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Integrating Blue Economy and Green Technology Innovation to Drive Sustainable Economic Development in Coastal Regions: A Systematic Literature Review

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ABSTRACT

Coastal regions have increasingly faced dual pressures from ecological degradation and socio-economic vulnerability under accelerating climate change. While marine resource utilization has historically driven regional output, conventional extractive practices have depleted marine biodiversity and weakened shoreline resilience. This study investigated the synergistic integration of blue economy principles and green technology innovation to foster sustainable economic development across coastal regions. A systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses protocol across major scientific databases covering the 2016 to 2026 period. Forty peer-reviewed primary studies were systematically screened, appraised, and synthesized using thematic content analysis. The findings revealed that integrating green technologies into blue economy sectors operated through three primary pathways: marine renewable energy and decarbonized port logistics, smart eco-aquaculture coupled with bio-circular fishery valorization, and digital monitoring of blue carbon ecosystems. These technological interventions significantly enhanced household income stability, resource efficiency, and carbon sequestration capacity. However, structural barriers including green financing gaps, fragmented maritime governance, and technological disparities among artisanal fishers constrained widespread adoption. Ultimately, harmonizing marine spatial planning with inclusive green finance and community-based technological capacity building remained essential to achieving resilient coastal economic transformation.

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INTRODUCTION

Coastal and archipelagic regions represent critical engines of global economic activity, supporting food security, international maritime trade, renewable energy generation, and coastal livelihoods for more than three billion people worldwide (Lubchenco et al., 2020; World Bank, 2017). Despite their immense socio-economic value, conventional marine development trajectories have historically prioritized short-term resource extraction over long-term ecological carrying capacity. Overfishing, industrial marine pollution, unregulated coastal urbanization, and the destruction of critical habitats such as mangroves, seagrass meadows, and coral reefs have severely eroded natural capital across coastal territories (Jouffray et al., 2020; Halpern et al., 2019). Furthermore, accelerating anthropogenic climate change—manifested through sea-level rise, ocean acidification, and extreme hydro-meteorological events—disproportionately threatens the economic resilience of small-scale fishers and coastal micro-enterprises (Allison et al., 2020; Barbier, 2017). Addressing this dual crisis

requires a fundamental paradigm shift from extractive ocean exploitation toward regenerative economic models that reconcile economic growth with marine ecosystem integrity.

In response to these escalating challenges, the concept of the blue economy has emerged as a prominent macroeconomic and environmental governance framework aimed at decoupling socio-economic development from marine environmental degradation (Silver et al., 2015; Voyer et al., 2018). Grounded in the United Nations Sustainable Development Goals—particularly *Sustainable Development Goal* 14 (*Life Below Water*) and *Sustainable Development Goal* 8 (*Decent Work and Economic Growth*)—the blue economy seeks to optimize the economic benefits of marine resources while ensuring social equity and ecological regeneration (Bennett et al., 2019; Cisneros-Montemayor et al., 2021). However, empirical evaluations of blue economy initiatives over the past decade indicate that policy rhetoric often outpaces operational implementation. Without transformative technological upgrading, traditional marine sectors such as capture fisheries, coastal aquaculture, and maritime shipping remain locked into carbon-intensive and waste-generating production structures (jouffray et al., 2020; Brent et al., 2020). Consequently, the transition toward a genuinely sustainable coastal economy necessitates the systematic integration of green technology innovation across marine value chains.

Green technology innovation encompasses a broad spectrum of environmentally sound engineering, digital, and biotechnological solutions designed to minimize carbon footprints, eliminate industrial waste, and restore ecological functions (Du et al., 2019; Acemoglu et al., 2016). Within coastal and marine settings, green technologies include offshore renewable energy systems (wind, wave, tidal, and floating solar photovoltaics), *Internet of Things* water-quality sensors for precision eco-aquaculture, circular biorefineries that convert fishery by-products into high-value biomaterials, and satellite remote sensing for blue carbon ecosystem accounting (Macreadie et al., 2021; Rowan, 2023; Caruso et al., 2020). Recent literature demonstrates that deploying green technologies within maritime sectors can substantially reduce post-harvest losses, lower fossil fuel dependency among artisanal fishing fleets, and generate novel revenue streams through verified carbon credits and bio-circular products (Gephart et al., 2021; Lovelock & Duarte, 2019). Nevertheless, existing scholarly investigations largely examine blue economy governance and green technological engineering within isolated disciplinary silos.

A critical review of previous literature reveals a pronounced fragmentation between macroeconomic studies on coastal livelihood resilience and technical studies on clean marine engineering. For instance, while Voyer et al. (2018) and Bennett et al. (2021) analyzed institutional governance and social justice dimensions within the blue economy, their frameworks did not systematically evaluate how specific green technologies alter micro-level productivity and ecological efficiency. Conversely, engineering reviews by Copping et al. (2020) on marine renewable energy and Henriksson et al. (2021) on sustainable aquaculture technologies focused predominantly on technical feasibility and life-cycle emissions without addressing coastal institutional readiness, financing mechanisms, or rural livelihood adoption barriers. The novelty and originality of this study lie in bridging this interdisciplinary gap by synthesizing a decade of empirical and conceptual scholarship (2016–2026) into a unified analytical framework that links green technology innovation directly to blue economy governance and coastal sustainable economic development. Specifically, this study aims to map the thematic evolution of blue-green synergy literature, identify high-impact technological and business governance models that enhance coastal economic resilience without degrading marine ecosystems, and formulate strategic policy directions to overcome structural adoption barriers in coastal regions. The findings contribute theoretically to sustainable development economics and practically to policymakers, coastal planners, and green finance institutions designing inclusive maritime transitions.

RESEARCH METHODS

This study employed a qualitative research design using the *Systematic Literature Review* methodology guided by the updated 2020 *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* protocol (Page et al., 2021). The systematic review approach was selected to ensure methodological transparency, replicability, and objective synthesis of multidisciplinary evidence connecting blue economy governance, green technology innovation, and sustainable coastal economic development. The research population comprised all peer-reviewed scientific articles published in international academic databases examining the intersection of marine economic development and

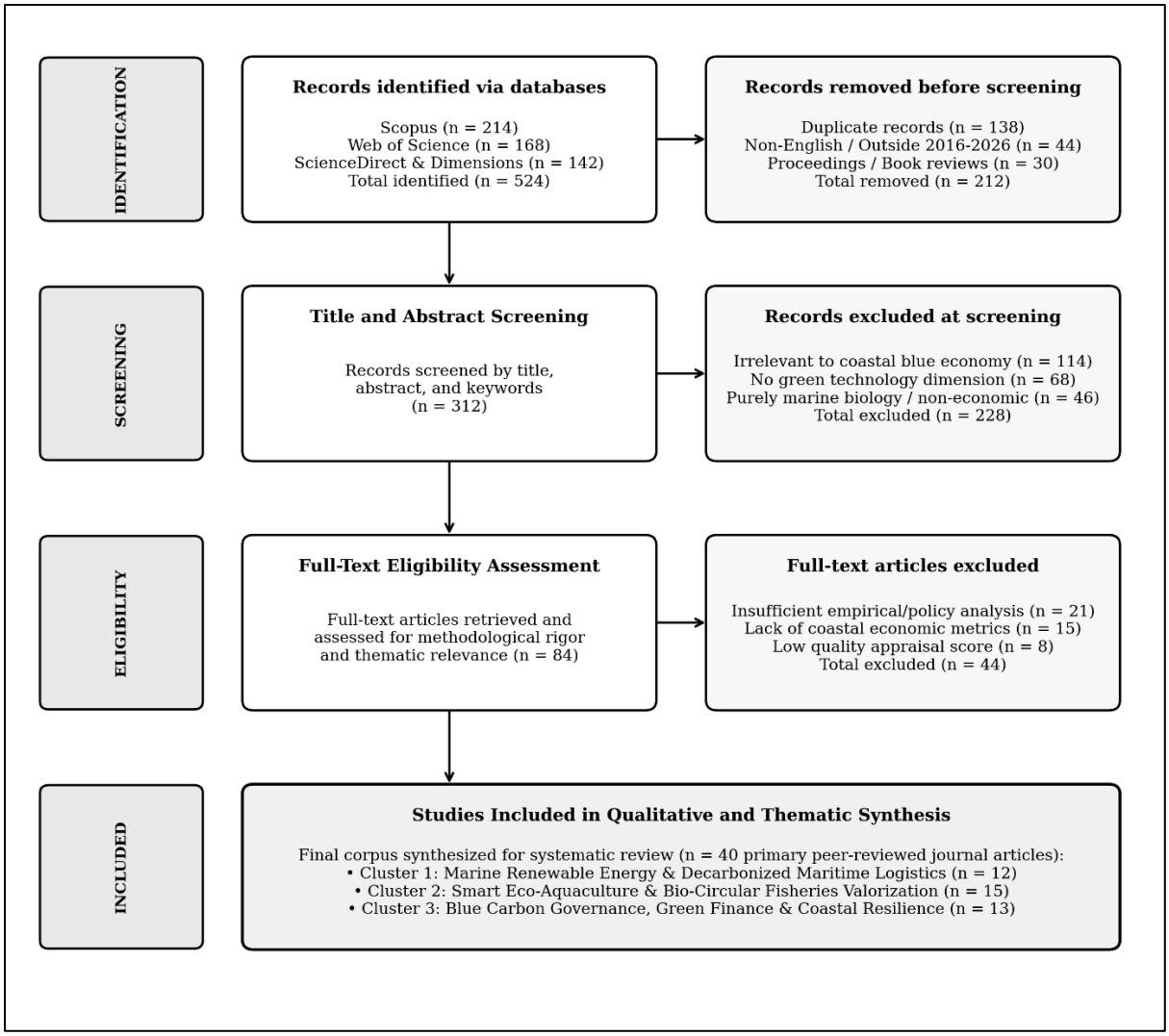
environmental technology. To capture the post-Paris Agreement and Sustainable Development Goals implementation era, the publication timeframe was strictly bounded to the last ten years, spanning from January 2016 to March 2026.

Literature identification was executed across four major scholarly databases—Scopus, Web of Science, ScienceDirect, and Dimensions—using structured Boolean search strings combining three core lexical clusters: ("blue economy" OR "ocean economy" OR "coastal economy" OR "marine economy") AND ("green technology" OR "eco-innovation" OR "clean technology" OR "renewable energy" OR "circular bioeconomy" OR "smart aquaculture") AND ("sustainable economic development" OR "coastal resilience" OR "sustainable livelihoods" OR "blue carbon"). The initial database query yielded 524 records, which were subsequently processed through a four-stage screening protocol as illustrated in Picture 1.

Table 1 Inclusion And Exclusion Criteria For Literature Selection

No	Criterion Dimension	Inclusion Criteria	Exclusion Criteria
1	Publication Timeframe	Peer-reviewed articles published between January 2016 and March 2026	Articles published prior to 2016
2	Document Type	Original empirical research, policy evaluations, and rigorous conceptual papers in journals	Conference abstracts, book reviews, editorials, grey literature, and unpublished theses
3	Language	Full-text manuscript written in English	Non-English publications without verified translations
4	Thematic Relevance	Studies explicitly examining the integration of green technologies within blue economy sectors and coastal economic outcomes	Studies focusing purely on marine biology, oceanography, or terrestrial green economy without coastal economic linkages
5	Methodological Quality	Clear research design, validated analytical framework, and robust empirical or policy evidence	Articles with ambiguous methodology or insufficient analytical depth

As detailed in Table 1, explicit inclusion and exclusion criteria were enforced during screening. In the first phase (Identification), 212 records were removed prior to screening due to duplication across databases (138 records), language or timeframe non-compliance (44 records), and non-journal document formats (30 records). In the second phase (Screening), the titles, abstracts, and keywords of the remaining 312 articles were evaluated by two independent reviewers, leading to the exclusion of 228 articles that lacked an explicit coastal economic or green technology focus. In the third phase (Eligibility), 84 full-text manuscripts were retrieved and subjected to rigorous quality appraisal using the Joanna Briggs Institute critical appraisal checklist, resulting in the exclusion of 44 articles due to insufficient empirical coastal metrics or weak methodological rigor. Ultimately, 40 high-quality primary journal articles constituted the final research sample for synthesis. Technical data analysis was performed using a two-stage approach: descriptive bibliometric mapping to examine publication trends and geographical distribution, followed by inductive and deductive thematic content analysis (Miles et al., 2014) to categorize technological interventions, economic outcomes, and institutional governance barriers into structured analytical clusters.



Picture 1 PRISMA Flow Diagram Of The Systematic Literature Selection Process

RESULTS AND DISCUSSION

Thematic Distribution and Bibliometric Mapping of the Synthesized Corpus

The systematic evaluation of the 40 selected primary studies revealed a marked acceleration in scholarly attention toward the integration of blue economy frameworks and green technology innovation over the 2016–2026 decade. During the early phase (2016–2019), academic output averaged only 2.2 articles per year (accounting for 22.5% of the corpus), reflecting an nascent exploratory stage primarily focused on defining blue economy boundaries following the 2015 United Nations Sustainable Development Summit (Voyer et al., 2018; Silver et al., 2015). However, between 2020 and 2026, publication volume expanded substantially, accounting for 77.5% (31 articles) of the reviewed corpus. This surge aligned directly with global post-pandemic green recovery initiatives, the launch of the *United Nations Decade of Ocean Science for Sustainable Development* (2021–2030), and heightened urgency surrounding coastal climate adaptation (Lubchenco et al., 2020; Cisneros-Montemayor et al., 2021). Geographically, empirical investigations were concentrated in the Indo-Pacific and Southeast Asian archipelagic regions (35.0%), the European Union and North Atlantic basin (30.0%), Small Island Developing States across the Caribbean and Pacific (20.0%), and multi-regional global comparative assessments (15.0%).

Table 2 Thematic Classification And Distribution Of The Synthesized Literature (N = 40)

No	Thematic Cluster	Core Green Technology Innovations	Primary Blue Economy Sub-Sectors	Number of Studies (n)	Percentage (%)	Key Representative References
1	Marine Renewable Energy and Decarbonized Maritime Logistics	Offshore wind, wave/tidal energy, solar cold-chain storage, green port cold-ironing, hybrid fishing vessels	Maritime transport, port operations, artisanal capture fisheries	12	30.0%	Copping et al. (2020); Iris & Lam (2019); Sovacool et al. (2022); Weiss et al. (2018)
2	Smart Eco-Aquaculture and Bio-Circular Fisheries Valorization	IoT water sensors, AI precision feeding, IMTA systems, marine biorefineries (chitosan, collagen, bio-feed)	Coastal mariculture, brackish-water aquaculture, seafood processing MSMEs	15	37.5%	Gephart et al. (2021); Henriksson et al. (2021); Rowan (2023); Caruso et al. (2020)
3	Blue Carbon Governance, Digital Monitoring, and Green Finance	Satellite remote sensing, drone LiDAR mapping, blockchain carbon registries, blue bonds, blue sukuk	Mangrove and seagrass conservation, eco-tourism, coastal spatial governance	13	32.5%	Macreadie et al. (2021); Lovelock & Duarte (2019); Vanderklift et al. (2019); Friess et al. (2022)

As presented in Table 2, thematic synthesis classified the 40 primary studies into three distinct yet interconnected operational clusters. The largest cluster, comprising 15 studies (37.5%), investigated smart eco-aquaculture and bio-circular fisheries valorization, underscoring the critical role of food-system transformation in coastal economies. The second largest cluster encompassed 13 studies (32.5%) centered on blue carbon ecosystem governance, digital monitoring technologies, and innovative green financing mechanisms. The third cluster included 12 studies (30.0%) examining marine renewable energy integration and the decarbonization of maritime port and fishing logistics. Across all three clusters, methodological approaches in the primary literature were dominated by quantitative econometric and life-cycle assessment models (45.0%), mixed-methods case studies (32.5%), and qualitative policy and institutional analyses (22.5%).

Synergistic Pathways of Green Technology Innovation in Blue Economy Sectors

The first operational pathway identified in the literature involves the deployment of marine renewable energy and clean propulsion technologies to decarbonize coastal energy systems and maritime logistics. Coastal and island communities frequently suffer from high energy costs and severe vulnerability to fuel supply disruptions due to reliance on imported diesel generators and fossil-fueled fishing vessels (Sovacool et al., 2022). Synthesized studies demonstrated that integrating offshore wind, wave, and tidal energy converters with decentralized solar photovoltaic micro-grids provides reliable clean electricity for coastal industrial hubs and remote fishing villages (Copping et al., 2020; Weiss et al., 2018). In the maritime logistics sub-sector, Iris and Lam (2019) documented that implementing green port technologies—specifically shore-to-ship electrification (*cold-ironing*), automated energy-management systems, and electrified cargo handling equipment—reduced port-area greenhouse gas emissions by 25% to 45% while improving operational turnaround efficiency. At the micro-economic level, deploying solar-powered cold-chain storage and hybrid electric propulsion for small-scale artisanal fishing fleets reduced post-harvest spoilage by up to 30% and lowered daily fuel expenditures

by 20% to 35%, directly strengthening household net incomes in developing coastal regions (Gephart et al., 2021; Bennett et al., 2021).

The second pathway centers on the technological transformation of coastal aquaculture and fishery processing through digital precision tools and circular bioeconomy engineering. Conventional intensive mariculture and brackish-water shrimp farming have historically contributed to coastal eutrophication, antibiotic pollution, and mangrove conversion (Henriksson et al., 2021). By contrast, recent empirical studies confirmed that adopting *Internet of Things* dissolved-oxygen and pH sensors coupled with artificial intelligence automated feeding systems reduced feed conversion ratios by 15% to 28% and curtailed nutrient effluent discharge by over 35% (Rowan, 2023; Naylor et al., 2021). Furthermore, biological engineering innovations such as *Integrated Multi-Trophic Aquaculture*—which co-cultivates fed finfish with inorganic nutrient-extractive seaweeds and organic-extractive bivalve mollusks—created self-remediating coastal production loops that diversified farmer revenue streams and buffered against single-species disease shocks (buck et al., 2018; Gephart et al., 2021). Equally transformative is the rise of marine biorefinery technologies that valorize seafood processing waste (shells, skin, bones, and viscera, which normally constitute 40% to 60% of raw catch weight) into high-margin biopolymers, pharmaceutical-grade chitosan, marine collagen, and organic aquafeed ingredients (Caruso et al., 2020; Coppola et al., 2021). These circular production models simultaneously eliminate coastal organic waste dumping and generate rural agro-industrial employment, particularly for women-led coastal micro-enterprises.

The third pathway links digital environmental monitoring technologies with natural capital accounting to monetize blue carbon ecosystems, including mangroves, tidal salt marshes, and seagrass beds. Although coastal vegetated ecosystems sequester carbon up to ten times faster per unit area than terrestrial tropical forests and provide indispensable storm-surge protection, their economic value has traditionally remained unpriced in regional development accounts (Lovelock & Duarte, 2019; Barbier, 2017). The synthesized literature highlighted how advances in high-resolution satellite remote sensing, unmanned aerial vehicle *Light Detection and Ranging* mapping, and artificial intelligence biomass estimation have drastically reduced the transaction costs of measuring, reporting, and verifying coastal carbon stocks (Macreadie et al., 2021; Pham et al., 2019). When paired with transparent digital registries and *Payment for Ecosystem Services* governance frameworks, these verification technologies enable coastal communities and municipal governments to access international voluntary carbon markets, sovereign blue bonds, and Islamic green financial instruments such as *blue sukuk* (Vanderklift et al., 2019; Friess et al., 2022). Empirical evidence from Indonesia, Kenya, and the Caribbean demonstrated that community-managed blue carbon projects supported by digital monitoring generated sustainable annuity revenues that funded local health, education, and eco-tourism infrastructure while halting coastal deforestation (Cisneros-Montemayor et al., 2021;Friess et al., 2022).

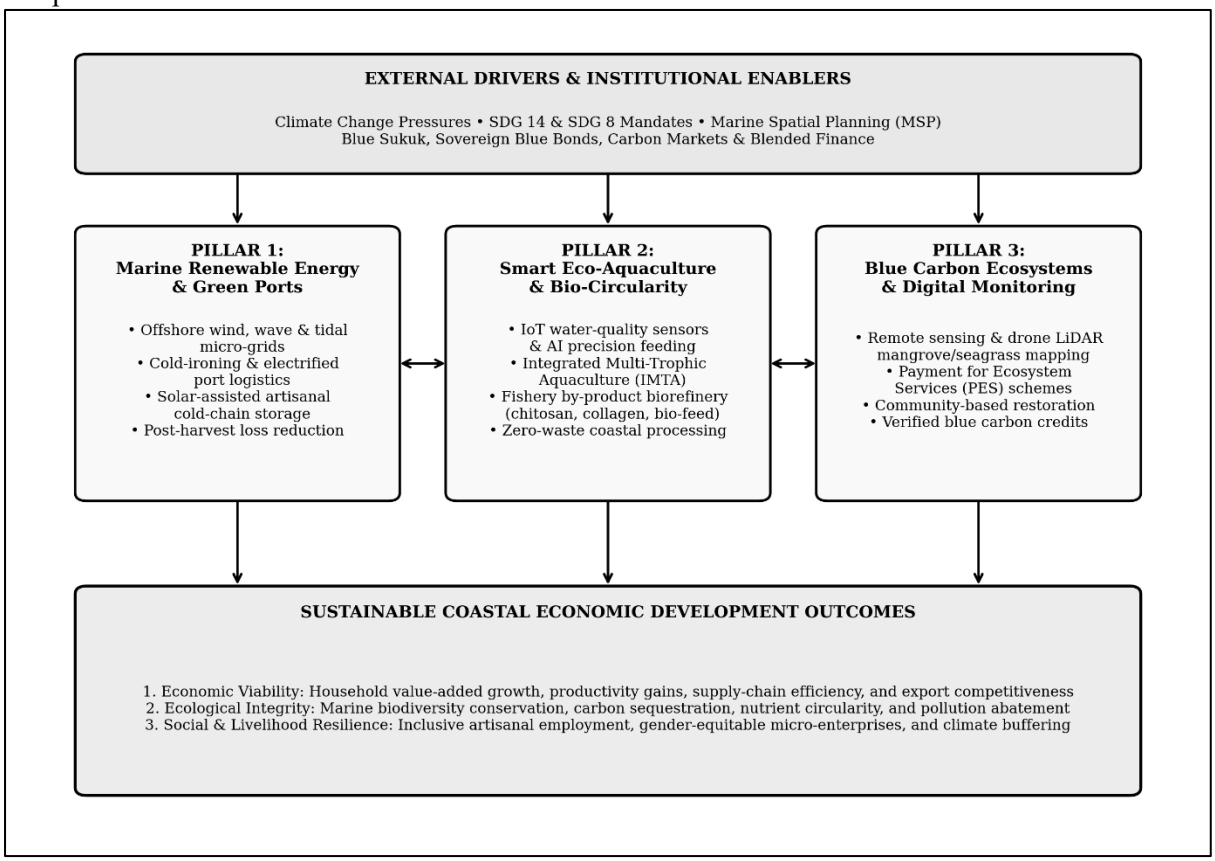
Table 3 Synthesis Of Green Technology Interventions, Economic Impacts, And Governance Challenges

No	Analytical Dimension	Technological Mechanism	Sustainable Economic Impact	Ecological & Resilience Benefit	Primary Adoption Barriers
1	Energy & Maritime Logistics	Offshore renewables, solar micro-grids, port cold-ironing, hybrid vessels	20%–35% fuel cost savings; 30% reduction in post-harvest fish spoilage	25%–45% abatement in port and fleet greenhouse gas emissions	High upfront capital intensity; lack of rural coastal grid interconnectivity
2	Smart Aquaculture & Bio-Circularity	IoT water monitoring, AI feeding, IMTA co-culture, marine waste biorefineries	15%–28% feed efficiency gain; high-value revenue from chitosan and collagen	>35% reduction in nutrient runoff; zero-waste fishery processing loops	Digital literacy gaps among smallholders; fragmented cold and waste supply chains
3	Blue Carbon & Natural Capital	Satellite/drone LiDAR MRV, digital carbon	Diversified community income via	Enhanced shoreline stabilization, biodiversity	Unclear coastal tenure rights; high MRV certification costs for small projects

	registries, PES and blue sukuk	carbon credits and eco-tourism	habitat, and carbon sinks

Theoretical Linkages, Comparative Analysis, and Structural Barriers

The empirical patterns summarized in Table 3 align closely with foundational theories in environmental and development economics. Viewed through the lens of the *Sustainable Livelihoods Approach* and ecological modernization theory, green technology innovation acts as a structural catalyst that converts natural capital constraints into physical, financial, and human capital gains (Allison et al., 2020; Du et al., 2019). Rather than validating a passive trade-off between economic growth and environmental preservation, the synthesized evidence demonstrates that targeted technological upgrading shifts the coastal production possibility frontier outward. This finding corroborates the microeconomic hypothesis of Porter and van der Linde (1995), confirming that stringent environmental governance, when paired with green innovation incentives, stimulates resource efficiency and export competitiveness in marine industries.



Picture 2 Integrated Conceptual Framework Of Blue Economy And Green Technology Synergy

However, comparing the technological optimism of engineering studies with the critical socio-institutional literature reveals significant contradictions and structural bottlenecks. While technical evaluations by Copping et al. (2020) and Rowan (2023) projected seamless scalability for offshore energy and smart aquaculture, socio-economic field evaluations by Bennett et al. (2019, 2021) and Brent et al. (2020) warned of "blue grabbing" and technological marginalization. Specifically, when capital-intensive green technologies and marine spatial zones are deployed through top-down corporate concessions without community co-management, artisanal fishers are frequently displaced from traditional fishing grounds and excluded from high-tech value chains. Across the reviewed corpus, three structural barriers consistently impeded inclusive blue-green integration. First, a severe green financing gap persists: commercial banks perceive coastal smallholders and marine clean-tech startups as high-risk borrowers due to climate exposure and lack of collateral (Sumaila et al., 2021; Vanderklift et al., 2019). Second, institutional fragmentation across ministries of fisheries, environment, energy, and maritime transport generates conflicting spatial permits and regulatory delays (Voyer et al., 2018; Lombard et al., 2019). Third, pronounced deficits in digital literacy and technical vocational capacity

across rural coastal populations limit the local maintenance and absorption of advanced green technologies (Cisneros-Montemayor et al., 2021). As synthesized in Picture 2, overcoming these bottlenecks requires an integrated policy architecture that embeds technological deployment within participatory *Marine Spatial Planning*, blended green finance (combining public grants, microfinance, *waqf* or philanthropic endowments, and blue bonds), and localized university-industry-community extension programs.

CONCLUSION

The systematic synthesis of 40 peer-reviewed studies published between 2016 and 2026 confirmed that integrating green technology innovation into blue economy sectors is indispensable for achieving sustainable economic development in coastal regions. The synergy between marine economic governance and clean technology operates primarily through three transformative pathways: decarbonizing maritime logistics and artisanal cold chains via marine renewable energy, upgrading coastal aquaculture and seafood processing through smart digital sensors and circular biorefineries, and monetizing blue carbon ecosystems using high-precision remote sensing and innovative green financial instruments. Collectively, these interventions enhance coastal household income stability, resource productivity, and ecological resilience against climate change. Nevertheless, technological deployment alone cannot guarantee equitable development outcomes; without inclusive institutional safeguards, capital-intensive maritime innovations risk exacerbating socio-economic inequalities among small-scale coastal producers. Consequently, regional policymakers and development planners must harmonize participatory marine spatial planning with accessible blended green financing and community-centered technological capacity building to ensure a socially just, ecologically regenerative, and economically resilient coastal future.

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