.

Digital Twin
A virtual model of a real operation, vessel or system used to support planning, analysis and decision-making.

Dry-Break Coupling
A specialised connection designed to minimise product release when hoses are connected or disconnected.

Emergency Shutdown (ESD)
A safety system that rapidly stops cargo transfer during dangerous or abnormal operating conditions.

Energy Security
The availability of reliable and affordable energy supplies for a country or region.

EU ETS (European Union Emissions Trading System)
A market-based mechanism that places a cost on greenhouse gas emissions from covered sectors, including maritime transport.

E-Methanol
Methanol produced using renewable electricity and low-carbon sources of carbon dioxide.

Fender
A protective structure placed between vessels during STS operations to absorb impact and prevent hull damage.

Floating Production, Storage and Offloading (FPSO)
An offshore facility that produces, processes, stores and transfers oil or gas.

Floating Storage
The use of vessels to temporarily store cargo before it is delivered to its destination.

Fuel Corridor
A shipping route or region where a specific alternative fuel is available and supported by infrastructure.

GHG (Greenhouse Gas)
A gas that contributes to global warming, such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

HAZOP (Hazard and Operability Study)
A structured process used to identify hazards and operational risks within a system or operation.

Hydrogen (H_2)
A potential zero-carbon fuel that presents significant storage, transfer and infrastructure challenges, especially as a cryogenic liquid.

Infrastructure
The facilities, equipment and systems needed to support fuel production, storage, transport and transfer.

Lightering
An STS operation in which cargo is transferred from a larger vessel to a smaller one, often to reduce the vessel's draft before entering port.

Lifecycle Emissions
Total greenhouse gas emissions produced throughout the entire production, transport and use of a fuel.

Liquefied Natural Gas (LNG)
Natural gas cooled to approximately -162°C so it can be transported and stored as a liquid.

Liquid Hydrogen (LH_2)
Hydrogen stored as a liquid at approximately -253°C, requiring very specialised cryogenic systems.

MARPOL
The International Convention for the Prevention of Pollution from Ships, established by the IMO.

Methane Slip
The release of unburned methane into the atmosphere from LNG-fuelled engines or systems.

Methanol (CH_3OH)
A liquid fuel that is easier to store than LNG but presents flammability and toxicity hazards.

Modular Equipment
Equipment designed to be adapted or reconfigured for different cargoes and operational requirements.

Net-Zero Emissions
A state in which greenhouse gas emissions released are balanced by emissions removed or prevented.

Offshore Operation
A marine activity conducted at sea rather than within a port or harbour.

Operational Window
The period during which environmental and safety conditions allow an operation to proceed safely.

Person in Overall Advisory Control (POAC)
The qualified individual responsible for advising and coordinating an STS operation.

Pilot Operation
A limited-scale trial used to test new procedures, equipment or fuels before full commercial deployment.

Port Authority
An organisation responsible for managing and regulating activities within a port.

Predictive Weather Tools
Digital systems used to forecast environmental conditions and support operational decision-making.

Regasification
The process of converting LNG from a liquid back into a gaseous state for use or distribution.

Risk Assessment
A systematic process used to identify hazards, evaluate risks and determine suitable control measures.

Sanctions
Legal restrictions imposed by governments or international organisations on countries, companies or individuals.

Scenario Planning
A strategic technique that evaluates multiple possible future developments rather than relying on a single forecast.

Ship-to-Ship Transfer (STS)
The transfer of cargo between two vessels while alongside each other, either at sea or within a designated location.

Shadow Fleet
A term commonly used for vessels operating with limited transparency, often linked to sanctions circumvention or regulatory avoidance, often illegal.

Spot Trading
The buying or selling of commodities for immediate delivery rather than under long-term contracts.

Stranded Asset
Equipment, infrastructure or investments that lose value because demand or regulations change.

STS Superintendent (STSSI)
A qualified STS specialist, often acting as the POAC, responsible for overseeing transfer operations.

Transfer Hose
A specialised hose used to safely transfer liquid or gaseous cargoes between vessels.

Utilisation Rate
The percentage of time equipment or assets are actively used compared with their total availability.

Vapour Cloud
A cloud of gas released from a liquid fuel that may create flammability or toxicity hazards.

VLCC (Very Large Crude Carrier)
A large oil tanker typically carrying between 200,000 and 320,000 deadweight tonnes of cargo.

ULCC (Ultra Large Crude Carrier)
One of the largest classes of oil tanker, generally exceeding 320,000 deadweight tonnes.

Weather Window
A forecasted period of suitable environmental conditions during which a marine operation can safely proceed.

Contents:

1. Project Planning and Aim

1.1 Project context

Ship-to-ship transfer (STS) is the controlled movement of cargo between two vessels, normally while they are alongside each other at sea or in a designated port or offshore location. It is an important logistical capability because it allows cargoes to be transferred without requiring both vessels to berth at the same terminal. The method can support cargo redistribution, lightering, trading flexibility, floating storage and regasification projects, and the optimisation of shipping schedules. STS is conducted for several key reasons such as:

•Draft and size restrictions: as large vessels such as VLCCs or ULCCs carry so much cargo they sit too deep into the water to enter most ports

•Cost efficiency and speed: as bypassing port terminals can avoid steep berthing fees and long wait times

•Cargo flexibility: the ability to split a large cargo load and distribute it to several regional destinations simultaneously

•Missing infrastructure: as STS can enable the delivery of energy resources such as ammonia or LNG to regions that lack the necessary fixed import or receiving terminals.

The purpose of this project is not to predict a single certain future. Instead, it is to investigate the factors that could change STS demand and then convert those findings into a practical readiness roadmap for JF Fendercare. This distinction is important because the fuel transition is uncertain: different fuels may develop at different speeds, regional energy systems will not change uniformly, and policy, economics and geopolitics can alter trade routes quickly.

1.2 Aim

To assess how STS demand, operating locations, equipment requirements, safety systems, training and strategic priorities may change to 2036 as global shipping transitions towards lower-carbon and alternative fuels, and to develop a practical, evidence-based readiness roadmap for JF Fendercare.

1.3 Research questions

- How might global shipping fuel use change over the next decade?
- How could these changes affect demand and supply for STS transfers?
- What changes occur when cargoes shift from conventional oil products towards LNG, ammonia, methanol, biofuels or hydrogen?
- How might STS transfer equipment, safety systems and crew training need to change?
- What regulatory, insurance, liability and sanctions factors could influence STS operations?
- Where is STS growth or decline most likely based on trade routes, energy flows and operational conditions?
- How should JF Fendercare prepare for multiple possible futures without over-investing in technologies that may not reach commercial scale?

1.4 Project objectives

1. Review authoritative evidence on maritime decarbonisation, fuel regulation and alternative-fuel development.
2. Compare the physical and safety characteristics relevant to STS transfers of oil, LNG, ammonia, methanol and hydrogen.

3. Assess how fuel transition could alter equipment, personnel competency, risk management and operating procedures.
4. Analyse market drivers including trade flows, LNG demand, sanctions, energy security, infrastructure and port development.
5. Identify regions and operating conditions where STS demand may grow, remain resilient or decline.
6. Develop a phased 2036 readiness roadmap using decision points rather than relying on one fixed forecast.
7. Evaluate the limitations and uncertainty of the research and identify how the project could be improved with additional operational data.

1.5 Project plan and time organisation

The project was divided into five connected stages. This structure follows the CREST guidance by making the work manageable, recording evidence systematically and allowing conclusions to be tested against the original research questions.

Stage	Main activity	Output	CREST evidence
Planning	Define aim, research questions, scope, risks and timetable	Project plan and research framework	Clear aim; smaller objectives; time management
Research	Collect primary company information and secondary evidence	Literature review and evidence log	Background research; sources and materials
Design & development	Create comparison framework and scenario-based roadmap	Fuel matrix, risk framework and readiness roadmap	Creative approach; sensible decisions
Analysis	Test evidence against demand, supply, operational and regulatory factors	Findings and strategic recommendations	Logical conclusions; problem solving
Conclusion & reflection	Evaluate confidence, limitations and lessons learned	Conclusion, reflection and improvement plan	Learning; implications; what would change

1.6 Materials and people required

- Publicly available reports and regulatory information from IMO and the European Commission.
- JF Fendercare company information and published technical material.
- Academic and industry literature on maritime fuels, safety and shipping transition.
- Market forecasts and trade-flow information treated cautiously where methodology is commercial or opaque.
- Discussions with JF Fendercare market experts and internship mentors, where available, to test whether desk research reflects operational reality.

- Word-processing, spreadsheet and presentation software for organising evidence, comparing fuels and communicating findings.

2. Methodology and Research Design

I used a mixed desk-research approach. First, I established the regulatory and scientific background using primary sources, particularly IMO and European Commission material. I then used JF Fendercare's own published information to understand the company's existing capabilities and strategic position. Academic research was used to explore alternative-fuel risks and stranded-asset uncertainty. Finally, market and industry sources were used to identify commercial trends and forecasts.

I deliberately separated evidence into three levels:
(1) established facts, such as current regulation or documented company capability;
(2) forecasts, such as projected LNG bunkering demand; and
(3) my own scenario-based conclusions about 2036. This prevents a commercial forecast from being presented as if it were a guaranteed fact.

2.1 Evidence quality and source hierarchy

Evidence type	Examples	How used
Primary / regulatory	IMO, European Commission	Used for legal and policy claims
Company primary sources	JF Fendercare / James Fisher	Used for current capabilities and company-specific evidence
Academic research	UCL, peer-reviewed literature	Used for technical and transition-risk analysis
Industry forecasts	Shell, market reports	Used as indicators, not certainties
Secondary media	Trade press	Used to identify case studies and corroborate events

3. Literature Review and Background Research

The literature reviewed for this project indicates that the maritime energy transition is not a simple replacement of one fuel with another. It is a system-wide change involving vessel design, fuel production, bunkering infrastructure, ports, safety regulation, crew competency, insurance and global trade.

The IMO's 2023 GHG Strategy established a direction of travel towards net-zero GHG emissions from international shipping close to 2050 and called for increased uptake of zero- and near-zero-emission fuels by 2030. In April 2025, IMO members approved the draft Net-Zero Framework containing a goal-based marine fuel standard and a global GHG pricing mechanism. However, the formal adoption process was adjourned in October 2025, so the exact regulatory timetable remains uncertain. This uncertainty is itself a relevant finding: businesses planning investment to 2036 need to be able to respond to regulation that may evolve rather than assuming every proposal becomes law on schedule. [1][2][3]

JF Fendercare's published material provides an important company-specific perspective. The company reports substantial experience in conventional STS and LNG operations and has invested in specialist LNG STS transfer systems. Its 2024 LNG discussion also describes a market moving from predominantly fixed, long-term LNG arrangements towards more dynamic and short-term trading, increasing the value of flexible STS capability. This supports the idea that STS can be a tool for commercial optimisation as well as a response to physical logistics. [4][5]

The literature on stranded assets adds another dimension. UCL research identifies risks to vessels and infrastructure if fossil-fuel demand declines faster than expected, while also highlighting the uncertainty created by tighter GHG regulation. For JF Fendercare, the equivalent strategic risk is that highly specialised equipment could become under-utilised if a predicted fuel market fails to scale. This supports the recommendation for modular investment, shared equipment pools and staged capability development rather than a single large bet on one alternative fuel. [6]

4. Global Shipping Decarbonisation and Fuel Outlook

4.1 How might global shipping fuel use change?

My assessment is that the next decade will be characterised by fuel diversification rather than one universal replacement fuel. Conventional oil-based fuels will remain significant because the existing fleet is large and ships have long operating lives. At the same time, regulatory pressure and new-build decisions will increase the use of lower-carbon options.

LNG is likely to remain commercially relevant through the 2030s, but it should be treated as a transition fuel rather than automatically classified as zero-emission. LNG can reduce some local air pollutants and, depending on engine technology and supply chain, can reduce GHG intensity compared with conventional fuels. However, methane emissions and lifecycle emissions remain important considerations. The commercial case for LNG will therefore depend on regulation, methane control, fuel availability, price and the economics of alternative fuels. Shell's 2026 LNG outlook forecasts LNG bunkering demand could grow seven-fold to 27 million tonnes by 2035. This is a credible signal of potential demand growth, but it is still a forecast rather than a guaranteed outcome. [7]

Ammonia and methanol are likely to become increasingly important areas of development. Their future scale depends on fuel production, vessel availability, port infrastructure, cost and lifecycle emissions. Green ammonia and e-methanol could offer lower lifecycle emissions when produced using low-carbon electricity and appropriate processes, but conventional or fossil-derived production does not automatically deliver the same benefits. Hydrogen has potentially significant long-term value but presents major storage and distribution challenges, particularly if used as cryogenic liquid hydrogen.

4.2 My 2036 fuel -transition scenario

- 2026–2030: Continued dominance of conventional marine fuels, alongside growth in LNG, biofuels and early alternative-fuel projects. Regulatory uncertainty remains significant.
- 2030–2033: Increased availability of methanol and ammonia infrastructure in selected major shipping hubs; LNG remains important where supply and economics support it.
- 2033–2036: More diversified fuel corridors emerge. The market is likely to be regional rather than uniform, with different hubs specialising in different fuels.
- By 2036: STS providers that can safely handle several cargo categories and rapidly mobilise equipment are likely to be better positioned than providers dependent on a single fuel.

5. Alternative Fuels: Scientific and Operational Comparison

The scientific properties of each fuel directly influence STS design. Temperature, pressure, volatility, toxicity, flammability, material compatibility and vapour behaviour determine the appropriate hose, coupling, monitoring, emergency shutdown and crew competency requirements. This is why the transition from oil to alternative fuels is not simply a matter of replacing the cargo inside an existing hose.

Cargo / fuel	Key physical issue	Main hazard	STS implication	Training focus	Strategic outlook
Conventional oil / petroleum	Generally liquid at ambient conditions; properties vary widely	Fire, pollution, vapour exposure	Established hoses, fenders, manifolds and procedures; spill prevention critical	Oil STS procedures, pollution prevention, emergency response	Resilient near term; possible long-term decline in some trades
LNG	Cryogenic liquid, typically around −162°C at atmospheric pressure	Cryogenic injury, flammability, vapour cloud, pressure effects	Specialist cryogenic transfer systems, cooldown, emergency shutdown and dry-break/quick-disconnect systems	Cryogenic handling, gas detection, ESD and emergency response	Potential strong transitional market; high equipment specialisation
Ammonia	Liquefied gas; toxic and corrosive; commonly transported under pressure or refrigeration	Toxic exposure, corrosivity, environmental harm	Specialist compatible materials, containment, gas detection, emergency planning and controlled transfer	Ammonia hazards, respiratory protection, HAZOP/risk assessment and emergency response	Potential major future fuel; infrastructure and safety standards still developing
Methanol	Liquid fuel with high volatility and flammability	Fire, vapour exposure, toxicity	Compatible transfer equipment, vapour control and fire protection	Flammable/toxic liquid handling	Potential growth, especially where e-methanol supply develops

Liquid hydrogen	Extremely cold cryogenic liquid, approximately −253°C	Cryogenic hazard, fire/explosion risk, hydrogen leakage and material effects	Very high technical requirements; specialist insulation, materials, transfer systems and boil-off management	Cryogenic hydrogen operations and emergency response	Longer-term possibility; significant infrastructure and engineering barriers

5.1 Scientific basis: why fuel properties matter

The temperature of a cargo determines the thermal stresses placed on equipment and the need for insulation and controlled cooldown. LNG, for example, is stored at cryogenic temperatures, so introducing it into equipment that is not designed for those conditions can cause rapid contraction and material failure. Transfer systems therefore need controlled preparation and monitoring.

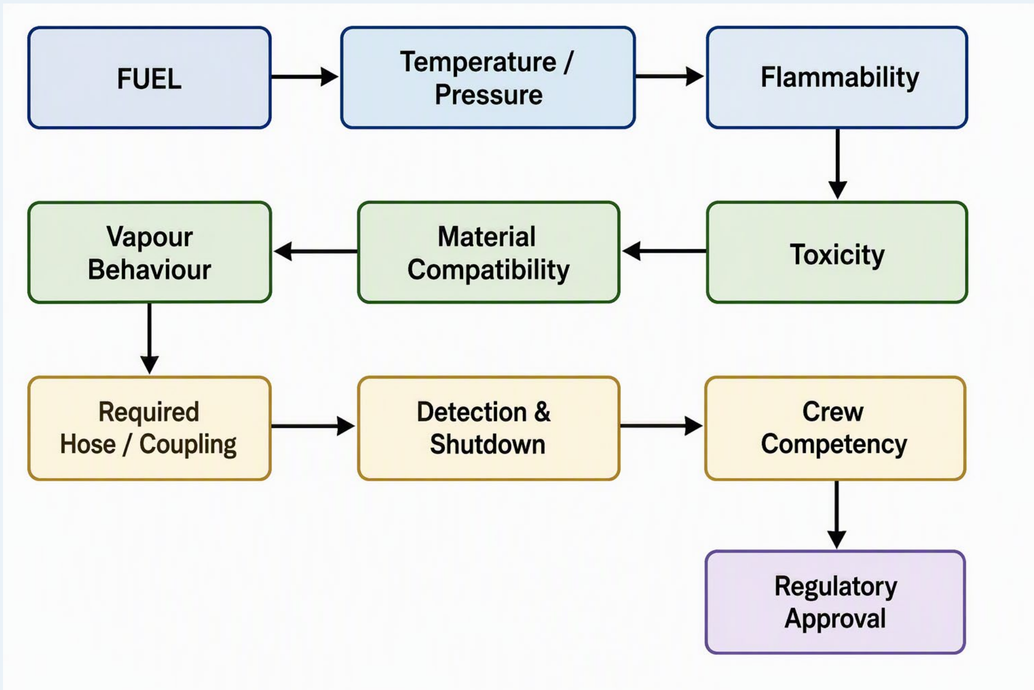
Ammonia creates a different risk profile. The key issue is toxicity: an uncontrolled release can present a serious hazard to people and the surrounding environment. This means gas detection, exclusion zones, emergency response and crew training become particularly important. JF Fendercare's own ammonia whitepaper notes that STS ammonia remains an emerging area, with the need for further infrastructure, policy development, training, risk assessments and HAZOP work. [8]

Methanol is comparatively straightforward to store as a liquid at normal ambient conditions, but it is highly flammable and toxic. This changes the emphasis of risk controls rather than eliminating risk.

Hydrogen presents an even more demanding technical challenge if transported as a cryogenic liquid. Its extremely low boiling point means that the equipment and containment requirements are substantially different from both oil and LNG. For this reason, I consider hydrogen a longer-term readiness issue rather than the most immediate commercial priority for 2026–2030.

5.2 Figure 1 – Fuel-property decision diagram

Framework showing how fuel properties influence STS system requirements.



6. STS Demand, Supply and Market Drivers

6.1 Demand

The effect of the energy transition on STS demand is likely to be mixed. Some conventional oil flows may decline over the long term, but STS demand can remain resilient because STS is driven by more than total fuel consumption. It is also influenced by vessel size, storage constraints, port depth, trading strategies, floating storage, disruption and the location of cargo supply.

The LNG market provides an example. JF Fendercare has described how changing LNG trading patterns have created demand for more flexible and prompt STS operations. This suggests that even when the total volume of a fuel is uncertain, changes in the way that fuel is traded can create additional STS requirements. [5]

6.2 Supply constraints

STS supply is constrained by more than the number of operators. A transfer requires suitable equipment, qualified personnel, vessel compatibility, approved procedures, insurance, regulatory permission and an operating location with acceptable environmental conditions. Alternative fuels increase the number of these constraints because specialist equipment and competence may not be interchangeable between cargoes.

This could create an opportunity for JF Fendercare. A provider with an established global network, experienced POACs and the ability to mobilise specialist equipment can potentially capture work when customers need capabilities that are difficult to build internally. However, the same specialisation creates capital risk: equipment can become stranded if demand does not materialise.

6.3 Market drivers

- Decarbonisation policy: IMO and regional measures increase pressure to reduce GHG intensity.
- EU ETS: creates an economic incentive to reduce covered emissions and may influence voyage and fuel economics.
- Fuel availability: vessels can only adopt alternative fuels where reliable supply exists.
- Trade-flow changes: geopolitical disruption can reroute vessels and change the geography of cargo demand.
- Sanctions: legal restrictions can remove certain trades from legitimate markets and increase compliance risk.
- Fleet renewal: new vessels are more likely to be designed around alternative fuels than the existing fleet.
- Port infrastructure: fuel availability and local approval can determine where STS activity is commercially viable.
- Energy security: countries may prioritise LNG and other fuels to diversify supply sources.
- Weather and geography: safe transfer windows, sea state and port depth influence operational feasibility.
- Commercial trading behaviour: increased spot trading and portfolio optimisation can increase the value of flexible STS capability.

6.4 Geographic outlook

South and Southeast Asia are strong candidates for continued growth because of increasing energy demand and their importance in global LNG and maritime trade. Europe is likely to remain strategically important because of energy security, LNG imports and decarbonisation regulation. The UK and North Sea region may also provide an important testbed for new fuels and specialist operations.

The Cape of Good Hope has become strategically more important when vessels are rerouted around southern Africa because of disruption to Red Sea routes. However, this should not automatically be interpreted as permanent STS growth: route changes may increase voyage distances and alter fuel demand, but the effect on STS depends on where vessels need to refuel, lighter or transfer cargo.

Areas affected by sanctions or conflict present a different picture. Legitimate STS activity can be restricted by sanctions, insurance concerns and local regulations. At the same time, the existence of so-called shadow fleets demonstrates why compliance screening is strategically important. JF Fendercare should avoid any assumption that increased STS activity in a sanctioned trade is automatically an opportunity; it may instead represent significant legal, reputational and insurance exposure.

7. Regulation, Insurance, Liability and Sanctions

7.1 IMO and MARPOL

STS operations are governed by a combination of international conventions, flag-state requirements, port/coastal-state rules and industry guidance. MARPOL Annex I contains requirements relevant to oil STS operations, including planning, procedures and notification requirements. The exact requirements depend on the vessel, cargo and location.

7.2 EU regulation

The EU ETS has applied to maritime transport since 2024. For covered vessels, emissions from voyages between EU ports and emissions within EU ports are covered at 100%, while voyages involving a non-EU port are generally covered at 50%. CO_2 is covered, with methane and nitrous oxide entering the ETS scope from 2026. This creates an economic incentive to reduce emissions, but it is important not to describe the system as a direct tax on every STS transfer. Its impact on STS is indirect as well as direct: it can influence fleet choices, route economics, fuel selection and demand for lower-carbon logistics. [10]

7.3 Insurance and liability

STS operations involve multiple parties and therefore complex insurance liability relationships. Potential exposures include collision, pollution, cargo loss, personal injury, equipment failure, environmental damage and delay. Alternative fuels introduce additional hazards. For LNG, the risk profile includes cryogenic damage and flammable vapour. For ammonia, toxic exposure becomes a major concern. Insurers may therefore require evidence of competent personnel, suitable procedures, certified equipment, emergency planning and robust risk assessment.

A practical implication is that JF Fendercare's competitive advantage should not be based only on owning equipment. Demonstrable competence, documented procedures, incident learning, training and a strong safety culture can become commercial differentiators.

7.4 Sanctions and shadow -fleet risk

Sanctions compliance should be treated as a core commercial and operational control. STS transfers can be used legitimately to optimise cargo logistics, but they can also create compliance risks where cargo ownership, vessel identity, destination or beneficial ownership is unclear. The company should therefore use appropriate sanctions screening and customer due diligence before accepting work. I have not treated sanctions as a simple reason for STS decline: instead, sanctions can redistribute legitimate trade flows while simultaneously increasing compliance risk in particular corridors.

8. Operational Realities: Weather, Ports, Offshore Locations and Permissions

8.1 Weather and sea state

STS is a marine operation, so weather is a fundamental limiting variable. Wind, wave height, swell, current and visibility can affect vessel manoeuvrability, mooring loads and the ability to maintain a safe relative position. The actual operating limits are not universal: they depend on vessel size, fender arrangement, transfer equipment, location and the approved operational procedure. A good approach is to state that each operation has defined environmental limits and that the transfer must be suspended if those limits are exceeded.

8.2 Offshore versus port operations

Offshore STS can provide greater flexibility and avoid some port restrictions, but it exposes operations to weather, swell and vessel-motion risks. Port operations can provide shelter and established infrastructure but may be constrained by draft, manoeuvring space, traffic, berth availability and local permissions.

Lightering is particularly relevant where a large tanker cannot safely enter a shallow port. A smaller vessel can receive part of the cargo offshore, reducing the draft of the larger vessel and allowing it to proceed. This can generate STS demand even where total cargo volumes are unchanged.

8.3 Local permissions

Local permissions can be a major commercial barrier. Coastal states and port authorities may impose requirements based on environmental risk, navigation, emergency response and local employment laws. These rules can differ substantially between countries. A practical readiness model should therefore include a database of approved locations, local agents, regulatory requirements and emergency-response capability rather than assuming that equipment can simply be moved anywhere.

8.4 Operational risk register

Risk	Potential impact	Mitigation	2036 implication
Poor weather / sea state	Collision, mooring or equipment damage	Defined environmental limits, weather monitoring, stop-work authority	Need better forecasting and decision-support tools
Loss of containment	Fire, pollution or toxic exposure	Compatible equipment, ESD, dry-break systems, gas detection, emergency plans	Fuel-specific controls become more important
Wrong fuel/equipment compatibility	Equipment failure or unsafe transfer	Pre-job compatibility checks and documented procedures	Digital compatibility databases could reduce error
Insufficient competency	Human error during complex operations	Training, assessment, POAC competence and continual learning	Specialist alternative-fuel competency will be a differentiator
Regulatory permission delayed	Operational delay and commercial loss	Early approval planning and local partnerships	Need stronger regulatory intelligence
Sanctions / compliance breach	Legal, financial and reputational damage	Screening, due diligence and documented compliance controls	Higher importance as trade patterns become more complex
Stranded equipment	Poor return on investment	Phased investment, modular equipment and scenario planning	Avoid single-fuel dependence

9. Analysis: What Could STS Look Like in 2036?

9.1 Base case – diversified STS

My base-case scenario is that STS remains an important part of global energy logistics in 2036, but the cargo mix becomes more diverse. Oil and petroleum products remain significant, LNG remains a mature specialist market in many regions, and ammonia and methanol develop into more established but geographically concentrated markets. Hydrogen is more likely to remain a specialist or emerging market than to become a universal STS cargo by 2036.

In this scenario, the winning capability is flexibility. JF Fendercare would need to combine established STS competence with specialist fuel capability and strong local regulatory knowledge.

9.2 High-transition scenario

If regulation becomes stricter and alternative-fuel production expands rapidly, demand for conventional oil STS could decline faster. However, STS demand could migrate rather than disappear. New fuel corridors could require specialist transfers, floating storage and redistribution. The company would benefit from early investment in ammonia and methanol competence, while maintaining the ability to serve remaining oil and LNG customers.

9.3 Slow-transition scenario

If alternative fuels remain expensive, infrastructure develops slowly and regulatory implementation is delayed, conventional oil and LNG could remain dominant for longer. Under this scenario, over-investment in specialised alternative-fuel equipment would create stranded-asset risk. A modular strategy would therefore be safer than committing too early to a large fleet of fuel-specific assets.

9.4 Disruption scenario

Geopolitical disruption could create sudden changes in trade routes, energy flows and STS demand. The Red Sea disruption demonstrated that shipping routes can change rapidly. Sanctions and conflict can also remove routes from legitimate trade or create additional compliance burdens. In this scenario, JF Fendercare's global network and ability to mobilise personnel and equipment could be more valuable than having the largest quantity of fixed assets.

9.5 Competitive Outlook to 2036.

JF Fendercare operates in a market that includes established marine service providers, specialist STS operators, LNG transfer specialists and companies expanding into alternative-fuel logistics. Competition is likely to increase as LNG, ammonia and methanol markets develop and new entrants seek opportunities in emerging fuel-transfer services. Some competitors may focus on equipment ownership, local presence or fuel-specific expertise.

However, competition should not be viewed solely in terms of equipment availability. STS operations require a combination of specialist equipment, experienced personnel, safety systems, regulatory knowledge, sanctions compliance and the ability to mobilise resources globally. These requirements create barriers to entry, particularly for alternative-fuel operations where competency, training and risk management are critical.

To remain competitive to 2036, JF Fendercare should focus on capabilities that retain value regardless of which fuel becomes dominant:

- Maintain leadership in conventional oil and LNG STS operations while building competence in ammonia and methanol.
- Develop multi-fuel operational capability rather than focusing on a single alternative fuel pathway.
- Invest in personnel training, competency assurance and fuel-specific safety expertise.
- Expand digital decision-support tools, including weather analysis, operational planning and transfer-risk assessment -keeping up to date with new technology
- Strengthen regulatory intelligence and sanctions-compliance capability to support customers operating in complex regions.
- Continue developing a global mobilisation model that enables rapid deployment of equipment and personnel where demand emerges.
- Pursue pilot projects and strategic partnerships to gain operational experience before making large capital investments.

9.6 Key analytical conclusion

My central finding

Demand may shift between cargoes, regions and operating models. The strategic challenge is therefore to identify which capabilities are durable across multiple scenarios and invest in those first while being flexible to account for any changes/disruptions in the world.

10. Strategic Readiness Roadmap for JF Fendercare

The following roadmap is my proposed response to the evidence. It is deliberately staged. Each phase contains actions that retain value across several possible futures, followed by trigger points that justify more specialised investment.

Period	Priority	Capability	Trigger for next investment	Main risk
2026–2028	Protect core STS capability	Maintain oil/LNG expertise; strengthen data on locations, demand and fuel projects	Confirmed customer demand and approved alternative-fuel projects	Over-investment before demand is proven
2028–2030	Build alternative-fuel competence	Training, HAZOP participation, compatibility studies, pilot	Multiple commercial operations and clear regulatory framework	Training without sufficient operational volume

		operations and partnerships		
2030–2033	Scale selectively	Modular equipment, specialist hoses/couplings, regional capability hubs	Utilisation rates justify additional assets	Fuel-specific assets become stranded
2033–2036	Optimise network	Digital planning, predictive weather tools, remote decision support and multi-fuel mobilisation	Technology proven safe and commercially valuable	Technology risk and cybersecurity

10.1 Digital and AI opportunity

Digital technology is a promising area for STS operations. The conclusion is that digital decision-support is likely to expand, while the extent of autonomous STS remains uncertain.

The IMO adopted a non-mandatory MASS Code in May 2026, with the Code taking effect in July 2026 and work continuing towards a future mandatory framework. This shows that autonomous and remotely operated shipping is moving from research towards regulated development, but it does not prove that fully autonomous STS operations will be routine by 2036 though this may be a possibility. [11][12]

A realistic near-term opportunity is therefore a digital "pre-operation twin": using vessel geometry, weather, currents and historical transfer data to model the planned operation before physical connection. This could support, rather than replace, human decision-making. The system could identify unsuitable weather windows, highlight potential relative-motion issues and improve planning. This is a creative extension of the project because it links operational safety, data analysis and future technology without assuming full autonomy.

10.2 Alternative strategic option: expansion into bunkering

Proposing that JF Fendercare could move away from STS towards LNG and alternative-fuel bunkering. I consider this a plausible option, but not a conclusion that can be justified solely from the evidence collected. The more robust recommendation is to investigate bunkering as an adjacent capability.

STS and bunkering share transferable competencies: marine transfer expertise, specialist hoses and couplings, safety management, fuel knowledge and operational planning. Developing both could diversify revenue while preserving the company's core STS identity. A formal investment decision would require internal analysis of margins, equipment utilisation, customer demand and competitive positioning.

11. Recommendations

Maintain and modernise core STS capability. The energy transition will take decades, and conventional cargoes will not disappear immediately.

1. Treat LNG as a significant near- to medium-term specialist market, while recognising its transition-fuel status and methane-related climate considerations.
2. Build ammonia and methanol capability through staged training, pilot operations and partnerships before committing to large-scale dedicated assets.
3. Treat hydrogen as a long-term monitoring priority unless customer demand and infrastructure develop faster than expected.
4. Create a multi-fuel equipment strategy based on modularity and compatibility, reducing the risk of stranded assets.
5. Develop a formal alternative-fuel competency framework covering fuel properties, emergency response, HAZOP, risk assessment and regulatory requirements.
6. Strengthen regulatory intelligence and local partnerships because permission to operate can be as important as physical equipment.
7. Integrate sanctions and customer due diligence into operational planning, particularly for complex or rapidly changing trade routes.
8. Develop digital decision-support tools that combine weather, vessel characteristics, current, transfer history and operational limits.
9. Investigate LNG and alternative-fuel bunkering as an adjacent market rather than assuming STS and bunkering are mutually exclusive but also potentially invest more into bunkering capabilities.
10. Use trigger-based investment: scale equipment only when demand, regulation, infrastructure and customer commitments reach defined thresholds.

12. Conclusion

This project set out to assess the future of STS operations to 2036 under the pressure of maritime decarbonisation. The evidence does not support a simple conclusion that the transition will either destroy or dramatically expand the STS market. Instead, the most defensible conclusion is that it will change the market's structure.

The conventional oil STS market may gradually face pressure as energy systems decarbonise, but the decline is unlikely to be uniform. Existing fleets, regional energy security and continued oil demand mean conventional operations will remain important for years. At the same time, LNG is creating specialist STS opportunities and flexible trading patterns, while ammonia and methanol could create new markets if infrastructure and regulation develop. Hydrogen has potential but presents greater technical barriers.

For JF Fendercare, the strategic implication is that flexibility should be treated as capability. A company that can move safely between cargo types, locations and regulatory environments is better positioned than one that relies on a single forecast. The recommended strategy is therefore a phased readiness roadmap: protect the core business, develop specialist alternative-fuel competence, invest modularly, monitor demand triggers and build digital capability.

The project also identified a key uncertainty: the future fuel mix cannot be predicted with confidence to 2036. This is why scenario planning is more appropriate than a single forecast. The most valuable investment decisions are those that remain useful across several possible futures.

13. Reflection and Evaluation

13.1 What I learned

The most important lesson I learned is that an engineering and energy-transition problem cannot be analysed using technology alone. Fuel properties affect equipment; equipment affects safety; safety affects training and insurance; regulation affects commercial viability; and geopolitics affects where the cargo moves. The project therefore required me to connect science, engineering, economics and operational decision-making.

I also learned the importance of distinguishing evidence from prediction. A source may report a current fact, a company's expectation or a market forecast. These are not equally certain. For example, Shell's 27 million tonne LNG bunkering forecast is useful evidence of potential market growth, but it should not be presented as a guaranteed future volume. Similarly, the IMO's Net-Zero Framework is a major policy signal, but its formal adoption timetable has changed. This improved my ability to evaluate sources critically rather than simply collecting statistics.

13.2 How confident am I?

I am most confident in conclusions based on established physical properties, current regulation and documented company capabilities. I am less confident in precise 2036 forecasts because the variables are highly uncertain. The greatest uncertainties are the speed of alternative-fuel adoption, the final form of international regulation, fuel production costs, geopolitical disruption and the rate at which ports develop infrastructure.

My confidence is therefore highest in the direction of change-greater fuel diversification and increased safety complexity-and lower in predicting the exact size of each future STS market.

13.3 Problems identified and overcome

- The initial research contained forecasts presented too confidently. I corrected this by separating facts, forecasts and scenarios.
- Some regulatory claims were over-generalised. I replaced universal statements with jurisdiction-specific wording and prioritised primary regulatory sources.
- The project initially treated decarbonisation as a direct decline in STS. I corrected this by considering trading behaviour, lightering, floating storage and new alternative-fuel cargoes.
- The original proposal for AI digital twins was highly speculative. I set it as a potential decision-support technology and clearly labelled it as a future possibility.
- The number of possible alternative fuels created scope creep. I prioritised oil, LNG, ammonia, methanol and hydrogen because they illustrate the main differences in temperature, toxicity, flammability and infrastructure.

13.4 What I would change if I repeated the project

1. I would obtain more internal operational data from JF Fendercare, particularly historic STS volumes by cargo type and location, equipment utilisation and the commercial reasons why customers choose STS.
2. I would interview a larger number of internal experts across operations, commercial, HSE, equipment and regulatory functions.

3. I would build a quantitative scenario model using variables such as fuel adoption, STS frequency, regional trade flows and equipment utilisation.
4. I would develop GIS maps showing current STS locations alongside major LNG, ammonia and methanol production and bunkering hubs.
5. I would perform a more detailed total-cost-of-ownership analysis comparing dedicated equipment with modular equipment pools.
6. I would include a more formal decision tree showing exactly which evidence would trigger each investment stage in the readiness roadmap.

14. References and Source Evaluation

The following sources were used as the core evidence base. The source list distinguishes primary regulatory/company sources from secondary market information. Access dates should be added immediately before final submission if required by the host organisation or CREST.

[1] International Maritime Organization – Revised GHG reduction strategy for global shipping adopted
https://www.imo.org/en/mediacentre/pressbriefings/pages/revised-ghg-reduction-strategy-for-global-shipping-adopted-.aspx

Primary regulatory source. Supports the 2023 IMO GHG Strategy and net-zero ambition.

[2] International Maritime Organization – IMO approves net-zero regulations for global shipping
https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-approves-netzero-regulations.aspx

Primary regulatory source. Supports the April 2025 approval of the draft Net-Zero Framework.

[3] International Maritime Organization – IMO Net-Zero Framework FAQs / MEPC process
https://www.imo.org/en/mediacentre/hottopics/pages/faqs-the-imo-net-zero-framework.aspx

Primary regulatory source. Used to avoid presenting the framework as already fully in force.

[4] James Fisher Fendercare – The future of LNG ship-to-ship transfers
https://www.james-fisher.com/news-and-insights/news/discussing-the-future-of-lng-sts-with-james-fisher-fendercare/

Primary company source. Supports current LNG STS capability, investment and changing LNG trading patterns.

[5] James Fisher Fendercare – LNG equipment rental and maintenance
https://www.james-fisher.com/divisions/maritime-transport/ship-to-ship/lng-equipment-rental-and-maintenance/

Primary company source. Supports specialist LNG equipment and operational support.

[6] UCL Bartlett – Supply-side and demand-side stranded asset risks in shipping
https://www.ucl.ac.uk/bartlett/publications/2025/jan/supply-side-and-demand-side-stranded-asset-risks-shipping

Academic/institutional research. Used for transition and stranded-asset risk.

[7] Shell – LNG Outlook 2026
https://www.shell.com/news-and-insights/newsroom/news-and-media-releases/2026/lng-outlook-2026.html

Industry primary source. Supports the 27 million tonne LNG bunkering forecast for 2035; treated as a forecast, not a certainty.

[8] James Fisher Fendercare – Ammonia whitepaper
https://www.james-fisher.com/media/2bqfqy23/jf-fendercare_ammonia-whitepaper_nov2024-final-web-individual-pages.pdf

Primary company technical source. Supports ammonia STS challenges, training and developing risk-assessment needs.

[9] IMO – MARPOL and STS regulatory material
https://www.imo.org/

Primary regulatory source. Used as the basis for discussing STS requirements; specific operational requirements must be checked for each vessel and jurisdiction.

[10] European Commission – Reducing emissions from the shipping sector / EU ETS
https://climate.ec.europa.eu/eu-action/transport-decarbonisation/reducing-emissions-shipping-sector_en

Primary EU regulatory source. Supports EU ETS scope and phased inclusion of maritime emissions.

[11] International Maritime Organization – IMO adopts first global Code for autonomous ships
https://www.imo.org/en/mediacentre/pressbriefings/pages/imo-adopts-mass-code.aspx

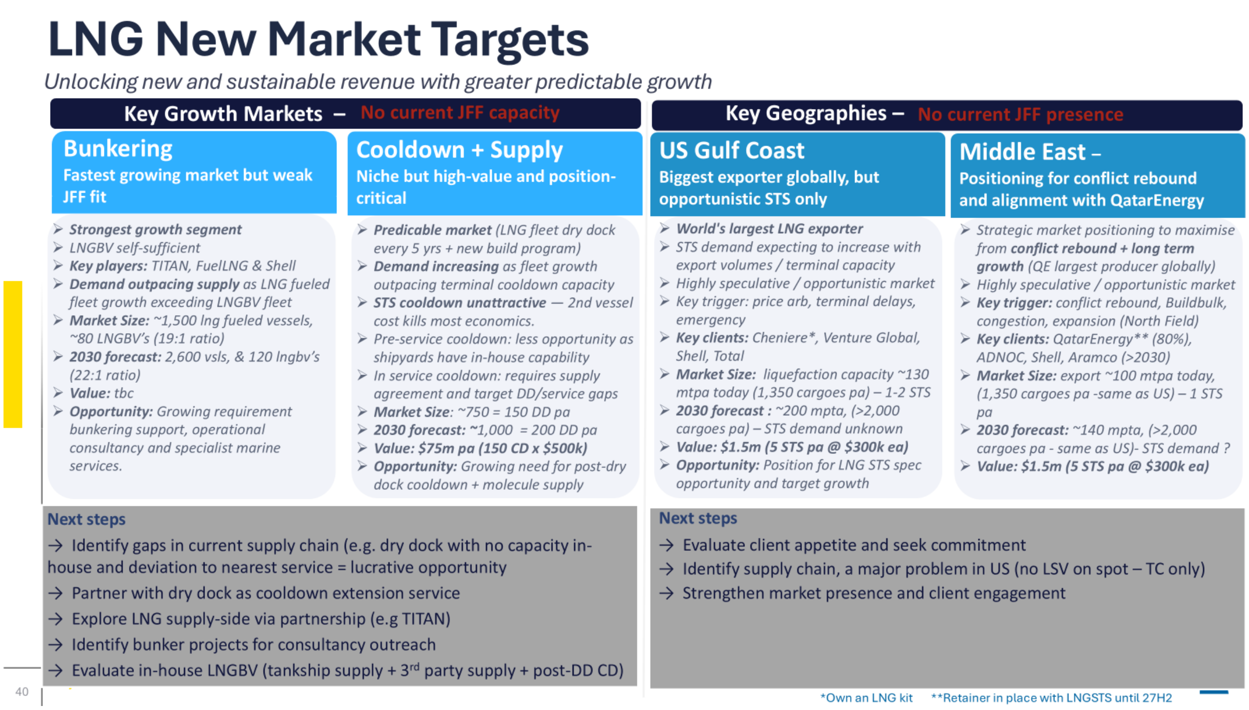
Primary regulatory source. Supports the 2026 MASS Code development.

[12] International Maritime Organization – Autonomous Shipping (MASS)
https://www.imo.org/en/ourwork/safety/pages/autonomous-shipping-%28mass%29.aspx

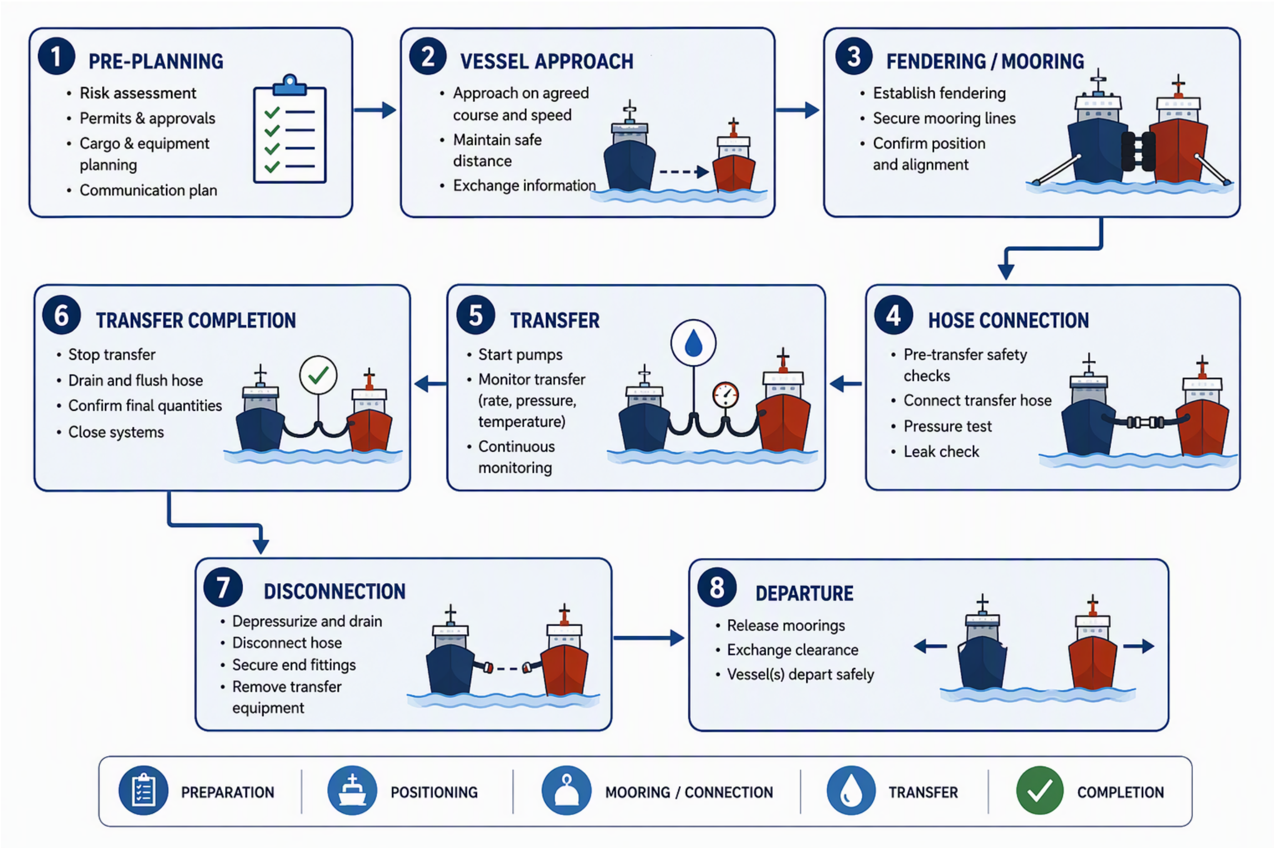
Primary regulatory source. Supports discussion of autonomous and remotely operated shipping.

Appendix A – Figures and Diagrams

1. Figure 2 - STS growth areas and sectors (Sections 6.4,10.2 ..)



2. Figure 3: STS Procedures and steps to completion



3. Figure 4 - Alternative-fuel comparison matrix showing temperature, toxicity, flammability, storage state and STS implications (Section 5).

ALTERNATIVE-FUEL COMPARISON MATRIX FOR STS OPERATIONS

Physical properties drive transfer system design, risk profile, training needs and operational response.

FUEL / CARGO	CONVENTIONAL OIL / PETROLEUM	LNG (LIQUID NATURAL GAS)	AMMONIA (NH_3)	METHANOL (CH_3OH)	LIQUID HYDROGEN (LH_2)
TYPICAL STORAGE CONDITIONS	Ambient pressure, near-ambient temperature	Atmospheric pressure, cryogenic	Pressurised (8–20 bar) or refrigerated	Atmospheric pressure, ambient temperature	Cryogenic, typically 1–10 bar
PHYSICAL STATE AT STS CONDITIONS	Liquid	Liquid	Liquefied gas	Liquid	Liquid (cryogenic)
TEMPERATURE	-20 °C to +60 °C (product dependent)	≈ -162 °C	≈ -33 °C at 1 bar (liquefied)	≈ +15 to +25 °C	≈ -253 °C
TOXICITY	Low to moderate (vapour exposure)	Low toxicity (asphyxiant in high concentrations)	High toxicity (respiratory irritant, corrosive)	Moderate toxicity (harmful if inhaled, ingested or absorbed)	Low toxicity (asphyxiant in confined spaces)
FLAMMABILITY	Flammable (vapour ignition risk)	Highly flammable (wide flammability range)	Flammable (15–28% in air)	Highly flammable (low flash point ~ 11 °C)	Extremely flammable (wide range in air)
KEY HAZARDS	Fire, explosion, pollution, vapour inhalation	Cryogenic burns, boil-off gas, vapour cloud, fire/explosion, pressure effects	Toxic exposure, corrosivity, vapour cloud, environmental harm	Fire, vapour cloud, toxic exposure	Cryogenic burns, fire/explosion (leakage, invisible flame), material embrittlement
MATERIAL / EQUIPMENT CONSIDERATIONS	Established materials and technologies	Cryogenic-rated materials, insulated hoses, ESD, dry-break / QCDC systems	Ammonia-compatible materials (avoid copper alloys), specialist seals, gas detection	Material compatibility, fire protection, vapour control, ESD	Specialist cryogenic materials, insulation, leak-tight systems, embrittlement control
STS IMPLICATIONS	Mature procedures and equipment; spill prevention critical	Cooldown required, controlled transfer, boil-off management, esd critical	Strict containment, gas detection, exclusion zones, emergency response planning	Vapour management, fire protection systems, compatible transfer equipment	Very high technical requirements, boil-off management, ventilation, spark control
TRAINING FOCUS	Oil STS procedures, pollution prevention, emergency response	Cryogenic handling, gas detection, ESD, emergency response	Toxicity awareness, PPE, HAZOP/risk assessment, emergency response	Flammable/toxic liquid handling, vapour control, fire and spill response	Cryogenic operations, hydrogen behaviour, leak response, fire control
STRATEGIC OUTLOOK TO 2036	Resilient in near term; possible long-term decline in some trades	Strong transitional market potential; high equipment specialisation	Potential major future fuel; infrastructure & standards developing	Growing potential, especially with e-methanol supply	Longer-term potential; significant infrastructure & engineering barriers

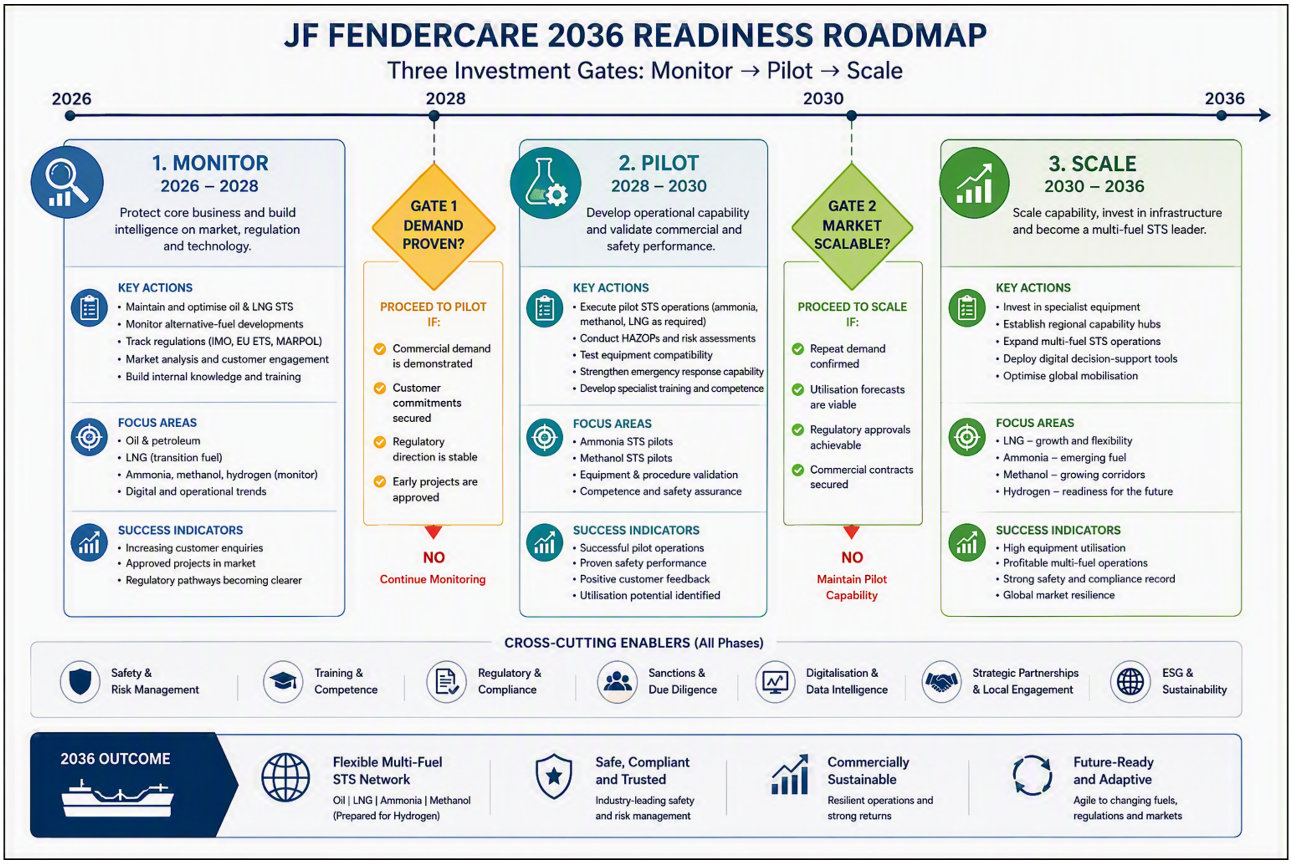
NOTES
- Properties are typical values. Actual conditions vary by cargo grade, pressure, equipment and operating limits.
- Safe STS operations require compliance with IMO, OCIMF and flag/port state requirements.

ABBREVIATIONS

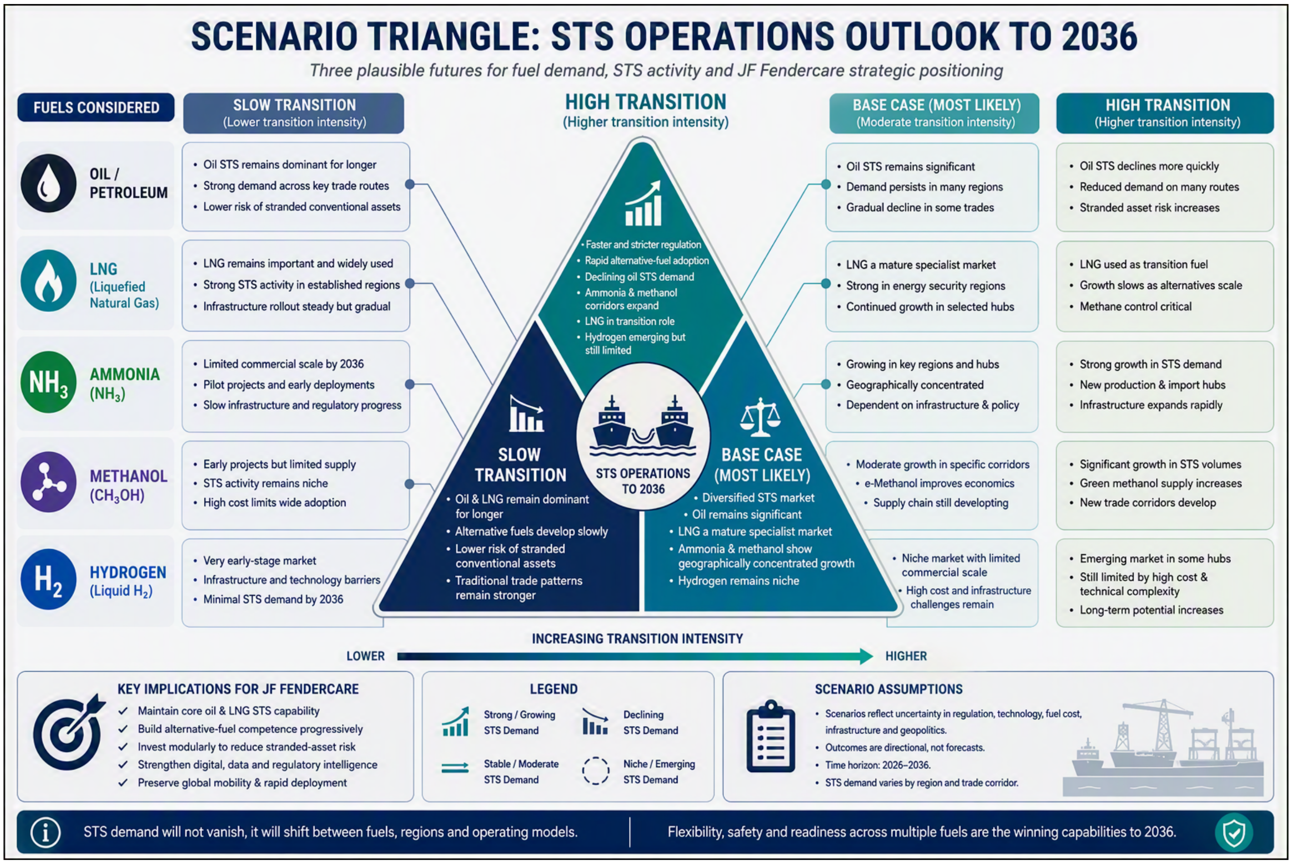
STS	Ship-to-Ship Transfer
ESD	Emergency Shutdown
QCDC	Quick Connect / Disconnect Coupling
HAZOP	Hazard And Operability Study
PPE	Personal Protective Equipment
OCIMF	Oil Companies International Marine Forum
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships

SOURCES
IMO, OCIMF, Shell LNG Outlook 2026, JF Fendercare Ammonia Whitepaper 2024, Academic and industry literature.

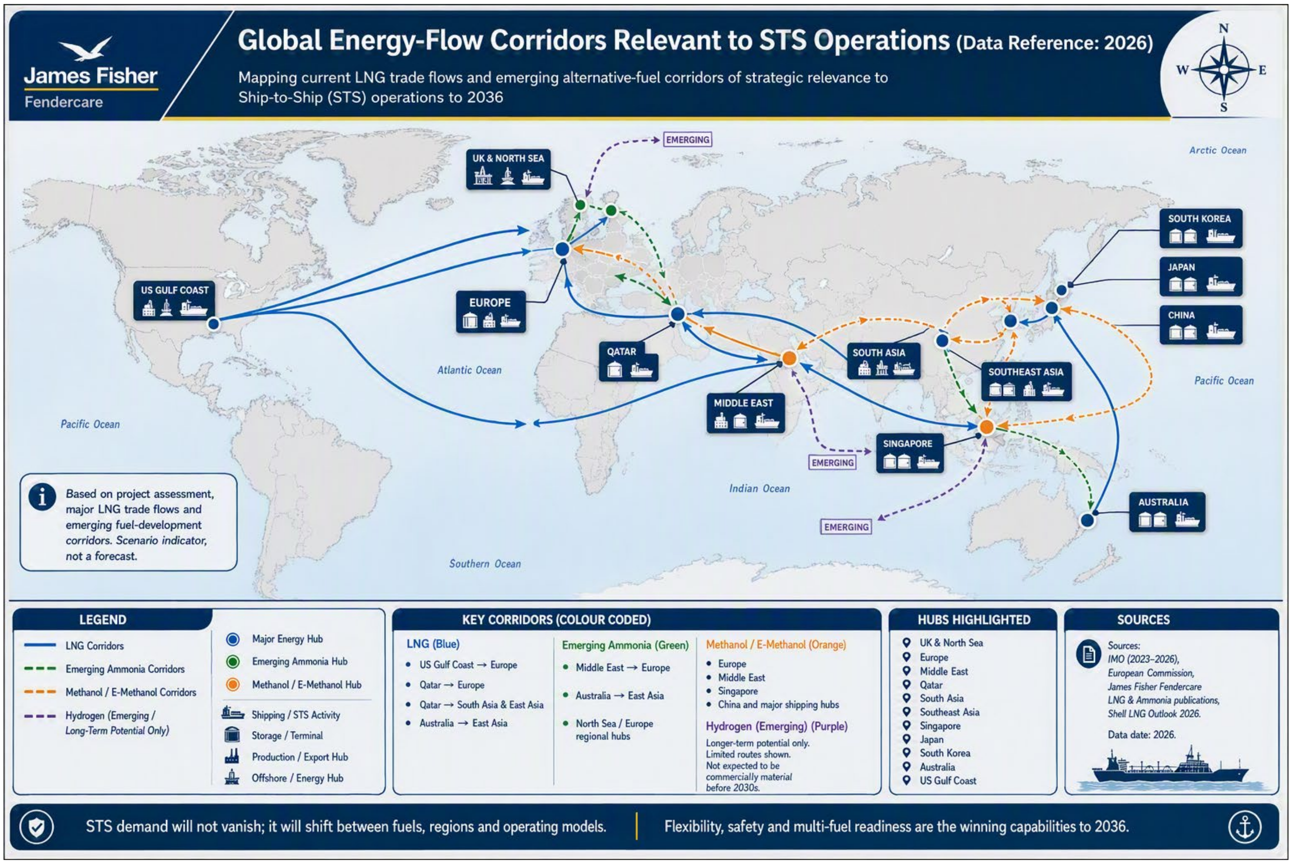
4. Figure 5 - 2036 readiness roadmap with three investment gates: monitor → pilot → scale. (Section 10)



5. Figure 6 -Scenario triangle: slow transition / base case / high transition, showing implications for oil, LNG, ammonia, methanol and hydrogen. (Section 10)



6. Figure 7 - Global energy-flow map showing major LNG and alternative-fuel corridors. (Speculative and scenario map only) (Section 6.4)



7. Figure 8 - Operational Realities image + Risk Rankings (Section 8)

STS OPERATIONS – OPERATIONAL RISK REGISTER

Key risks, potential impacts, mitigation measures and implications for 2036.

James Fisher Fendercare

RISK	POTENTIAL IMPACT	MITIGATION MEASURES	2036 IMPLICATION	RISK OUTLOOK TO 2036
Poor weather / sea state	• Collision • Mooring or equipment damage • Transfer delay or suspension	• Defined environmental limits • Continuous weather monitoring • Decision-support tools • Stop-work authority	Better forecasting and real-time decision-support will reduce weather-related risk and improve operational uptime.	HIGH – Remains high due to climate variability and extreme events.
Loss of containment	• Fire or explosion • Pollution • Toxic exposure (for certain fuels) • Environmental damage	• Compatible equipment selection • ESD systems and dry-break couplings • Gas detection and monitoring • Emergency response planning	Fuel-specific controls and advanced monitoring will be critical as more hazardous fuels are transferred.	HIGH – Increases with more hazardous alternative fuels entering the market.
Wrong fuel / equipment compatibility	• Equipment failure • Uncontrolled release • Operational delay • Safety incident	• Pre-job compatibility checks • Digital compatibility database • Approved equipment lists • Documented procedures	Digital tools and data integration will reduce compatibility errors and improve safety.	MEDIUM – Moderate, but reduces with digital systems and standardisation.
Insufficient competency	• Human error • Incorrect decision-making • Incident and injury • Reputational damage	• Competent POAC / STSSI • Training and assessment • Alternative-fuel specific training • Continuous learning culture	Specialist alternative-fuel competence will be a key differentiator and client requirement.	HIGH – Increases as operations become more complex and multi-fuel.
Regulatory permission delayed	• Operational delays • Cost increases • Contract penalties • Loss of commercial opportunity	• Early engagement with authorities • Local partnerships and agents • Regulatory intelligence database • Strong documentation	Local regulatory knowledge and relationships will remain as important as technical capability.	MEDIUM – Remains moderate because regulatory complexity is likely to increase.
Sanctions / compliance breach	• Legal penalties • Financial loss • Loss of insurance • Reputational damage	• Sanctions screening • Customer due diligence • Compliance training • Documented controls	Higher importance as trade patterns become more complex and sanctions enforcement increases.	HIGH – High and rising due to geopolitical uncertainty.
Stranded equipment / poor utilisation	• Poor return on investment • High maintenance costs • Reduced competitiveness	• Phased investment approach • Modular equipment strategy • Scenario-based decision making • Utilisation monitoring	Need flexible, modular assets that can be redeployed across fuels, regions and customers.	MEDIUM – Moderate risk; higher if over-investment occurs early.
Security / geopolitical disruption	• Route diversion • Delays and cost increases • Increased insurance costs • Crew safety concerns	• Route risk assessment • Real-time intelligence • Strong security protocols • Contingency planning	Geopolitical disruption will remain a major driver of route changes and STS re-distribution demand.	HIGH – High and unpredictable due to ongoing geopolitical tensions.

KEY PRINCIPLE

Safety, compliance and competence underpin every successful STS operation. Risk-effective controls protect people, the environment and commercial value.

LEGEND – RISK OUTLOOK TO 2036

- HIGH – High likelihood or high impact; requires strong ongoing control
- MEDIUM – Moderate likelihood or moderate impact; requires active management
- LOW – Lower likelihood and/or lower impact; monitor and manage

NOTES

- Risks vary by fuel type, location, vessel characteristics and regulatory environment.
- Risk ratings reflect relative outlook to 2036 based on project assessment and industry evidence.
- This register supports JF Fendercare's phased readiness roadmap and decision-gate investment approach.

SOURCES

- IMO (2023–2026) Regulations and Guidance
- OCIMF STS Guidelines
- JF Fendercare Internal Knowledge and Operational Experience
- Academic and Industry Literature

Appendix B – Evidence and Assumptions Register

Statement	Evidence status	Treatment in report
LNG bunkering could reach 27 Mt by 2035	Forecast by Shell	Used as a scenario indicator, not a guaranteed result
IMO Net-Zero Framework	Approved draft; adoption process delayed/ongoing	Presented as regulatory direction and uncertainty
EU ETS maritime coverage	Current regulation	Presented as established fact with scope explained
Alternative-fuel STS demand	Emerging market	Presented as conditional on infrastructure and regulation
AI/digital twins for STS	Emerging technology	Presented as a proposed future capability, not a certainty
Regional STS growth	Scenario-based assessment	Avoids unsupported precise forecasts