INTERNATIONAL MARITIME ORGANIZATION

Marine Environmental Protection Committee | **MEPC 83/15**

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Agenda item: Reduction in GHG Emission from Ships | **Original: ENGLISH**

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Reduction in GHG Emission from Ships focusing on Economic Element with reference to Industry 4.0

The Smart Horizon: AI, IoT, and the Economic Transformation of Maritime Decarbonization

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SUMMARY

Executive summary: This research explores a smart hybrid membrane-cryogenic carbon capture system (OCCS) powered by AI and IoT to accelerate maritime decarbonization. The system enables real-time monitoring, predictive maintenance, and adaptive operations, enhancing both safety and efficiency. Integrated with Industry 4.0 technologies, it reduces fuel penalties, helps avoid carbon taxes, and creates revenue through onboard CO_2 reuse (e.g., firefighting, fuel cells). Though it requires upfront investment, the system offers fast payback and positions early adopters for economic and competitive advantage, proving that decarbonization is both a technological and financial opportunity for the shipping industry.

Strategic direction, if applicable: 3.2

Output: 3.

Action to be taken: 4.1 to 4.5

Related documents:

Maritime Decarbonization Through Smart Carbon Capture: A National Strategy

"The ocean carries our goods; we must not let it carry the burden of our emissions."

1. The Crisis We Can No Longer Ignore

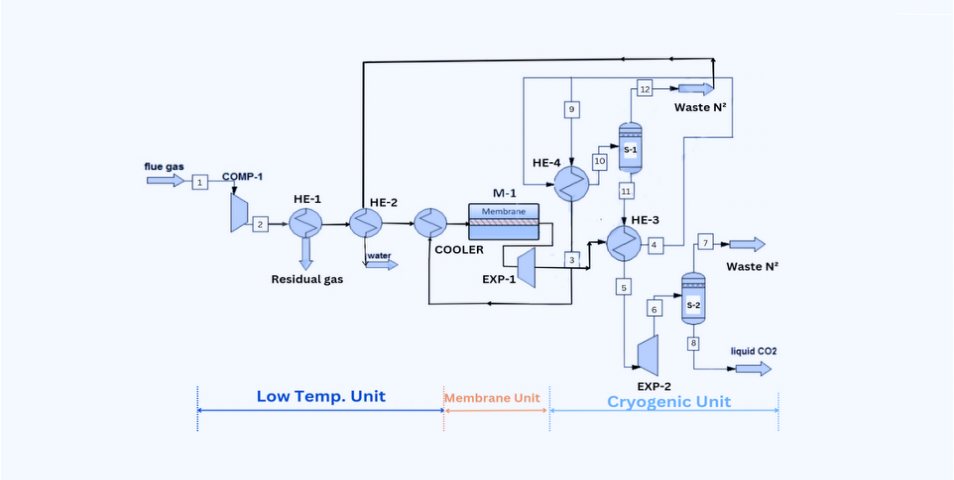
Over 100,000 vessels emit 1,076 million tonnes of CO_2 annually, ranking global shipping as the world's sixth largest emitter. Maritime emissions surged 9.6% between 2012 and 2018, reaching 706 million metric tons in 2023. The IMO's 2023 strategy demands net zero by 2050 with 20% reduction by 2030 revolutionary targets for an industry where vessels last 20-30 years.

2. Our National Position and the Path Forward

Achieving net zero by 2050 through alternative fuels alone faces formidable challenges infrastructure timelines, fuel availability, and economic constraints struggle to meet targets. The maritime industry involves diverse stakeholders with competing priorities: shipowners on thin margins, port authorities managing investments, developing nations with limited capital, seafarers requiring retraining, and supply chains demanding reliability. Solutions must balance environmental urgency with economic reality. As a nation with substantial fiscal capacity, robust R&D infrastructure, significant fossil fuel reserves, and thriving shipbuilding capabilities, we recognize transitional technologies bridging current operations and future zero emission fleets as essential. Our shipbuilding sector and seafarer workforce position us as solution providers, transforming decarbonization from compliance burden into industrial opportunity.

3. Our National Proposal: Smart Onboard Carbon Capture

Our nation proposes AI enhanced onboard carbon capture enabling immediate emissions reductions from existing vessels while alternative fuel infrastructure matures. The technology separates CO_2 from exhaust gases, purifies it, and enables onboard utilization allowing continued fleet operation while achieving substantial reductions.



Our hybrid membrane cryogenic system integrates two stages. Flue gases pass through sub ambient membrane separation increasing CO_2/N_2 selectivity by two to four times (achieving 90.5 ratio), then enter cryogenic purification reaching 95.86% purity. Thermal integration cold nitrogen pre cooling incoming gases, pressure recovery generating 15.52 kW enables consumption of just **449 kJ per kg CO_2**, versus 1,422 kJ/kg for conventional systems or 11,448 kJ/kg for MEA absorption.

IoT sensors and machine learning algorithms achieve **91% accuracy predicting deviations**, enabling early membrane fouling identification and automatic dry ice prevention. Predictive maintenance **reduces downtime by 40%** and **component costs by 15%**. Digital twins simulate operational scenarios before encountering actual conditions.

Traditional carbon capture fails on storage logistics. Our approach integrates captured CO_2 into existing operations: fire suppression systems, life saving equipment leveraging CO_2's superior density, thermal energy recovery using 300-400°C exhaust for boiler preheating achieving **3 5% fuel savings**, pipeline washing, and future CO_2 to carbon fibre conversion for onboard 3D printing. The majority provides onboard value before minimal port offloading. The remaining captured CO_2 will be stored in IGC Type C Tanks.

3.2. Implementation Strategy: **Phase A (Years 0-2)** establishes 8-12 pilots with $40 70M investment, one port hub, 200 trained engineers. **Phase B (Years 3-6)** scales to 200 800 vessels with domestic manufacturing (50-200 units annually), reduces costs from $4.5M to $2.7-3.4M, expands to 3-10 ports, trains 2,000+ professionals, leverages $200-400M public investment mobilizing $800-1,600M private capital. **Phase C (Years 7-10)** achieves 30-50% fleet coverage, $150-300M export revenue, 5,000-10,000 direct jobs, 15-25% emissions reduction.

3.3. Economics: Systems achieve 3-4 year payback generating $600,000-1,200,000 annual savings post payback. National deployment (500 vessels by 2035) requires $450-675M public investment, mobilizes $1.6-2.0B private capital, captures 4 million tonnes CO_2 annually, generates $240-320M fleet savings plus $200-400M carbon credits yearly.

4. REQUEST TO THE COMMITTEE/SUB-COMMITTEE

4.1. Recognition of AI Enhanced Onboard Carbon Capture as Qualifying Technology

Committee Addressed: Marine Environment Protection Committee (MEPC)

Current Framework: Resolution MEPC.377(80) 2023 IMO Strategy on Reduction of GHG Emissions from Ships lacks explicit recognition of digitally enhanced carbon capture as qualifying transitional technology.

Requested Action: Adopt new Resolution explicitly recognizing AI enhanced onboard carbon capture systems (OCCS) as qualifying transitional technology under the 2023 IMO GHG Strategy. Recognition should acknowledge that while zero emission fuels remain the ultimate goal, transitional technologies enabling immediate emissions reductions from existing vessel in the given infrastructure timelines. Specify that verified carbon capture qualifies for recognition under existing CII and EEXI frameworks (Resolution MEPC.328(76)), with proper MRV protocols credited in carbon intensity calculations.

Justification: Alternative fuel infrastructure faces significant timeline barriers, particularly in developing regions. Our system demonstrates viability (449 kJ/kg consumption, 91% predictive accuracy, 3-4 year payback), addressing practical pathway needs while infrastructure matures.

4.2. Development of Standardized MRV Protocols for Onboard Carbon Capture

Committee Addressed: MEPC, with technical work delegated to ISWG GHG

Current Framework: The 2023 IMO GHG Strategy emphasizes lifecycle assessments but lacks standardized MRV protocols for onboard capture. Existing frameworks under EU MRV Regulation and IMO DCS (Resolution MEPC.278(70)) focus on fuel consumption rather than captured emissions.

Requested Action: Instruct the Secretariat, with Member States and classification societies, to develop comprehensive MRV protocols by MEPC 85 (2026) establishing: verification methodologies for capture efficiency; standardized data formats integrating with SEEMP under MARPOL Annex VI; certification procedures for classification societies; transparent emissions accounting determining how captured CO_2 credits against vessel carbon intensity; digital twin validation requirements; and port based verification protocols ensuring proper sequestration or utilization. **Member States with relevant capabilities should submit pilot program data by MEPC 84 (April 2025), including vessel specifications, system performance, energy impacts, operational challenges, training approaches, economic data, and infrastructure requirements.** Secretariat should compile submissions into summary documents enabling evidence based standards.

Justification: Without standardized MRV, shipowners cannot demonstrate compliance, port states cannot verify claims, carbon markets cannot trust credits. Our pilot program (8-12 vessels) offers practical testbed. This parallels LNG fuel MRV development (Resolution MEPC.308(73)) where pilot operations informed standards, preventing fragmented national approaches.

4.3. Integration into Economic Measures Framework

Committee Addressed: MEPC and ISWG GHG

Current Framework: ISWG GHG discussions on GHG Fuel Standard and Maritime GHG Emissions Pricing Mechanism lack explicit carbon capture integration.

Requested Action: Direct ISWG GHG to incorporate onboard capture into economic measures, clarifying: whether captured emissions reduce effective fuel carbon intensity under GHG Fuel Standard; how Maritime GHG Emissions Pricing generates credits with verification standards and tradability; economic modelling including capture adoption scenarios; and recognition of capture as technology development opportunity qualifying for Technical Cooperation support under differential treatment for developing nations.

Justification: Economic measures represent the Committee's primary acceleration tool beyond technical mandates. Without explicit integration, market signals may inadvertently disadvantage this pathway despite viability. Our analysis demonstrates that GFI Tax reaching \$100/tCO_2 for Tier 1 and \$380/tCO_2 for Tier 2 (discussed in ISWG GHG) makes systems highly attractive (generating \$400,000-800,000 annual value), but only if mechanisms properly credit verified capture. Regulatory certainty is essential for mobilizing the \$1.6-2.0B private capital our program projects.

4.4. Capacity Building and Technology Transfer Support

Committee Addressed: MEPC, implemented through IMO Technical Cooperation Division and MTCCs

Current Framework: Resolution A.1128(31) establishes capacity building framework but lacks specific programs for advanced decarbonization technologies.

Requested Action: Direct Technical Cooperation Division, with MTCCs, to develop targeted programs addressing: training frameworks (40-80 hour foundational courses, hands on training, advanced certification); certification standards enabling domestic approval processes; technology transfer mechanisms through licensing, joint ventures, or open source approaches; financing guidance connecting nations with multilateral banks and climate funds; shipyard capability assessments enabling domestic manufacturing.

Justification: CBDR RC principles recognize developing nations require support. Our program demonstrates that with appropriate support (40-60% grants, 2.5% loans), adoption mobilizes private capital at 4:1 ratios. Structured frameworks accelerate global decarbonization while creating sustainable industries in developing regions.

4.5. Port Infrastructure Development Coordination

Committee Addressed: MEPC, coordinating with Port State authorities and international port organizations

Current Framework: Resolution MEPC.323(74) encourages port shipping cooperation but lacks specific guidance on carbon capture offloading infrastructure.

Requested Action: Encourage port authorities and Member States to develop CO_2 reception infrastructure at major trading hubs with voluntary progress reporting. Actions include: identifying suitable ports based on traffic patterns and proximity to sequestration sites; collaborating with port organizations to develop technical guidance learning from LNG bunkering; coordinating planning with national/regional CCS development; and exploring public private partnership financing models.

Justification: Coordinated infrastructure development breaks chicken and egg challenges where shipowners need offloading capacity before installing systems while ports need vessel demand before investing. Our phased approach (one port expanding to 3-10) demonstrates strategy enabling globally operational vessels rather than route restricted deployments.