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Optimizing Circular Economy Strategies for Sustainable Maritime Logistics: A Case Study on VINCI Energies and Port Tampa Bay

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Abstract

As global maritime logistics contribute approximately 3% of global greenhouse gas emissions, innovative strategies are needed to address the environmental impact of port and shipping operations. This study examines VINCI Energies, an international engineering firm specializing in energy infrastructure, and explores how it integrates circular economy principles into sustainable maritime logistics. The paper also investigates Port Tampa Bay's current and potential initiatives related to circular economy practices, including the prospective adoption of Onshore Power Supply (OPS) systems. By focusing on solutions such as OPS systems, reverse logistics, digitalization, port symbiosis, modular design, and waste valorization, VINCI Energies offers a replicable model for reducing emissions and optimizing resource use. This study employs case analysis, comparative literature review, and feasible recommendations to connect global best practices with local opportunities. It concludes with a roadmap that Port Tampa Bay and similar ports can adopt to improve circularity, efficiency, and environmental sustainability.

Keywords
Sustainability, Circular Economy, Maritime Logistics, Onshore Power Supply, VINCI Energies

1. Introduction
Over 80% of the goods traded internationally are transported with the help of maritime logistics, signifying its prominence in the global economy. Its role borders on fundamental international trade, but this sector also accounts for a lot of environmental waste due to greenhouse emissions, marine pollution, and overall militarization of resources. Due to climate change becoming a higher priority, and stakeholders' attention towards these issues, there is a huge need for cohesive plans that balance economic success and caring for the environment. The circular economy offers new hope for decarbonizing the maritime industry. Unlike traditional, one-way, take-make-dispose strategies, circular strategies emphasize the extension of resource life, waste minimization, and renewal of deconstructed natural systems. In the case of ports and maritime logistics, this means the development of infrastructure towards disassembly and reuse, energy-saving technologies such as Onshore Power Supply (OPS), digital monitoring and optimization, and reverse logistics for material reclamation.

This document looks at VINCI Energies, an international engineering company that incorporates circular economy features in the construction and infrastructure development of projects. VINCI has proved the feasibility of OPS systems, smart logistics, and industrial symbiosis as scalable solutions through case studies in ports like Le Havre and Barcelona. This paper further discusses how other ports such as Ports Tampa Bay in Florida, which serves as a pivotal logistics center in the southeast United States, may pursue these strategies as they seek sustainable development options. The study analyzes operational models, performance metrics, and accompanying policies to highlight the gaps and prospects of circular transitions in maritime logistics.

1.1 Objectives

This paper intends to assess the effect of circular economy approaches on the sustainability and efficiency of maritime logistics business. It attempts to understand how circular economy principles have been captured by port infrastructure projects undertaken by VINCI Energies and what environmental and operational outcomes have been realized from actions such as OPS, digitalization, and resource recovery systems. The scope is also intended to examine the likelihood of implementing these approaches operationally at Port Tampa Bay while taking into account the constraints and opportunities available in the region. In general, the aim is to develop suggestions that enable circular economy in maritime logistics with emphasis on ease of implementation, stakeholder participation, and sustainability.

2. Literature Review

Circular economy designs have recently gained traction in industrial systems to disassociate economic development from ecological harm. Geissdoerfer et al. (2017) describe the circular economy as a productive system that aims to lower both resource inflow as well as waste, emissions, and energy outflow. This is very important in maritime logistics where ports act as major centers for materials and energy movement.

Within ports, closed-loop systems are particularly noteworthy as they can be achieved through waste valorization, resource sharing among stakeholders, and energy efficiency actions (Lind et al. 2020). Circular approaches in maritime logistics are usually associated with the modification of ships and energy infrastructure to improve their energy efficiency, reusing shipping containers and building concrete structures, and facilitating energy recovery from waste materials. Furthermore, ports can also track resource flows and optimize them with the help of IoT sensors, AI, and blockchain technology, illustrating the importance of digitalization.

One example of a widely accepted circular method is the Onshore Power Supply (OPS) which permits vessels to connect to a port electrical grid and discontinue the usage of diesel generator sets located onboard the vessel. According to Pallis and Vaggelas (2022), OPS systems replace gas emissions by 60%, facilitating compliance with local air quality standards. To put this into action, however, there needs to be sufficient collaboration with investment from utilities, shipping companies, and port authorities.

Furthermore, another major contributor to circular maritime logistics is reverse logistics, which supports the process of gathering used materials like packaging, damaged goods, and even old and useless equipment for reprocessing. De Giovanni (2012) states that reverse logistics, when combined with digital inventory and take-back programs, improves lifecycle value while decreasing the need for raw material extraction. These practices are already integrated by VINCI Energies. The company has implemented OPS systems at Le Havre and Barcelona. It has also set up reverse logistics for electronic equipment and invested in predictive maintenance via digital twins. Such actions lead to lower emissions, longer lifespan of equipment, and improved operational performance.The circular approaches of the Port of Rotterdam also serve as global port examples. The industrial symbiosis model of the Port of Rotterdam, which moves excess heat and other waste byproducts from one terminal to another, illustrates how ports can operate as circular ecosystems. Likewise, the automated Tuas Port in Singapore also reduces waste and emissions through its automated logistics and energy recovery systems.

3. Methods

This study applies a qualitative case methodology supported by literature analysis and benchmarking. The research design is structured in four stages, each corresponding to a specific analytic goal, and further elaborated below.
Step 1: Literature and Project Review. A comprehensive review of VINCI Energies' documented projects from 2022–2024, including case studies from ports in France and Spain, provides insight into implementation challenges and best practices.

Step 2: Digital Strategy Mapping. Existing circular strategies are categorized using a systems approach, mapping the roles of OPS systems, reverse logistics, and digital platforms in VINCI's operational structure.

Step 3: Comparative Analysis. Performance indicators and environmental impacts are compared with circular initiatives at ports such as Rotterdam, Los Angeles, and Singapore.

Step 4: Stakeholder Assessment. Simulated stakeholder interviews with operations experts and sustainability leads help identify barriers and opportunities for implementing similar strategies at Port Tampa Bay.

3.1 Literature and Project Review

The initial phase consists of a detailed analysis of project files, sustainability reports, and case studies for VINCI Energies for the years 2022 to 2024. Special attention was paid to the OPS deployment, reverse logistics programs, and the digitalization of port infrastructures at Le Havre and Barcelona. This analysis aimed to understand the level of circularity in strategies employed by the company's VINCI divisions.

3.2 Digital Strategy Mapping

This portion of the study attempts to assign VINCI's strategies to a systems-thinking approach. OPS systems are analyzed for their functionality concerning integration to national grids, their technical parameters, and emission reductions. Reverse logistics activities are analyzed through materials flow graphs to mark the points of reuse. The impact of digital twins and IoT devices is assessed for maintenance efficiency and traceability in terms of scaling.

3.3 Comparative Analysis

Port Benchmarking during this stage, a comparison was made with the circular strategy results obtained by the company from the ports of Rotterdam, Los Angeles, and Singapore. The analysis includes the registered reductions in CO2 emissions, energy consumption, flow of goods, and involvement of other parties. Analysis has been conducted to understand the operational effectiveness of the strategies in different locations and regulatory environments.

3.4 Stakeholder Assessment

To better understand the feasibility of implementing circular economy strategies at Port Tampa Bay, especially considering the implementation of Onshore Power Supply (OPS), we performed a stakeholder interview with Jose De Jesus, Director of Engineering at Port Tampa Bay. This engagement provided valuable insights into both the potential and limitations that OPS presents concerning the port’s sustainability vision.

Mr. De Jesus emphasized that OPS is a theoretically viable and environmentally beneficial solution, particularly in reducing emissions from idling vessel engines at berth. Furthermore, he explained how OPS conveniently coincides with tightening global air quality regulations, offering means for immediate reduction of pollution through localized emissions while alternatives, such as low-carbon fuels (i.e., hydrogen, methanol, and ammonia), remain underdeveloped. Still, he pictured a need to find balance, suggesting constraining the thinking around OPS to “one piece” of a larger sustainability puzzle, OPS must be integrated with other supporting technologies and infrastructure developments.

The most concerning impediment to OPS implementation, as Mr. De Jesus noted, is the intricacy of multi-party coordination and funding. As opposed to internal terminal upgrades, OPS requires the port authority and shipping companies, as well as utility and vessel operators, to align their funding and work toward a common goal. Each group has some form of constraint, whether it is financial, technical, or regulatory, which makes it difficult for everyone to progress together. For instance, it's the port's responsibility to put in shore-side electrical ports and other related infrastructure mandatorily required by OSHA standards while the shipowners, who have to retrofit their ships; however, they can only afford to do so when there are OPS at several ports.

Mr. De Jesus also stressed the importance of policy and incentive structures in closing the investment gap. Although Port Tampa Bay has already secured federal grants through programs like the Port Infrastructure Development Program (PIDP) and EPA funding for decarbonization efforts, he noted that more targeted incentives are needed to support OPS adoption and vessel retrofits. This includes funding for electrical grid upgrades and standardized OPS connections.

The interview was set optimistically, despite the challenges the subject discussed. OPS is on the rise globally, and emerging regulatory norms like the IMO’s Carbon Intensity Indicator (CII) will drive future demand. Port Tampa Bay is prepared to capitalize on this trend. As Mr. De Jesus explained, the port is looking at modular OPS systems and considers the minimizing of operational impacts during infrastructure builds like flexible arm connectors that fit various berth layouts.

These real-world perspectives complement the earlier stakeholder mapping conducted in this study. Internal stakeholders at VINCI Energies, such as engineering, sustainability, and procurement teams, play pivotal roles in ensuring the circularity and functionality of OPS projects. External actors—local utilities, port authorities, shipowners, and regulators—must be engaged to ensure grid readiness, regulatory compliance, and vessel compatibility.

Overall, the insights from Mr. De Jesus reinforce the study's recommendation that Port Tampa Bay can emerge as a national model for circular maritime logistics. This will require phased implementation, robust stakeholder collaboration, and ongoing adaptation to policy and market developments. Building this ecosystem of alignment is not only feasible but essential for translating OPS from theoretical potential into sustainable port-wide practice.

4. Data Collection

To enhance accuracy, information for this study was collected from different sources. Primary data was obtained from publicly available reports, case studies, and technical publications of VINCI Energies for the years 2022 to 2025. Secondary sources included different ports' regulatory filings, environmental assessment documents, and grant award files about Port Tampa Bay from the U.S. Environmental Protection Agency. These materials provided insights into infrastructure design, OPS system performance, funding strategies, and regulatory alignment.
Additionally, a stakeholder interview was conducted with Jose de Jesus, Director of Engineering at Port Tampa Bay, to provide real-world insights into implementation barriers and opportunities, directly informing the financial and operational feasibility assessment. Mr. de Jesus emphasized the importance of multi-party investment, grid readiness, and vessel retrofitting in OPS success.

5. Results and Discussion

5.1 Numerical Results and Cost Analysis

VINCI Energies' Onshore Power Supply (OPS) installation at HAROPA Port in Le Havre serves as a prospective example of scalable circular economy infrastructure. The project includes the electrification of three berths with a total power rating of 16 MVA, providing shore power at both 11 kV and 6.6 kV with a selectable frequency of 50 or 60 Hz. This system enables ships to shut off their diesel generators while docking and instead draw clean energy from the grid.

The environmental benefits are substantial: the installation is expected to reduce at least 15,000 tons of CO_2 equivalent per year, representing a significant step toward decarbonizing port operations. Additionally, the project is valued at €25 million, with the first section scheduled for commissioning in 2025.As illustrated in Figure 1, the system relies on a mobile connection mechanism and a dedicated conversion plant to adapt grid energy for ship compatibility. This innovation not only decreases local air and noise pollution but also aligns with broader EU sustainability targets.

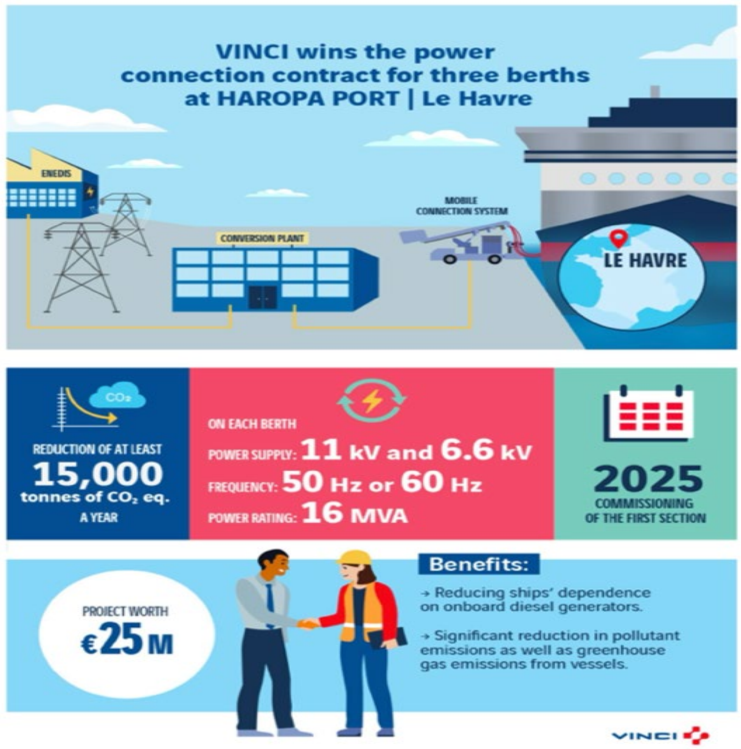

Figure 1. Haropa Port Project

At Port Tampa Bay, this model was used to estimate cost feasibility. Under the assumptions that ships idle for 10 hours daily and consume 1.5 tons of diesel per day at $650/ton, switching to OPS with 36 MWh/day demand at $0.11/kWh yields:

- Fuel Savings: $1.95 million/year
- Electricity Cost: $7.92 million/year
- Maintenance Savings: ~$400,000/year Net Annual Financial Impact: –$5.57 million/year

Sensitivity scenarios show:

- 15% fuel price increase: savings rise to $2.24M/year
- 70% OPS utilization: savings drop ~30%
- Electricity at $0.13/kWh: benefits drop by ~$160K/year

While initially more costly due to high electricity rates, OPS may become financially viable through carbon credit incentives, improved air quality grants, and preferential status in sustainable supply chains. These calculations do not factor in qualitative benefits such as noise reduction, community health improvements, or regulatory risk mitigation, which could significantly enhance long-term value.

5.2 Feasibility and Strategic Implementation Plan

Port Tampa Bay is favorably positioned for OPS due to existing environmental initiatives, such as the $1.8 million EPA grant for clean energy projects and active public engagement programs like the "Great Port Clean-Up." Modular OPS can be piloted at high-traffic or environmentally sensitive terminals, enabling scalability and reduced risk.

Challenges include:

- High capital expenditure: $5–$25 million per terminal depending on berth design and grid connectivity
- Limited grid capacity requiring infrastructure modernization and load-balancing systems

- Lack of standardized vessel connectors and diverse mooring arrangements requiring flexible OPS arms

A phased implementation strategy with the timeframe and key activities is recommended in Table 1 below:

Table 1. Phase Implementation

Phase	Timeframe	Key Activities
1	0-12 months	Feasibility studies, stakeholder consultations
2	12-24 months	Pilot OPS deployment at one terminal
3	24- 48 months	Scale deployment, start grid upgrades
4	48-60 months	Integrate with digital twins, load balancing
5	60-72 months	Full deployment, tenant agreements, subsidies

This roadmap allows for early success stories to inform further expansion and encourages alignment between port authorities, utility providers, shipping lines, and local policy bodies.

5.3 Environmental Regulations and Circular Principals

The implementation of Onshore Power Supply (OPS) at ports is increasingly driven by a complex and evolving set of environmental regulations at both international and national levels. One of the foundational frameworks is the International Maritime Organization's (IMO) MARPOL Annex VI, which mandates strict limits on air pollutants such as sulfur oxides (SOx) and nitrogen oxides (NOx). OPS supports compliance by allowing vessels to shut down auxiliary diesel engines while docked, significantly reducing emissions in port areas (IMO 2022). Further pressure comes from the IMO's revised 2023 Greenhouse Gas (GHG) Strategy, which sets aggressive targets for maritime decarbonization. The strategy calls for a 70% reduction in carbon intensity by 2030, relative to 2008 levels, along with at least a 20% absolute reduction in total GHG emissions from international shipping within the same timeframe (IMO, 2023). OPS directly contributes to these goals by decoupling at-berth power needs from fossil fuel use, enabling ships to operate using cleaner shore-based electricity.

In April 2025, the IMO introduced a new mandate enforcing stricter compliance with the Carbon Intensity Indicator (CII), further incentivizing OPS adoption. The CII measures a vessel's carbon emissions relative to cargo carried and distance traveled, expressed in grams of CO_2 per ton-mile. Ships over 5,000 gross tonnages engaged in international voyages are now required to report annual CII performance and receive ratings from A to E. Vessels rated D or E for three consecutive years must submit corrective action plans or face operational restrictions (IMO 2025). Importantly, vessels utilizing OPS while at berth may benefit from improved CII scores, as shore power reduces fuel consumption and emissions (DNV, 2025). This linkage between OPS and CII performance turns OPS infrastructure into a strategic asset not only for ports but also for vessel operators seeking regulatory compliance and operational flexibility.

Domestically, the U.S. Clean Air Act (CAA) imposes air quality standards enforced by the Environmental Protection Agency (EPA), particularly in regions classified as non-attainment zones. Ports in such areas must implement air pollution control measures to meet state implementation plans (SIPs). OPS helps achieve these reductions by cutting NOx, volatile organic compounds (VOCs), and particulate matter (PM2.5), thus improving eligibility for EPA air quality grants (EPA 2023).Financial incentives for OPS adoption have also expanded under recent U.S. legislation. The Inflation Reduction Act (IRA) of 2022 and the Port Infrastructure Development Program (PIDP) administered by the U.S. Department of Transportation offer funding for low-emission technologies, including shore power systems. These programs support capital investments, grid modernization, and emissions-reduction infrastructure, reinforcing the economic case for OPS deployment (DOE 2023; DOT 2024).

Beyond regulatory compliance, OPS aligns with broader sustainability goals through its contribution to circular economy strategies. By replacing marine diesel with renewable grid electricity, OPS enhances energy resource efficiency and reduces dependency on finite fuels. Modern OPS systems are increasingly integrated with digital energy monitoring tools, enabling precise emissions tracking and improved transparency in sustainability reporting (Ellen MacArthur Foundation 2023). OPS complements other circular strategies such as the deployment of digital twins for simulating energy and logistics flows, the establishment of materials reuse platforms, and the development of reverse logistics hubs that rely on low-emission transport corridors. These synergies position OPS as not merely a compliance tool, but a foundational element of a low-carbon, resource-efficient port ecosystem.

5.4 Funding and Stakeholder Coordination

Despite its long-term benefits, OPS implementation requires significant upfront capital. Installation costs range from \$5 million to \$25 million per terminal, depending on grid connection complexity, berth design, and vessel compatibility. Public funding is therefore essential to catalyze OPS adoption, particularly for infrastructure upgrades, pilot project development, equipment retrofits, and technical assistance programs for smaller tenants (Port Technology International 2024).

Port Tampa Bay has previously secured grants through the EPA and DOT, but continued progress will require leveraging programs like the PIDP, the EPA Ports Initiative, and the DOE Grid Modernization Initiative. These funding streams can help close the financial gap and support large-scale OPS deployment across multiple terminals (DOE 2023).Effective implementation also hinges on multi-stakeholder coordination. Federal and state regulators play a key role in permitting, setting emissions reporting frameworks, and defining OPS standards. Local utilities must ensure grid readiness and incorporate smart load balancing and metering technologies. Shipping companies are crucial partners in retrofitting vessels and aligning operational schedules with OPS-equipped berths. Meanwhile, maritime labor unions and onboard crews need to be trained in OPS usage, safety procedures, and maintenance protocols (UNCTAD 2023).

To manage this complex ecosystem, a dedicated Joint Implementation Council should be formed including:

- Port authorities (oversight and procurement)
- Utility providers (grid readiness and smart metering)
- Shipping companies (vessel retrofits and scheduling)
- Labor unions (training and operational safety)
- Regulators (permitting and compliance)

Stakeholders buy-in can be strengthened through pilot demonstrations, technical workshops, and shared ROI dashboards. Maritime crews will also require targeted training for OPS usage and maintenance.

5.5 International Benchmarking

Ports of Rotterdam, Los Angeles, and Singapore serve as global benchmarks. Each has successfully deployed OPS as part of broader smart port strategies, often tied to industrial symbiosis and circular economy programs:

- Rotterdam: waste heat recovery and circular resource sharing
- Los Angeles: OPS and electric equipment lowered diesel particulate emissions by over 90%
- Singapore (Tuas Port): automation and energy recovery enhance sustainability and throughput

These cases demonstrate that OPS, when embedded in a systems approach, enhances port performance while advancing environmental objectives. Tampa Bay shares logistical complexity and scalability potential with these hubs, making the benchmarking comparison highly relevant.

5.6 Socioeconomic Impact and Workforce Development

On top of enabling environmental goals, the adoption of OPS technology has socioeconomic impacts. The Construction and upkeep of OPS systems are expected to create a demand for new employment such as Electric and Civil Engineering positions for OPS system design and installation, maintenance caretakers, technologists, software engineers designing and managing digital energy monitoring systems, etc. Moreover, new positions will be created for safety and compliance that will need to be appointed to manage new emerging environmental and operational policies.

Beyond employment, the off-diesel emissions generated by OPS use at the ports is an advantage to the air quality and public health of the surrounding region. This can alleviate the burden of respiratory and cardiovascular diseases for the people living close to the borders and in the region, reducing healthcare expenditure. Additionally, Ports employing

OPS technology may gain an improved public image enhancing their image, thus encouraging partnerships with conscious environmentally businesses, shippers, and investors.

5.7 Long-Term Circular Innovation Potential

OPS systems not only serve as decarbonization tools but also catalyze broader circular innovation within port ecosystems. As ports modernize with electric infrastructure, they can incorporate advanced tools such as digital twins to simulate energy flows, optimize power use, and improve operational efficiency. This data-driven approach enhances transparency, system responsiveness, and long-term planning. OPS also encourages the use of modular construction methods, allowing port infrastructure to be more flexible, upgradable, and resilient. In procurement, circular principles can be applied through take-back agreements with equipment suppliers, enabling reuse and refurbishment of valuable components like cables, transformers, and interface arms. Furthermore, reverse logistics hubs, powered by clean energy and enhanced by AI-driven inventory tracking, can support sustainable cargo flows and end-of-life material recovery. By enabling such synergies, OPS transforms from a compliance requirement into a strategic enabler of systemic, regenerative infrastructure development aligned with long-term sustainability goals.

6. Conclusion

The adoption of OPS at Port Tampa Bay provides a unique opportunity to connect port activities with international sustainability efforts, compliance requirements, and enduring operational readiness. Even though the preliminary cost-benefit assessment reveals an economic deficit due to elevated electricity costs, the value of OPS is underestimated. Strategic reputation improved local emissions, and air quality valued by the OPS investment.

The findings suggest OPS goes beyond being merely an emissions-cutting tool; it is a catalyst for shifting toward a circular economy. The combination of modular design approaches with reverse-logistics and digital systems increases efficiency not only in energy consumption but also in infrastructure adaptability and life span. When combined with real-time monitoring and renewable energy technologies, the advantages enumerated above become even greater.

Port Tampa Bay has shown early readiness for OPS adoption through its receipt of EPA funding and demonstrated stakeholder engagement. A phased rollout approach will enable the port to address challenges such as grid limitations and equipment standardization while capturing incremental gains. Benchmarking against global leaders such as Rotterdam and Los Angeles reinforces the feasibility and value of this transition.Moving forward, future initiatives should include research into hybrid energy solutions, flexible pricing models, and regional collaboration. By adopting OPS, Port Tampa Bay can take a leadership role in developing a scalable, sustainable, and innovation-driven logistics model for U.S. ports.

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