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ENERGY MARKETS OUTLOOK

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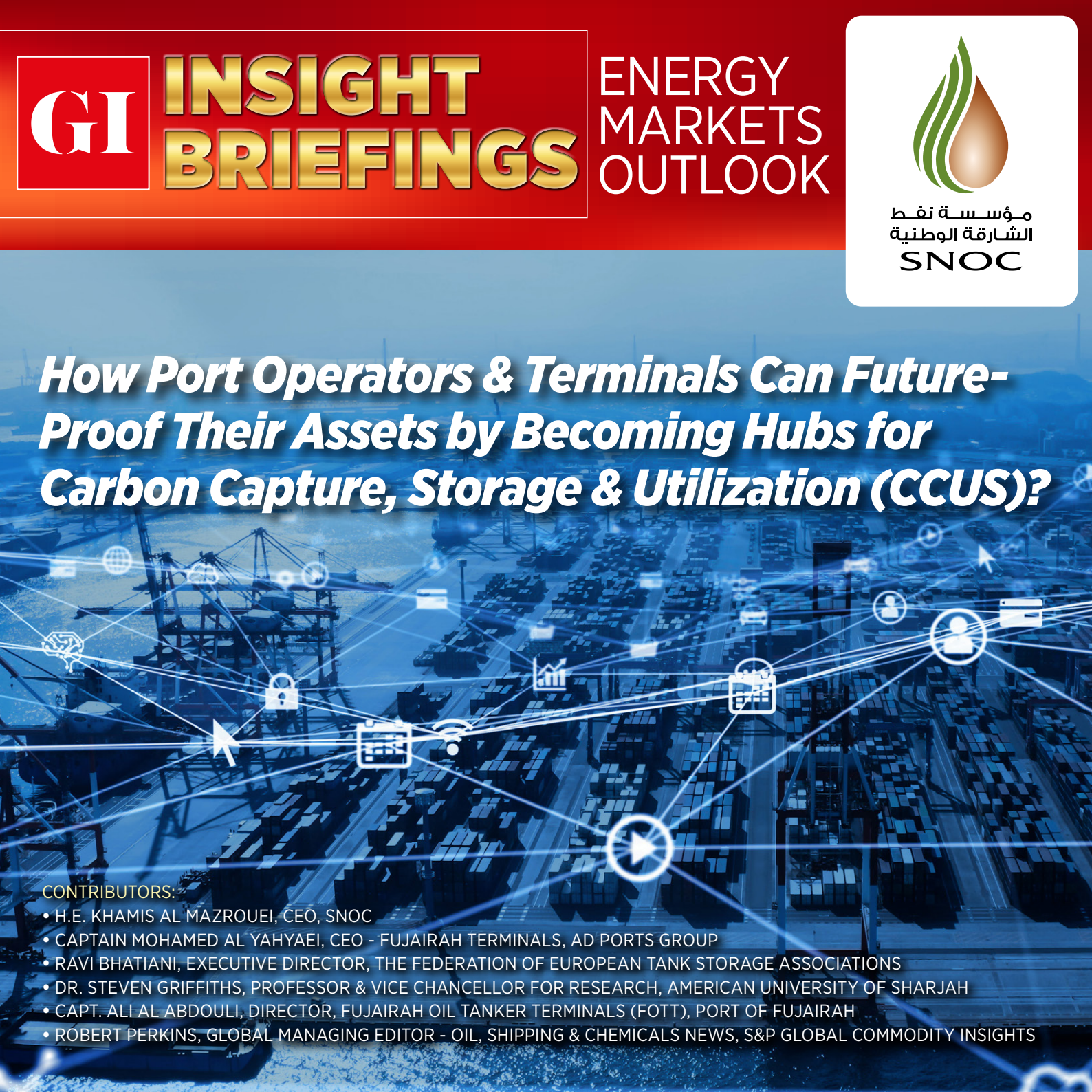
SNOC

How Port Operators & Terminals Can Future-Proof Their Assets by Becoming Hubs for Carbon Capture, Storage & Utilization (CCUS)?



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TOP 20 RECOMMENDATIONS

Future-Proofing the Ports: Turning Carbon Capture into the Next Great Maritime Industry

Ports have always mirrored global trade trends — from crude oil to containers, and soon, carbon. The next frontier is clear: ports and terminals must evolve into CCUS hubs where captured CO_2 can be aggregated, processed, shipped, and stored permanently. This shift transforms ports into climate infrastructure — the connective tissue of a decarbonized global economy.

The transition starts with pilot projects, not mega schemes. Port authorities and operators should launch small-scale, low-risk CCUS pilots that test capture technologies, simulate transport routes, and build data familiarity. Early proof-of-concepts, even at 1% of potential scale, attract private capital and generate policy confidence that unlocks larger investment phases.

Yet ambition without regulation remains a gamble. Governments must create clear legal frameworks defining carbon ownership, storage liability, transport standards, and tariff structures. Without this, investors face uncertainty that delays or kills projects before they start. Just as IMO 2020 brought clarity to low-sulfur fuels, a regional carbon-governance framework can trigger similar acceleration.

To maximize efficiency, disaggregate the CCUS value chain. Capture, transport, and storage should each be managed by specialized entities — ports can excel in aggregation, shipping, and storage, while technology firms handle capture at industrial sites. This "modular chain" approach minimizes risk and attracts niche expertise rather than demanding a single vertically integrated player.

Ports are uniquely positioned to offer "storage as a service." Acting as aggregators, they can collect CO_2 from nearby emitters, compress it on site, and channel it via pipeline or tanker to geological storage. By bundling this service, ports create a new recurring revenue stream while helping industries comply with tightening emissions frameworks.

Many coastal regions sit atop depleted oil and gas fields, ideal for long-term CO_2 storage. These dormant reservoirs can be repurposed as secure carbon sinks — converting legacy hydrocarbon infrastructure into low-carbon assets. It's a symbolic and practical bridge between yesterday's energy economy and tomorrow's climate economy.

Building the Business Case for Carbon Infrastructure

The economics of carbon storage hinge on pricing. Without a defined carbon price or incentive, investment will stagnate. Policymakers must introduce carbon-credit systems or border-adjustment mechanisms (like the EU's CBAM) to make domestic capture and storage competitive. This clarity attracts investors and rewards early movers who invest before mandates arrive.

Digitalization and data monitoring systems (MVV) will be central to future port competitiveness. Reliable data on captured, transported, and stored CO_2 ensures compliance, transparency, and credibility. Ports should embed digital twin technology to measure emissions in real time, providing verifiable proof of carbon reduction for certification and financing purposes.

Future-ready ports won't operate in isolation — they will partner with academia and industry. Universities provide R&D depth, ports bring logistical know-how, and private firms supply capital. Together, these partnerships reduce capture costs, enhance storage safety, and expand regional capacity. The result: an innovation corridor that anchors the port's position in the green economy.

Before large-scale carbon capture matures, ports must decarbonize their own operations through electrified cranes, cold-ironing for vessels, and renewable-powered facilities. These incremental improvements both cut emissions and demonstrate leadership, signaling that ports are serious about sustainability and willing to apply to themselves the same standards expected of others.

To connect emitters and reservoirs efficiently, multimodal CO_2 transport networks are essential. These include short-distance pipelines linking industrial clusters to port terminals, and specialized tankers that can move compressed CO_2 between regions. As these networks mature, ports will become the crossroads of the global carbon-trade system.

Safety and reliability demand that CO_2 transport and storage follow international quality standards. Uniform thresholds for purity, pressure, and corrosion prevention will create interoperability between ports and storage facilities. Standardization is also key to unlocking cross-border trade of captured CO_2, ensuring safe handling and reducing insurance costs.

Ports should be designed for dual-use functionality — handling both inbound CO_2 for storage and outbound low-carbon products like methanol, hydrogen, and sustainable aviation fuel (SAF). This dual design future-proofs infrastructure and enables ports to profit from both the "carbon inflow" and "green fuel outflow" sides of the new energy trade.

Given the scale of capital and time required, public–private partnerships (PPPs) are critical. Governments can take post-closure liability for stored carbon after 20 years, reducing investor risk. Private firms, in turn, build and operate the infrastructure. This model mirrors the success of early LNG terminals that matured under similar risk-sharing arrangements.

Governance, Risk, and the Global Race for Scale

To thrive, CCUS must be embedded in broader energy-transition strategies. Rather than treating carbon storage as an isolated task, ports should integrate it with hydrogen, ammonia, and SAF corridors, ensuring synergy between fuel supply chains and storage capacity. This cross-sector alignment magnifies returns and prevents stranded assets.

Data transparency will be the competitive differentiator. Openly publishing verified CO_2 data attracts financiers, builds public trust, and enables informed policymaking. Data is the new currency of climate credibility — the faster ports make theirs public, the sooner they'll be recognized as credible green hubs.

Because carbon flows don't respect borders, regional collaboration across the Gulf is vital. A harmonized Gulf CCUS framework — covering liability, certification, tariffs, and safety — would position the region as a single carbon-storage network. This collective effort would mirror Europe's hydrogen corridors but with far greater geological potential.

> *"By combining regulatory clarity, public–private investment, and technological innovation, Gulf ports like Fujairah, Khalifa, and Hamriyah could become the "Carbon Harbors" of the 21st century."*

Establishing research and innovation clusters within port zones is key. Collaboration between ports, universities, and technology startups can advance membrane separation, mineralization, and direct-air capture methods. Such clusters turn ports into living laboratories — places where maritime engineering meets climate innovation.

A critical concern for investors is long-term storage liability. Governments must guarantee monitoring, verification, and remediation after site closure. No private operator can assume 100-year liability. Regulatory certainty here will decide whether major energy players commit or hesitate.

Finally, ports can accelerate momentum by anchoring CCUS growth to existing methanol and hydrogen projects. These industries already depend on CO_2 capture for product qualification under international standards. By co-locating such projects, ports secure baseline demand for storage services, ensuring steady cash flows and market validation.

Conclusion: The Race to Build the Carbon Harbors of the Future

CCUS isn't just an environmental necessity — it's an industrial revolution waiting to be claimed. The world's most successful ports in 2050 will be those that act now to blend climate responsibility with commercial foresight.

The UAE, with its unique geological reservoirs, global trade connectivity, and policy ambition, is ideally placed to lead this transformation. By combining regulatory clarity, public–private investment, and technological innovation, Gulf ports like Fujairah, Khalifa, and Hamriyah could become the "Carbon Harbors" of the 21st century — gateways not only for global trade, but for the planet's decarbonized future. ■

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How Port Operators & Terminals Can Future-Proof Their Assets by Becoming Hubs for Carbon Capture, Storage & Utilization (CCUS)?

1. Develop Ports as Integrated CCS Hubs

Ports must evolve from traditional trade nodes into integrated CCUS ecosystems connecting emitters, shipping, and depleted reservoirs. Acting as logistical, storage, and processing gateways for captured carbon positions ports at the center of the decarbonization value chain, enabling them to monetize CO_2 flows, attract investors, and drive long-term sustainability transformation.

2. Begin with Small-Scale, Commercially Viable Pilot Projects

Early adoption requires small, focused pilot projects that demonstrate capture, transport, and storage feasibility. These pilots prove technical reliability, attract partners, and create early datasets critical for scale-up. Gradual expansion reduces financial risk, builds local technical capability, and allows regulations and business models to mature organically around real-world performance results.

3. Create a Regional Legal & Regulatory Framework

Without clear carbon regulations, investment will stagnate. Governments must establish legal frameworks defining CO_2 ownership, liability, storage duration, transport protocols, and tariffs. Unified regional standards across Gulf ports would reduce uncertainty, enable cross-border cooperation, and ensure carbon captured, stored, or traded meets internationally recognized verification and reporting criteria.

4. Separate the CCS Value Chain for Efficiency

Breaking up the CCUS value chain into specialized functions — capture, transport, and storage — maximizes efficiency. Ports should focus on aggregation, logistics, and injection readiness, while industrial clusters or technology providers specialize in capture. This modular approach lowers barriers to entry, increases competition, and speeds up infrastructure deployment at scale.

5. Offer "Storage as a Service" to Emitters

Ports can act as aggregators of carbon by collecting CO_2 from nearby industrial emitters, compressing it, and transporting it to secure geological storage. By commercializing storage as a subscription-style service, ports generate new revenue streams, create investor confidence, and offer industries a one-stop decarbonization solution aligned with net-zero strategies.

6. Leverage Depleted Gas Fields as Permanent Storage Sites

Many ports sit near depleted oil and gas reservoirs — assets that can be repurposed for permanent carbon storage. Converting these fields creates low-cost, high-integrity CO_2 sinks that extend the life and value of legacy infrastructure, providing ports with a scalable, long-term competitive advantage in the carbon-management industry.

7. Introduce Carbon Pricing and Incentives

To make CCUS commercially viable, policymakers must create carbon pricing mechanisms, tax credits, or tradeable certificates that reward emissions reduction. A predictable carbon price encourages early movers to invest in capture and storage infrastructure, providing the economic certainty necessary for long-term capital deployment and sustainable industrial transformation.

8. Use Data Monitoring and Verification Systems (MVV)

Ports should deploy advanced data platforms for real-time monitoring of CO_2 capture, transfer, and storage. Verified datasets build investor and regulator confidence, enable carbon-credit certification, and ensure compliance with emerging border-adjustment measures. Accurate MVV systems transform ports into transparent, data-driven environmental custodians with measurable climate-impact credibility.

9. Prioritize Partnerships Between Ports and Industry

Effective CCUS development depends on strong collaboration among ports, industrial emitters, academia, and technology providers. Joint ventures allow shared investment, knowledge transfer, and risk distribution. Such partnerships accelerate innovation, integrate infrastructure planning, and align sustainability commitments — turning ports into engines of collective industrial decarbonization rather than isolated operators.

10. Invest in Cold-Ironing and Electrification

While large-scale CCS matures, ports can immediately decarbonize by electrifying cranes, introducing cold-ironing (ship-to-shore power), and transitioning vehicles to electric or hybrid models. These steps reduce baseline emissions, strengthen ESG credentials, and demonstrate proactive environmental leadership, positioning ports as credible climate partners in future carbon-management ecosystems.

11. Encourage Multimodal CO_2 Transport Networks

Ports should develop multimodal CO_2 transport systems combining pipelines, road networks, and specialized tankers. These interconnected routes enable efficient movement of captured carbon from industrial clusters to storage hubs. Integrated logistics design enhances flexibility, builds redundancy, and allows ports to serve both regional emitters and international CO_2 trading corridors.

12. Adopt International Standards for CO_2 Quality and Safety

To ensure safe and efficient CO_2 handling, ports must comply with globally recognized standards for purity, pressure, and corrosion control. Standardization fosters interoperability between ports, pipelines, and storage operators, enabling international carbon-shipping trade and reducing technical risks associated with cross-border carbon transportation and offshore injection operations.

13. Design Port Infrastructure for Dual Use (Import/Export)

Future-proofed ports should be engineered to handle both inbound CO_2 for storage and outbound low-carbon products such as methanol, hydrogen, or sustainable aviation fuel. This dual functionality ensures ports capture value from both the inflow and outflow of carbon-based commodities, maximizing revenue diversification and strategic resilience.

14. Build Long-Term Public–Private Partnerships (PPPs)

Governments must collaborate with private operators through long-term PPP frameworks that balance investment risk. Public entities should assume long-term storage liability beyond 20 years, while private firms build and manage operations. This structure de-risks projects, encourages early participation, and ensures continuity in national decarbonization infrastructure development.

15. Integrate CCUS into Broader Energy Transition Strategies

CCUS should not operate in isolation. Ports must embed it within broader clean-energy strategies covering hydrogen, ammonia, LNG decarbonization, and renewable integration. This systems-based approach allows shared infrastructure, streamlined permitting, and coordinated investment, making ports the convergence point for multiple low-carbon technologies and circular-economy initiatives.

16. Promote Data Transparency and Open Reporting

Ports can differentiate themselves by publishing transparent, verifiable CO_2 data. Open access builds public trust, attracts green-finance institutions, and facilitates collaboration across sectors. As data integrity becomes a global competitive advantage, transparent ports will be first to secure recognition as credible, science-based decarbonization hubs in global shipping.

17. Develop Regional Collaboration Across the Gulf

CCUS requires scale, and scale requires cooperation. Gulf nations should harmonize policies on liability, tariff structures, certification, and safety to form a regional carbon-storage network. Coordinated action will reduce duplication, share infrastructure costs, and position the Gulf as a unified carbon-management powerhouse serving global emitters.

18. Create Port-Based Research and Innovation Clusters

Establishing innovation zones within ports brings together scientists, engineers, and entrepreneurs to test new capture materials, pipeline sensors, and digital-twin solutions. R&D collaboration accelerates cost reductions and safety advances, transforming ports into living laboratories for climate technology and ensuring continual modernization of the carbon-storage value chain.

19. Address Long-Term Storage Liability and Risk Management

Long-term CO_2 containment poses legal and financial challenges. Governments must take ultimate responsibility for post-closure monitoring and liability. Clear rules on ownership transfer, insurance, and remediation are essential to attract institutional investment and ensure environmental integrity for centuries beyond a project's operational lifetime.

20. Use Methanol and Hydrogen Projects as Anchors for CCS Growth

Ports can anchor early CCS investment by co-locating methanol, hydrogen, and e-fuel projects that require captured CO_2 as feedstock. These industrial anchors create guaranteed offtake demand for storage services, proving commercial viability and turning carbon capture from a compliance obligation into a profitable circular-economy business model. ■


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