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Benchmarking Green Port Competitiveness: Mixed-Methods Evidence from PQA, KPT, and International Peers

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ABSTRACT

This paper examines whether sustainability in ports should be interpreted as a cost burden or a source of competitive advantage, with particular emphasis on Port Qasim Authority (PQA) and Karachi Port Trust (KPT). Using a mixed-method desk-based research design, the study combines peer-reviewed literature published between 2017 and 2026 with official port authority publications, international institutional reports, and selected industry sources. The analysis integrates qualitative thematic synthesis with descriptive comparison of publicly available performance indicators, including throughput, container volumes, vessel traffic, disclosed investments, and reported sustainability initiatives.

The findings show that sustainability is initially experienced by ports as compliance and capital cost, especially where investment is required in pollution control, effluent treatment, electrification, digital systems, or clean-fuel readiness. However, the evidence also shows that sustainability can enhance competitiveness when it reduces energy and delay costs, improves regulatory preparedness, strengthens stakeholder legitimacy, attracts cargo and investment, and supports resilient port-hinterland systems. International examples from Rotterdam, Antwerp-Bruges, Los Angeles, Singapore, and Tianjin Port demonstrate that ambitious decarbonisation and operational competitiveness are not mutually exclusive.

For PQA and KPT, sustainability is best described as an emerging strategic capability. PQA's climate-resilience framing, biodiversity platform, mangrove stewardship, and environmental infrastructure planning provide a credible base for green-port positioning. KPT's solarisation, marine-pollution controls, planned wastewater treatment, and container-oriented operating base similarly indicate movement toward greener operations. Both ports can strengthen the commercial value of these initiatives through clearer public disclosure of emissions baselines, project payback, and outcome-linked key performance indicators.

Introduction and Problem Statement

Ports remain decisive nodes in world trade. The sustainability debate matters because ports are not peripheral infrastructure; they mediate the cost, speed, reliability, and resilience of global supply chains. Recent review evidence notes that ports handle around

80% of global trade by volume and more than 70% by value, while the World Bank's Container Port Performance Index emphasises that vessel time in port is materially important for logistics efficiency and sustainable port development (UN Trade and Development, 2024; World Bank, 2024).

The regulatory environment is also becoming more demanding. The International Maritime Organization's 2023 greenhouse-gas strategy sets a stronger framework for shipping decarbonisation, while FuelEU Maritime is increasing pressure on vessels and ports to support cleaner fuels and onshore power. The International Association of Ports and Harbors (IAPH) World Ports Tracker 2026 indicates that more than half of responding ports have publicly announced carbon-neutrality plans ahead of the IMO's around-2050 horizon. Sustainability is therefore no longer only a reputational project; it is increasingly connected with licence to operate, regulatory preparedness, cargo attraction, and long-term competitiveness (European Commission, 2025; International Association of Ports and Harbors, 2026; International Maritime Organization, 2023).

This shift creates the core research problem: when does sustainability remain a cost, and when does it become a competitive advantage? In some ports, green investment may initially appear as a burden because it requires capital expenditure, operating coordination, grid capacity, user uptake, and longer payback periods. In others, similar investment supports faster port calls, improved energy security, stronger local legitimacy, green-corridor participation, customer retention, and lower future compliance risk. The answer is therefore not binary. Sustainability should be understood as a capability that moves through stages, from compliance value to operational efficiency and then to strategic advantage (Alamoush et al., 2021; Cocuzza et al., 2025; Song, 2024).

The question is especially relevant for Pakistan's two principal Karachi-area gateways. Port Qasim is one of Pakistan's major ports, with 18 berths and annual handling capacity of 89 million tonnes; it is also a large industrial-port ecosystem with more than 400 industrial and commercial units and significant power generation in its industrial zones. Karachi Port reports potential to handle more than 125 million tonnes of cargo and 4.25 million TEU and is deeply embedded in Pakistan's urban and national logistics system (Karachi Port Trust, 2026a; Port Qasim Authority, 2026a). Both ports face similar global decarbonisation pressures, but their cargo mixes, investment profiles, land-use contexts, and stakeholder relationships differ.

Accordingly, this paper asks four linked questions. First, how has recent scholarship conceptualised the sustainability-competitiveness relationship in ports? Secondly, what do official global port cases suggest about the real balance of cost and advantage? Thirdly, where do PQA and KPT presently sit on that spectrum? Finally, what sequence of actions would help both ports convert green spending into measurable competitive gain?

Literature Review

The literature published since 2017 shows a clear conceptual evolution from "environmental management in ports" toward broader notions of port sustainability, green competitiveness, and smart-sustainable performance. Alamoush et al. (2021) argue that port sustainability includes both internal port-side action and external ship- and land-interface action. Dağıstan et al. (2025) identify four recurring themes in smart-port sustainability: digital transformation, green-port initiatives, governance and stakeholder collaboration, and implementation challenges. This suggests that sustainability is increasingly inseparable from digital and organisational capability.

A second strand of literature focuses on measurement. Port sustainability assessment has strategic value because it clarifies whether ports are meeting operational, environmental, and managerial goals (Environmental performance evaluation in ports, 2024). More recent work argues that green-port evaluation has become more sophisticated, with more refined indicators, stronger ESG language, and clearer differentiation between environmental, social, and governance dimensions (Cocuzza et al., 2025; Nguyen et al., 2025).

A third strand deals with the connection between sustainability and competitiveness. Evidence from Chinese coastal ports suggests that green competitiveness has generally improved and that stronger green competitiveness can positively affect hinterland economic systems, especially their scale and quality (The impact of port green competitiveness on the hinterland economy, 2024). Nguyen et al. (2025) go further by proposing an integrated framework for smart and sustainable port competitiveness, showing that rankings based only on throughput and infrastructure are incomplete when digitalisation and sustainability are omitted. The implication is that sustainability increasingly belongs inside port competitiveness rather than outside it.

The governance literature reinforces the same point. Studies of port smartisation argue that data integration, computational interconnection, and digital platforms contribute to green and low-carbon ports. Evidence from 44 Chinese port cities also indicates that public environmental concern can improve port sustainability, particularly when cities have stronger digital infrastructure and more transparent environmental information (The impact of public environmental concerns on port sustainability, 2024). Green performance is therefore not only an engineering issue. It is also shaped by disclosure, public trust, institutional coordination, and stakeholder governance.

The literature remains cautious on cost and implementation. Seaport decarbonisation reviews classify measures into operational, technical, fuel-and-energy, infrastructural, digitalisation, and policy or collaboration categories. Song (2024) stresses that net-zero pathways require combined action across these categories. A 2024 review of port-decarbonisation research similarly warns that many studies repeat similar problems while implementation gaps remain (Trends in port decarbonisation research, 2024). This helps explain why the “green port” label often advances more quickly in policy language than in disclosed port outcomes.

Shore power is the clearest example of sustainability as both cost and advantage. Shore power can reduce berth emissions and noise, and it may support maritime competitiveness, but adoption remains constrained by grid capacity, vessel retrofits, tariff design, and coordination between terminal operators, shipowners, and power suppliers. Studies also indicate that public investment in shore power can be socio-economically beneficial across container, bulk, tanker, and general-cargo operations when pricing and uptake are aligned (Bullock et al., 2023; Economics of shore power under different access pricing, 2023; Shore power for reduction of shipping emission in port, 2024).

Industry and institutional literature broadens the picture. The IAPH World Ports Tracker 2026 presents a sector in transition, with member ports representing major cargo volumes and a growing share of carbon-neutrality commitments. ESPO’s environmental reporting and UN Trade and Development’s maritime review similarly treat sustainability and resilience as core components of future maritime infrastructure (European Sea Ports Organisation, 2024; International Association of Ports and Harbors, 2026; UN Trade and Development, 2024). These sources do not deny cost. They show that, under emerging market and regulatory conditions, some green costs are becoming the entry price for remaining competitive.

The literature therefore supports a three-part interpretation. Sustainability is a cost when treated only as compliance. It is an efficiency lever when connected to energy, operations, water, waste, and digitalisation. It becomes a competitive advantage when linked to customer retention, green-corridor participation, investment attraction, public legitimacy, and regulatory readiness. This framework guides the comparative analysis that follows.

Methodology

This study adopts a mixed-method desk-based comparative case-study design. The focal cases are Port Qasim Authority and Karachi Port Trust. These are analysed against benchmark ports selected for their documented sustainability and operating performance: Rotterdam, Antwerp-Bruges, Los Angeles, Singapore, and Tianjin Port. The purpose is not to estimate a causal econometric model. Rather, the study assesses whether the available evidence supports the proposition that sustainability can be transformed from a cost centre into a competitive capability.

The evidence base covers 2017–2026 and prioritises three source categories: peer-reviewed academic articles; official port authority publications and webpages; and institutional or industry reports from bodies such as the International Maritime Organization, UN Trade and Development, IAPH, ESPO, the World Bank, and the Maritime and Port Authority of Singapore. For Pakistani cases, official PQA and KPT webpages and performance pages were prioritised over media coverage wherever accessible. Where public official data remained partial, the latest verifiable figures were used and the limitation was stated.

Sampling was purposive rather than random. Rotterdam and Antwerp-Bruges were chosen because they integrate sustainability with European energy-transition strategy and publish relatively mature official material. Los Angeles was chosen because it offers a long-running, measurable shore-power programme and an emissions-inventory tradition linked to container growth. Singapore was chosen because its decarbonisation blueprint explicitly connects sustainability with hub-port competitiveness. Tianjin Port was added because it offers a Chinese benchmark for combining automation, digitalisation, renewable energy, and zero-carbon terminal positioning. PQA and KPT were chosen because they are the relevant Pakistani ports under study and because they represent different operational profiles: PQA is more industrial-cluster and energy oriented, whereas KPT is more urban, containerised, and general-cargo facing.

Analytically, the paper combines three techniques. The first is thematic synthesis of the academic literature on green-port competitiveness. The second is descriptive KPI extraction, focusing on throughput, TEU volume, vessel calls, disclosed investment scale, and named sustainability measures. The third is a comparative interpretive framework that distinguishes compliance value, efficiency value, and strategic value. Because public emissions and project-payback data for PQA and KPT are limited, the analysis is strongest on comparative and strategic dimensions and more tentative on quantified environmental return.

The design is appropriate for comparative policy analysis, but it has limitations. It depends on public-source transparency, which is uneven across ports. It does not attribute throughput changes causally to green investment. It also treats partial-year and recently published figures cautiously. These constraints do not negate the study's conclusions, but they narrow the strength of project-level financial inference for the Pakistani cases.

Analysis and Case Studies

Global Evidence on Whether Sustainability Is a Cost or Advantage

A useful way to interpret port sustainability is to ask what kind of value each initiative creates. Basic compliance systems, such as waste reception, sludge handling, pollution monitoring, and effluent treatment, create defensive value by reducing legal and environmental risk. Resource-efficiency systems, such as rooftop solar, efficient lighting, electrified equipment, and port-call optimisation, create operational value through lower cost and better reliability. Strategic systems, such as shore power, alternative-fuel infrastructure, green shipping corridors, public carbon targets, and high-quality ESG disclosure, create market-facing value by attracting users, finance, and partnerships. The literature broadly supports this progression from compliance to advantage (Alamoush et al., 2021; Cocuzza et al., 2025; Song, 2024).

Table 1: Indicative Sustainability Measures, Cost Profiles, Benefits, and KPIs

Sustainability measure	Typical cost profile	Main cost components	Main benefits	Typical KPIs
Waste reception and pollution control	Low to medium	Reception facilities, monitoring, training, collection and disposal contracts	Compliance, fewer incidents, social licence to operate	Waste receipts, spill incidents, MARPOL compliance
Rooftop or distributed solar	Low to medium	Panels, inverters, rooftop reinforcement, grid integration	Lower electricity cost, visible green positioning, partial resilience	Installed kW, kWh generated, payback period, avoided emissions
Effluent and sewerage treatment	Medium to high	Civil works, treatment systems, chemicals, sludge handling, O&M	Industrial-cluster attractiveness, lower discharge risk, environmental compliance	MGD treated, discharge quality, industrial uptime
Port-call optimisation and digital systems	Low to medium	Software, data integration, training, interoperability	Lower waiting time, lower fuel burn, smoother berth use	Vessel waiting time, turnaround time, berth productivity
Shore power	High	Grid reinforcement, substations, cables, ship retrofits, tariff design	Lower berth emissions and noise, regulatory readiness, customer retention	Connection rate, kWh sold, local pollutant reduction
Alternative-fuel bunkering and hydrogen infrastructure	Very high	Storage, safety systems, permitting, terminal retrofits, training	First-mover hub advantage, new revenue streams, corridor participation	Number of calls, fuel volumes, safety performance

Note. The synthesis is derived from review and economics literature on port sustainability, decarbonisation, digitalisation, and shore power, together with institutional guidance on port competitiveness and maritime decarbonisation (Bullock et al., 2023; Cocuzza et al., 2025; Song, 2024).

Benchmark Port Evidence

Rotterdam shows how a port can move from compliance toward strategic positioning. Official material records substantial investment while the port continues to develop shore-power strategies and wider energy-transition infrastructure. Rotterdam handled 435.8 million tonnes in 2024 and reported container growth to 13.8 million TEU, while continuing to frame sustainability as part of its long-term competitiveness and industrial transformation (Port of Rotterdam Authority, 2025a, 2025b, 2025c). This does not prove that sustainability alone caused commercial performance, but it shows that large-scale green positioning can coexist with high-volume port operations.

Antwerp-Bruges presents a similar pattern. Official material frames the port's ambition as reconciling economic performance, climate goals, renewable-electricity shore power, and hydrogen-hub positioning. The port handled 277.7 million tonnes in 2024 with strong container growth (Port of Antwerp-Bruges, 2023, 2025a, 2025b). The lesson is not that green policy automatically creates cargo. Rather, it is that energy-transition positioning can reinforce long-term attractiveness for industrial and logistics users.

Los Angeles provides a strong operational example. Its Alternative Maritime Power programme dates back to 2004 and has become one of the world's most established shore-power systems. The port's 2024 air-emissions inventory summary reports record container volume of 10.3 million TEU and major reductions in diesel particulate matter, sulphur oxides, and nitrogen oxides compared with the 2005 baseline (Port of Los Angeles, 2025, 2026). This case is useful because it shows that green infrastructure can mature from initial compliance and capital cost into operating credibility and public legitimacy.

Singapore represents sustainability as hub strategy. The Maritime Singapore Decarbonisation Blueprint sets out focus areas that include port terminals, harbour craft, future marine fuels, bunkering standards, carbon accounting, and green financing. Singapore has also pursued green and digital shipping corridors to link decarbonisation with continued hub relevance (Maritime and Port Authority of Singapore, 2022, 2026). In this case, sustainability is not one flagship project but a system-wide strategy for maintaining competitiveness in a changing maritime economy.

Tianjin Port adds an important Chinese benchmark. Official Chinese reporting describes Tianjin's intelligent zero-carbon container terminal as a smart-port project using 5G, artificial intelligence, autonomous driving, and cloud computing. The same source reports that the terminal involved investment of about 5.2 billion yuan and increased the operating efficiency of a single gantry crane by more than 40%, while reducing labour costs by 60% (State Council of the People's Republic of China, 2024). Tianjin's relevance for this paper is that it links green competitiveness with automation, renewable-energy use, and terminal productivity. It therefore offers a useful comparison for ports that want green transition to be treated not only as environmental compliance, but also as productivity improvement.

Port Qasim Authority

Port Qasim is a distinctive industrial-port ecosystem rather than a stand-alone maritime gateway. Official information describes 18 berths, annual handling capacity of 89 million tonnes, and a large industrial zone with more than 400 industrial and commercial units. PQA's current vision explicitly connects industrial productivity with climate resilience, blue-economy objectives, global maritime investment, and uninterrupted trade flow (Port Qasim Authority, 2026a, 2026b). Those features matter because PQA's sustainability challenge is inseparable from industrial ecology, water management, energy systems, land-use planning, and port-hinterland reliability.

PQA's latest accessible official performance series shows a commercially solid picture. In FY2024–25, the port handled 45.305 million tonnes in total and 1.003 million TEU, with 1,544 ships. Of the 45.305 million tonnes, 13.480 million tonnes were dry cargo, 19.091 million tonnes were liquid cargo, and 12.734 million tonnes were container tonnage. Relative to the stated 89-million-tonne annual capacity, this implies approximate cargo-capacity utilisation of 50.9%. Compared with FY2022–23's grand total of 40.375 million tonnes, the FY2024–25 total is approximately 12.2% higher (Port Qasim Authority, 2026c).

The sustainability side of the PQA case is strongest on environmental infrastructure, biodiversity, and industrial-environment management. PQA's Business and Biodiversity Platform, launched in December 2017 with IUCN and private-sector partners, is described as Pakistan's first such platform at Port Qasim. The Glow Green by PQA initiative focuses on afforestation planning, restoring native flora and ecosystem value, countering air pollution and heat-island effects, and improving public environmental awareness (Port Qasim Authority, 2026d). Conservation literature also reports that PQA has administrative control over approximately 64,000 hectares of mangrove forests, mud flats, and creeks in the Port Qasim area (Mangroves for the Future, 2016). This should be framed positively as ecological stewardship rather than merely as a regulatory responsibility.

PQA's disclosed pipeline contains meaningful environmental capital expenditure. Official listings and tender material refer to sewerage treatment plants, road lights, broader water and drainage works, and a 4.0 MGD combined effluent treatment plant with rehabilitation of an existing 1.3 MGD sewerage treatment plant or combined effluent treatment plant (Port Qasim Authority, 2026e, 2026f). These projects are not always presented as high-profile decarbonisation projects, but they are foundational for an industrial port. For PQA, environmental service infrastructure can support cleaner industrial activity, reduce discharge risk, improve investor confidence, and strengthen the port's long-term resilience.

On the basis of accessible public material, PQA can be described as moving from compliance and environmental management toward strategic green-port positioning. A balanced interpretation is preferable: PQA has credible sustainability assets, especially mangrove stewardship, biodiversity collaboration, and treatment-infrastructure planning, but it would benefit from clearer public KPI disclosure showing emissions baselines, project outcomes, avoided pollution, cost savings, and industrial-user benefits. Such disclosure would allow PQA to convert existing environmental work into a clearer market-facing competitive proposition.

Karachi Port Trust

Karachi Port Trust occupies a different operating context. Official material describes Karachi Port as the pioneer seaport of Pakistan and reports capacity to handle more than 125 million tonnes of cargo, including 4.25 million TEU. Karachi Port is deeply connected with the urban economy of Karachi and with national trade flows, which makes local air quality, harbour cleanliness, traffic efficiency, and visible energy transition especially relevant to its competitive and political environment (Karachi Port Trust, 2026a).

KPT's recent operating performance is strong. Public reporting based on port authority statements indicates that Karachi Port closed FY2024–25 with approximately 54 million tonnes of cargo and a record 2.65 million TEU, with 1,943 vessels handled. Dry cargo reached about 41.68 million tonnes, liquid bulk reached about 12.28 million tonnes, exports reached about 20.02 million tonnes, and imports reached about 33.93 million tonnes. Relative to stated cargo capacity of more than 125 million tonnes, throughput utilisation is approximately 43.2% (Business Recorder, 2025; Karachi Port Trust, 2026a). These figures suggest that KPT has a strong operating base from which green measures could be connected with service quality and customer confidence.

KPT's sustainability activity is visible and should be described in a constructive manner. On the compliance side, KPT's Marine Pollution Control Department was established in 1996 to address environmental issues in Karachi Harbour, an area of approximately 62 square kilometres. The department's continuing work in harbour cleanliness and marine-pollution control directly supports the port-city interface and public legitimacy (Karachi Port Trust, 2026b). On the energy side, KPT has commissioned distributed solar projects, including solarisation at KPT Izhar Abbasi Hospital and KPT Secondary School, Keamari, while additional on-grid solarisation at KPT Head Office has also been pursued through public procurement processes (Karachi Port Trust, 2025a, 2025b, 2025c).

KPT's planned wastewater-treatment work may become strategically important if it is implemented through a phased and financially sustainable model. A phased 100 MGD sewerage-treatment concept, with an initial 30 MGD phase, can support harbour water quality, protect marine assets from acidic pollutants, create treated effluent for industrial reuse and horticulture, and strengthen mangrove rehabilitation. If methane capture from sludge treatment is technically and financially viable, it may also reduce plant energy costs. This point should be presented cautiously as a potential sustainability and circular-economy benefit, subject to feasibility studies, statutory approvals, and disclosed project economics.

KPT also increasingly uses green-transition language in institutional messaging, including commitments around climate-risk assessment, green-port initiatives, smart transformation, mangrove rehabilitation, clean energy, and compliant bunkering services. This shows that KPT understands sustainability as part of future port strategy. The next step is to connect these commitments with measurable annual indicators, such as renewable generation, harbour waste collected, treated wastewater volume, avoided emissions, vessel turnaround indicators, and customer-service outcomes. Such indicators would help KPT convert visible green activity into a more systematic commercial and environmental programme.

Compared with benchmark ports, KPT appears to be in an intermediate stage: stronger than simple compliance, but not yet fully translated into an integrated public framework with recurring performance dashboards, decarbonisation pathways, and monetised business cases. This should not be framed negatively. KPT has a large container business, urban visibility, and active environmental initiatives. If these are linked to service reliability, cleaner port-city relations, and transparent customer-facing indicators, sustainability can become a genuine competitive lever rather than only a reputational add-on.

Comparative Reading of PQA and KPT

Table 2: Indicative Comparative Position of PQA and KPT

Dimension	Port Qasim Authority	Karachi Port Trust
Latest accessible official full-year used here	FY2024–25	FY2024–25
Total throughput	45.305 million tonnes	Approximately 54 million tonnes
Containers	1.003 million TEU	Approximately 2.68 million TEU
Vessel traffic	1,544 ships	1,943 ships
Stated annual capacity	89 million tonnes	More than 125 million tonnes and 4.25 million TEU
Approximate cargo-capacity utilisation	50.9%	44%
Cargo profile	More liquid- and energy-oriented; strong industrial-cluster integration	More dry-cargo and container oriented; stronger urban interface
Most visible green initiatives	Biodiversity platform, afforestation, waste reception, CETP/STP planning, climate-resilience vision	Marine pollution control measures. KPT also pursuing plantation of mangroves, wherein 100k mangroves will be planted within next one year (by June 2027) Establishment of new sewerage treatment plants of 30 MGD in phases, the estimated cost of phase-I amounts to Rs 30 Bn.
Publicly disclosed green or enabling capex in accessible sources	Rs. 1,000 million sewerage treatment plants; Rs. 90 million road lights; effluent-treatment tender	Port is pursuing Solar Power installation in various phases (Total 3.4 Mega Watt). In phase I, 512 kW solar power has been commissioned, whereas additional 506 Kw solar power installation in progress. In 2nd Phase, 1400 kW solar plants will be installed, thereby making total of 2.4 Mega Watt. Similarly, in Phase III, 01 Mega watt will be installed within KPT area of jurisdiction.
Current strategic position	Sustainability strongest as compliance and industrial-environment management, with emerging resilience framing	Sustainability strongest as visible urban greening and energy-efficiency signalling, with emerging green-port branding. Both the ports are investing in improvement of road infrastructure, rail connectivity and various decongestion measures.
Future outlook	More liquid- and energy-oriented; strong industrial-cluster integration	More dry-cargo and container oriented; stronger urban interface

Note. PQA data are based on official PQA performance and capacity information. KPT capacity is based on official KPT port-statistics information, while FY2024–25 throughput figures are based on public reporting of port authority statements. Utilisation calculations are author calculations based on stated capacity and reported throughput (Business Recorder, 2025; Karachi Port Trust, 2026a; Port Qasim Authority, 2026c).

The comparison suggests that both ports possess credible foundations for green competitiveness, although their routes are different. PQA's advantage is that its industrial-port setting makes water systems, effluent treatment, mangrove stewardship, and resilient utilities immediately relevant to industrial investors and land users. KPT's advantage is that its container orientation and urban location make visible improvements in clean energy, harbour water quality, air quality, and logistics transparency more likely to produce reputational, operational, and stakeholder returns.

The future outlook is positive if both ports sequence their investments carefully. PQA can use sustainability to strengthen its position as a climate-resilient industrial gateway, while KPT can use sustainability to improve cleaner port-city relations and container-service credibility. Both ports are already investing in road infrastructure, connectivity, decongestion, environmental management, and energy improvements. If these measures are tied to annual indicators and customer-facing reporting, sustainability can become a measurable competitive asset rather than a general policy statement.

Discussion

The evidence assembled here supports a qualified answer to the research question. Sustainability is initially a cost, but it becomes an advantage when ports move from isolated projects to integrated capability. This conclusion is strongest where official benchmark cases and the literature overlap: shore power, digital coordination, energy management, water treatment, environmental governance, and ESG disclosure impose capital and coordination costs, yet they can also improve future compliance, reduce selected operating costs, enhance local legitimacy, and support customer retention (Alamoush et al., 2021; Bullock et al., 2023; Song, 2024).

For advanced ports, sustainability has already shifted toward strategic advantage. Rotterdam and Antwerp-Bruges are embedding sustainability in energy-transition and industrial strategy. Singapore is embedding it in hub positioning and corridor diplomacy. Los Angeles demonstrates that legacy green investment can support strong present-day throughput and substantially lower emissions. Tianjin shows that smart-port automation and zero-carbon terminal strategy can be linked with productivity and labour-efficiency gains (Maritime and Port Authority of Singapore, 2022; Port of Antwerp-Bruges, 2025a; Port of Los Angeles, 2025; Port of Rotterdam Authority, 2025a; State Council of the People's Republic of China, 2024).

For PQA and KPT, the answer is transitional but encouraging. At present, sustainability is partly cost and partly emerging advantage. PQA's activities align most clearly with industrial-environment management, biodiversity, mangrove stewardship, and climate-resilient port-industrial planning. KPT's activities align most clearly with harbour pollution control, distributed solarisation, urban-interface improvement, and green-port branding. Both ports have the beginnings of a strategic platform.

The evidence supports a contingent proposition: sustainability becomes an advantage when three conditions are met. First, the port must measure and disclose it. Secondly, it must link green action to operations rather than treat it only as corporate social responsibility. Thirdly, it must align projects with the cargo mix and competitive position of the port. PQA should therefore emphasise industrial-environment services and resilient utilities, while KPT should prioritise energy efficiency, urban air quality, harbour cleanliness, and container supply-chain transparency.

In this context, container supply-chain transparency means that customers and regulators can see reliable information on cargo movement, vessel arrival and departure status, berth and gate performance, emissions-related indicators, and documentation flow. It does not mean exposing confidential commercial data. It means improving the visibility and reliability of port processes so shipping lines, terminal operators, transporters, importers, exporters, and regulators can plan better, reduce delays, and verify cleaner operations. For KPT, this is especially relevant because container users value predictability and because transparent operational information can support both competitiveness and environmental reporting.

Recommendations

Build a common Pakistan green-port KPI architecture. PQA and KPT should publish annual, comparable dashboards covering electricity use, renewable generation, waste handled, water and effluent metrics, vessel and berth emissions proxies, harbour-cleanliness indicators, project-level financial return, and relevant turnaround indicators. Without recurring KPI disclosure, sustainability will remain rhetorically valuable but commercially under-converted. Benchmark ports and institutions increasingly treat disclosure as part of competitiveness, not merely compliance (International Association of Ports and Harbors, 2026; UN Trade and Development, 2024).

Prioritise no-regret projects before headline projects. In this paper, "no-regret projects" means practical interventions that are useful even if future fuel rules, vessel technologies, or shipping-line demand change. Examples include distributed solar, efficient lighting, electrified internal equipment where feasible, environmental-service digitisation, wastewater treatment, harbour waste controls, and vessel or berth workflow optimisation. These projects usually have clearer local benefits, shorter learning cycles, and lower risk than immediate large-scale clean-fuel infrastructure. The literature repeatedly shows that high-capex measures such as shore power create benefits only when grid readiness, pricing, user demand, and supporting systems are aligned (Bullock et al., 2023; Economics of shore power under different access pricing, 2023).

Match green strategy to cargo structure. PQA should foreground industrial-water systems, combined effluent and sewerage treatment, biodiversity management, mangrove stewardship, and utility resilience because those are structurally tied to its industrial-cluster model. KPT should foreground clean electricity, pollution control, harbour water quality, urban-interface improvements, and eventually selective berth electrification where container and urban-air-quality benefits are highest. A single green roadmap is unlikely to fit both ports equally well.

Prepare selectively for shore power and future fuels, but do not copy flagship schemes without local feasibility work. The global direction of travel is clear under IMO and FuelEU pressures. However, the literature shows that infrastructure cost, power quality, tariff design, and user uptake determine the real return. Pakistan should therefore begin with feasibility studies, grid-readiness mapping, berth suitability assessment, and user-demand assessment. Grid-readiness mapping means checking whether the local electrical network, substations, transformers, cables, safety systems, and tariff structure can supply high-power vessels or terminal equipment reliably without disrupting existing operations. Berth suitability assessment does not mean replacing the normal first-come, first-served berthing principle. It means identifying which berths or terminals should be equipped first because they have repeated calls by compatible vessels, longer berth stays, stronger urban-air-quality benefits, adequate grid access, and clearer user demand.

Use sustainability to improve investment narratives. PQA already highlights a climate-resilient vision and a BOT or FDI development model. KPT already uses green-port messaging in conferences and public events. Both should now tie these narratives to concrete investor propositions: lower environmental risk, better utility reliability, cleaner industrial interfaces, improved stakeholder relations, and readiness for future shipping corridors. This is how sustainability begins to alter competitive perception rather than merely satisfy institutional expectation.

Institutionalise port-city and stakeholder governance. The literature increasingly shows that digital infrastructure, public concern, disclosure, and collaborative governance strengthen port sustainability outcomes. KPT's urban context and PQA's industrial-community context both require stakeholder-oriented sustainability, not only engineering-led sustainability. Mangrove restoration, biodiversity work, harbour cleaning, pollution control, and wastewater treatment should therefore be incorporated into structured port-community governance rather than being presented as isolated programmes.

Develop a positive public communication framework. Because PQA and KPT are national assets and essential trade gateways, the paper should avoid language that appears accusatory or dismissive. A balanced formulation is more appropriate: both ports have taken meaningful steps and possess different green-competitiveness strengths, but both would benefit from more systematic disclosure, integrated planning, and outcome-based reporting. This phrasing recognises progress while still making a defensible academic argument.

Conclusion

The most defensible answer to the paper's title question is this: sustainability in ports is a cost if it remains narrow, reactive, and unmeasured; it becomes an advantage when it is operationalised, disclosed, and strategically aligned with cargo, energy, regulation, customer demand, and stakeholder legitimacy. The world's leading green ports already treat sustainability as part of competitiveness. PQA and KPT are moving in that direction, although their pathways are different.

For PQA, the route to advantage lies in turning environmental infrastructure, mangrove stewardship, biodiversity collaboration, and climate resilience into a stronger industrial-port value proposition. For KPT, the route lies in converting visible green initiatives into a broader clean-energy, pollution-control, wastewater-treatment, harbour-quality, and container-service strategy. In both cases, the decisive next step is measurement. Once the ports can show not only what they are doing, but also what those actions are delivering in cost, reliability, environmental performance, stakeholder confidence, and customer value, sustainability will cease to be viewed mainly as expense and will begin to function as competitive capital.

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