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# Accelerating Port Electrification in Singapore and Asia

**By Victor Nian, Jun Yuan, Jude Lee**

Centre for Strategic Energy and Resources

POLICY BRIEF

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## Highlights

1. Electrification brings visible environmental and health benefits through greenhouse gas and pollutants reductions while serving as an additional driver for power sector decarbonisation.
2. Without proper emission attribution, shore power could 'undo' nearly one-third of port decarbonisation gains by shifting ships' emissions to ports.
3. Shore power mandates and cost restructuring (tariffs and carbon pricing) are needed to close the cost gap.
4. Blended finance and stronger demand signals are required to break the port-ship investment deadlock.
5. Regional coordination and standardisation are key to enabling green corridors and accelerating shore power adoption.

## Summary

Port electrification is essential to reducing greenhouse gas and air pollutant emissions while maintaining the prestigious status of Singapore as a global maritime hub, as shipping lines increasingly prioritise "green port" capabilities in routing decisions. In addition to managing rapid increase in demand assuming a fully electrified port by 2035, high upfront costs and a persistent port–ship investment deadlock continue to delay adoption. Without proper emission attribution, shore power risks shifting emissions to the power sector and undermining decarbonisation gains. Decisive policy signals, cost restructuring, and coordinated investment are required to unlock deployment at scale.

## What's the issue?

Singapore's Maritime and Port Authority (MPA) and port operators have explicit decarbonisation goals tied to electrification. Both major terminal operators, PSA Corporation and Jurong Port, aim to reduce total greenhouse gas (GHG) emissions from port operations by at least 60 per cent by 2030 versus 2005 levels, with an ultimate target of net-zero emissions by 2050.[1] In 2024, MPA announced that all new harbour craft operating in port waters must be fully electric, capable of using B100 biofuels, or compatible with net-zero emission fuels from 2030 onward.[2] Flagship projects, such as the development of Tuas Port, are central to this vision. As one of the world's largest automated ports, Tuas is deploying electric Automated Guided Vehicles (AGVs) and quay cranes, with infrastructure designed to integrate smart grid management and battery energy storage

[1] Maritime and Port Authority of Singapore. *Maritime Singapore Decarbonisation Blueprint: Working towards 2050*. Maritime and Port Authority of Singapore, 2022.

[2] Maritime and Port Authority of Singapore. "Singapore gears up to meet net-zero needs of shipping," April 17, 2024.

systems. To promote clean shipping, since 2011, MPA has implemented financial incentives like the Maritime Singapore Green Initiative, including a pledge of up to S$100 million over five years to encourage early adoption of zero and near-zero emission technologies and fuels.[3]

Beyond decarbonisation objectives, these developments have direct implications for Singapore's competitiveness as a global maritime hub, particularly when port electrification is increasingly shaped by three interrelated structural challenges: (i) a global regulatory uncertainty that weakens investment decisions, (ii) a coordination deadlock between ports and shipowners, and (iii) rising system-level energy constraints. These challenges together limit the pace and scale of deployment.

A recent study led by the Centre for Strategic Energy and Resources (CSER) further highlights that aggressive electrification could significantly reshape the port's energy profile. Assuming a pathway towards full electrification, Singapore's ports could experience more than a twofold increase in electricity demand. This growth is driven by large-scale deployment of electric cranes, AGVs and their charging systems, and the expansion of onshore power supply (OPS). However, the transition to a fully electrified port remains complex, shaped by evolving global policy and regulatory frameworks on maritime decarbonisation, industry attitude, and perceived economic and technical barriers. This creates a risk of misaligned investment pathway, where infrastructure may be either underbuilt, constraining growth, or overbuilt and underutilised.

At the global level, the regulatory context is defined by the International Maritime Organization's (IMO) 2023 GHG Strategy, which sets ambitious targets to reduce total annual greenhouse gas emissions from international shipping by at least 20 per cent, striving for 30 per cent, by 2030, and by at least 70 per cent, striving for 80 per cent, by 2040, compared to a 2008 baseline.[4]

While the strategy encourages the provision of OPS from renewable sources, it does not yet mandate it globally. There is no regulation committing to creating sufficient demand certainty for OPS deployment at scale. This creates a critical "regulatory gap" which in practice means that ports and shipowners lack clear, long-term signals on whether and when investments will be utilised, delaying infrastructure investment and coordinated deployment.

This uncertainty was exacerbated in October 2025 when the IMO voted to delay the adoption of its comprehensive Net-Zero Framework, which includes a global carbon pricing mechanism by one year, pushing its earliest possible enforcement to March 2028.[5] This delay postpones the strong market signal needed to justify massive, coordinated investments in OPS infrastructure by ports and shipowners alike. In the absence of a unified global mandate, regional regulations, particularly the European Union's FuelEU Maritime initiative, risk becoming the de facto standard, potentially complicating

[3] Maritime and Port Authority of Singapore. "Maritime Singapore Green Initiative." March 25, 2026.
[4] International Maritime Organization. "2023 IMO Strategy on Reduction of GHG Emissions from Ships." July 7, 2023.
[5] International Maritime Organization. "Marine Environment Protection Committee (MEPC 82)." 30 September – 4 October 2024.

compliance pathways for a global hub like Singapore. This delay further weakens the interlinks among regulation, investment and OPS deployment.

Findings from the CSER study suggest that regulatory uncertainty directly affects infrastructure timing decisions. Given that peak hourly electricity demand under a full electrification pathway could experience a more than three-fold increase, delays in global carbon pricing signals may discourage timely investment in grid capacity and OPS systems, thereby exacerbating long-term transition risks. This highlights a growing risk of "misaligned timing," where infrastructure development lags behind future demand, potentially leading to bottlenecks and higher long-term system costs.

The environmental benefit of port electrification is contingent on the source of electricity. Due to geographical limitations, Singapore has very limited options to scale up domestic renewable energy supply.[6] With a target to deploy at least 2 gigawatt-peak (GWp) of solar energy by 2030, only a small fraction of Singapore's energy demand can be met.[7] As such, Singapore turns to clean energy imports as part of its decarbonisation strategy in which Singapore plans to import approximately 6 GW of low-carbon electricity by 2035, which is about one-third of projected demand.

This approach, however, creates a dual risk nexus. First, it exposes Singapore's decarbonisation goals to the political, regulatory, and infrastructural timelines of partner countries, creating potential delays. Second, it introduces new energy security vulnerabilities, shifting dependency from diversified fossil fuel imports to specific cross-border electricity transmission lines, which could be susceptible to geopolitical or technical disruptions.

This constraint becomes more critical when viewed against projected demand growth. CSER's study shows that Singapore port's electricity consumption alone is expected to exceed 600 GWh annually by 2035, with strong linear coupling between throughput growth and energy demand over the outlook period of 2026 to 2035. This implies that electrification not only shifts energy type but also significantly amplifies total electricity requirements, intensifying reliance on imported low-carbon electricity and increasing exposure to external energy supply risks. In the absence of sufficient low-carbon energy, the shift towards shore power introduces an emerging emissions accounting challenge, where emissions may be transferred from ships to the power sector.

At the industry level, the rollout of OPS faces a classic coordination problem between ports and shipowners, creating a persistent investment deadlock. Retrofitting vessels for OPS requires significant upfront investment with long payback periods,[8] discouraging shipowners in the absence of widespread infrastructure availability. Many owners are reluctant to commit these funds when the availability of OPS infrastructure at ports

[6] Ministry of Sustainability and Environment. "Energy Reset." Singapore Green Plan 2030, February 2021.
[7] Energy Market Authority. "The Future of Singapore's Energy Story." Press release, October 29, 2019.
[8] Bouman, Evert A., Elizabeth Lindstad, Agathe I. Rialland, and Anders H. Strømman. "State-of-the-Art Technologies, Measures, and Potential for Reducing GHG Emissions from Shipping – A Review." *Transportation Research Part D: Transport and Environment* 52 (2017): 408–421.

along their key trade routes remains patchy and utilisation is uncertain.

Conversely, port authorities view the high capital expenditure for electrical infrastructure, including high-voltage grid connections, substations, and berth-side equipment as a significant financial risk if utilisation remains low. The business case for OPS is highly sensitive to utilisation rates, with payback periods extending significantly if usage is low.[9] This deadlock is gradually being broken by regional mandates in places like California and the EU, which force adoption. Furthermore, an increasing number of new-build vessels, especially in the container and cruise segments, are being constructed as "OPS-ready," which will gradually expand the potential user base. However, for a global port like Singapore, serving a diverse fleet where many vessels may not be retrofitted for years, stimulating demand remains a key challenge.

This reflects a classic "chicken-and-egg" problem: ports hesitate to invest without assured demand, while shipowners delay retrofits without reliable infrastructure availability.

Findings from the CSER study reinforce this coordination challenge from a utilisation perspective. The economic viability of OPS and electrified systems is highly dependent on utilisation rates. The study shows that shore power demand alone is expected to increase to about 48 GWh by 2035. Yet insufficient vessel-side adoption could lead to underutilisation of infrastructure in the early phases, further weakening investor confidence and delaying investment decisions.

Beyond coordination issues, port electrification confronts immediate, practical barriers. The capital costs are substantial and multi-faceted. For ports, expenses include not only the OPS infrastructure itself but also the necessary reinforcements to the local electrical grid with High Voltage Shore Connection systems which are required to power large container vessels and other major ships (typically drawing more than 1 MVA power) while at berth.[10] For terminal operators, electrification of land-side equipment remains costly with battery-electric terminal tractors projected to remain 14–34 per cent more expensive than their diesel alternatives by 2030, partly due to productivity losses from charging downtime.[11]

From a technical standpoint, while the physical connection interfaces are relatively standardised globally, there are differences in voltage and frequency across different countries and ports which may require a "universal converter". However, the critical lack of standardisation lies with communication protocols between ships' onboard systems and shore-based systems (preventing "plug-and-play" operations), operational rules (such as cross border settlement and fault attribution), and regulatory frameworks (such as harmonised mandatory requirements). These cost and technical challenges, while manageable in the long term, reinforce the

[9] ShipUniverse. "Port Power Wars: Who Controls the Electrical Future of Shore Power? – Ship Universe," May 19, 2025.
[10] Sustainable Ships. "Overview of Shore Power Sockets and Plugs - IEC/IEEE 80005 — Sustainable Ships." Sustainable Ships, January 23, 2025.
[11] Makkonen, Jesse, and Joseph Moore. "Port Electrification – The Challenges and Opportunities of an Electrified Port Industry." Kempower, December 18, 2024.

need for early policy intervention to de-risk investment and accelerate standardisation.

Finally, demand side management for a diverse fleet of electric equipment, from cranes and AGVs to trucks and vessels, for optimised load profile management in the context of 24/7 carbon-free energy is becoming an increasingly important topic for countries with net-zero commitment, like Singapore. This underscores the importance of integrating port electrification into broader energy system planning, rather than treating it as a standalone infrastructure issue.

Beyond upfront costs, the study by CSER highlights both the economic potential and financial burden of electrification. Under a full electrification scenario, cumulative operational savings could reach approximately S$320 million by 2035 as compared to a reference scenario based on the current electrification target. In addition, rising carbon tax trajectories (up to S$115/t by 2035) further improve the economic case, with net present carbon tax savings estimated at S$30 million in Singapore's context.

However, these benefits come at the expense of significantly higher capital expenditure. Infrastructure investment under full electrification could reach approximately S$2.53 billion based on peak power demand, compared to about S$1.58 billion under a more gradual transition scenario. Notably, peak-load-driven investment requirements far exceed those estimated based on total energy consumption, with annual investment potentially surging to over S$600 million by 2035.

# Why is this important?

Accelerating port electrification is a critical, multi-faceted imperative for Singapore. It is essential to improve air quality and protect public health, while safeguarding Singapore's position as a global maritime hub, as shipping lines increasingly prioritise "green port" capabilities in routing decisions. It is also central to ensuring regulatory compliance, future-proofing economic leadership, and building a resilient energy ecosystem. Failure to act decisively risks ceding Singapore's hard-won position as a premier global maritime hub.

From a public health and environmental perspective, the primary local benefit of port electrification is the dramatic reduction of air pollution in addition to GHG emissions. Ships at berth run auxiliary diesel engines, emitting notable amounts of air pollutants including nitrogen oxides, sulphur oxides, and particulate matter directly into the densely populated portside environment. [12] These pollutants are linked to serious respiratory and cardiovascular diseases. Switching to OPS, eliminates these harmful emissions at the source which directly supports the health objectives outlined in Singapore's Green Plan 2030 and aligns with global trends where port cities are enacting strict Emission Control Areas to protect their citizens.

[12] Hall, William J. "Assessment of CO2 and Priority Pollutant Reduction by Installation of Shoreside Power." *Resources, Conservation and Recycling* 160 (2020): 104883.

CSER's study further confirms these benefits based on emission modelling analysis. Under a full electrification scenario, diesel consumption is projected to decline to zero by 2035, completely eliminating local air pollutants. Compared to a partial electrification pathway, this could reduce approximately 73 kt of $CO_2$ emissions annually by 2035, while achieving full elimination of local pollutants. The public health co-benefit provides a powerful justification for the significant infrastructure investment required. This is one of the most immediate and politically salient benefits of electrification.

From a competitiveness perspective, green port capabilities are rapidly becoming a decisive factor in global shipping network decisions. This is increasingly reflected in routing decisions, as shipping lines favour ports that can provide reliable, low- and zero-emission services as part of their decarbonisation strategies.

Major shipping lines like Maersk and CMA CGM have set ambitious net-zero targets and are actively selecting port partners based on their ability to provide low- and zero-emission services.[13] Ports in North America (e.g., Los Angeles, Long Beach) and Europe (e.g., Rotterdam, Hamburg) are already making multi-billion-dollar investments in OPS and electrified equipment. Failure to keep pace risks not only carbon leakage but also long-term erosion of Singapore's hub status as traffic shifts to better-prepared ports. This would directly threaten transhipment volumes, maritime services revenue, and the entire ecosystem of ancillary businesses.

Conversely, leadership in electrification could allow Singapore to export its expertise, standards, and other sustainable port solutions, creating new economic opportunities.

From a regulatory perspective, Singapore's maritime sector operates within an increasingly stringent global regulatory framework. Electrification is not an optional future pathway but a necessary compliance strategy.

The IMO 2023 GHG Strategy sets binding checkpoints for the international shipping fleet, including a 40 per cent reduction in carbon intensity by 2030 and a commitment to reach net-zero GHG emissions by or around 2050. While OPS is not yet a global mandate, it is explicitly recognised as a key supportive measure for ports to facilitate ship-level compliance. Access to low- or zero-carbon OPS is a critical component of shipping lines' compliance strategy to meet their operational carbon intensity requirements while in port.

Regional regulations are moving faster and will directly impact Singapore's competitive landscape. The European Union's FuelEU Maritime regulation, part of the "Fit for 55" package, will mandate the use of OPS or equivalent zero-emission technologies for container and passenger ships at major EU ports from 2030. As a global hub, a significant portion of Singapore's vessel calls are on routes to or from Europe. Shipping lines will

[13] Psaraftis, Harilaos N., and Christos A. Kontovas. "Decarbonization of Maritime Transport: Is There Light at the End of the Tunnel?" Sustainability 13, no. 1 (December 29, 2020): 237.

increasingly factor port green credentials into routing decisions, favouring ports that offer compliant, seamless green services to avoid penalties and meet their own corporate targets.

These regulatory developments clearly underscore the need for policy signals to create demand certainty so as to enable infrastructure investment and scaling.

Domestically, port electrification is the linchpin for achieving the targets set forth in the MPA's Maritime Singapore Decarbonisation Blueprint. The MPA's mandate for all new harbour craft to be fully electric, B100 biofuel, or net-zero fuel compatible from 2030 creates an internal ecosystem that can help accelerate portside electrification. As such, electrification is no longer optional but a necessary compliance pathway under tightening global and regional regulations.

From an energy systems perspective, port electrification can become more than a sizable load on the national grid, which can also contribute to grid stability and innovation. Furthermore, the strong correlation between throughput growth and electricity demand highlights that ports can serve as stable, large-scale electricity off takers. This predictable demand profile supports long-term power import agreements and enhances the financial viability of regional renewable energy projects, reinforcing Singapore's broader energy transition strategy.

Ports are large, flexible energy consumers. Through smart energy management systems, port operations can be optimised to act as a "grid-responsive" load. Charging of electric cranes, AGVs, and vessels can be scheduled during periods of low national demand or high renewable output. Furthermore, large-scale battery energy storage systems installed at ports can store cheap or excess renewable energy and discharge it during peak periods, providing valuable grid-balancing services and reducing strain on the centralised network.

Singapore's strategy to import 6 GW of low-carbon electricity by 2035 requires stable, high-capacity off-takers. A large-scale electrified port provides a predictable, baseload demand for this green power, improving the business case for import projects and ensuring the imported electrons directly decarbonise a critical sector. This turns a national constraint into a synergistic opportunity, positioning the port as a cornerstone of the future green energy ecosystem.

From an energy resilience perspective, electrification reduces Singapore's reliance on imported marine diesel and transitioning to a diversified electricity mix (domestic solar, regional renewables, and possibly hydrogen-derived fuels) buffers the maritime sector from volatile global fossil fuel prices and supply chain disruptions. It future-proofs the nation's most important economic engine against the dual shocks of the energy transition and geopolitical instability, ensuring its operations remain cost-competitive and secure in the long term.

Therefore, it is crucial to position port electrification within the broader maritime decarbonisation pathway. Electrification is particularly critical for port operations and at-berth emissions, complementing the role of alternative fuels (such as ammonia, methanol, and hydrogen) for long-distance shipping. This complementary relationship reinforces the need for a system-level approach, rather than viewing electrification as a standalone solution.

Despite the collectively positive decarbonisation between ships and ports, shore power will lead to a shifting of GHG inventories from ships to ports which in turn adds to the national GHG inventory. CSER's study found that "compared to GHG removal due to port electrification, shore power can effectively 'undo' nearly one third of the benefits from port equipment electrification," in the Singapore context (currently 95 per cent of electricity is generated from natural gas). This also exposes potential gaps in the global GHG inventory or emission attribution framework due to the cross-sectoral nature of maritime decarbonisation.

This creates a structural policy misalignment that risks weakening incentives for ports like Singapore to invest in OPS infrastructure. Therefore, it is important for port electrification to be properly positioned to bridge between Singapore's current maritime dominance and its sustainable, competitive future while addressing concern over decarbonisation, economic interests, and national energy security.

Addressing this issue presents an opportunity for Singapore to take a leadership role in shaping global standards for emissions accounting in port electrification.

# What should the policymakers do?

## 1. Implement phased mandates, cost restructuring, and internationally aligned standards for shore power deployment

The deployment of OPS should transition from an optional measure to a mandatory requirement through a phased regulatory approach combined with market-based incentives. This can help establish demand certainty, unlock infrastructure investment and enable cost reduction through scale. A clear implementation roadmap should be established, initially requiring vessels to be equipped with shore power reception capabilities, followed by the gradual expansion of mandatory usage, prioritising vessels with longer berthing durations while allowing for differentiated exemptions where appropriate.

From an economic perspective, policies should aim to achieve a "cost reversal" between shore power usage and auxiliary engine generation. This can be realised through dedicated low electricity tariffs for OPS, time-of-use pricing schemes, and fuel-use disincentives such as carbon taxation or port fees. Complementary measures including electricity consumption-based subsidies, green port fee reductions, and incentives for frequent users should be introduced to enhance adoption.

In parallel, Singapore should establish a comprehensive and unified technical standard system covering connection interfaces, voltage levels, and frequency specifications, aligned with international standards such as those developed by the International Electrotechnical Commission and Institute of Electrical and Electronics Engineers. Proactive alignment with emerging global regulatory frameworks, including those in key markets such as the European Union, will ensure interoperability, reduce retrofit costs, and reinforce Singapore's position as a future-ready global maritime hub. Infrastructure planning for OPS should also be integrated into national grid development strategies, prioritising high-activity berths and key green shipping corridors.

## 2. Strengthen integrated infrastructure planning and grid–port coordination

Port electrification should be treated as a national infrastructure and energy system challenge rather than a standalone port-level initiative. Coordinating load timing and capacity planning prevents stranded assets and ensures efficient utilisation. A dedicated Port Electrification Grid Integration Taskforce could be established, comprising key stakeholders such as the Maritime and Port Authority of Singapore, the Energy Market Authority, grid operators, and terminal operators. This taskforce should be responsible for conducting comprehensive and regularly updated power demand assessments, including the combined load from OPS and electrified port equipment.

Policy should shift from passive grid expansion to proactive system optimisation. This includes the development of port microgrids integrating photovoltaic systems, shore power loads, and battery energy storage, supported by intelligent energy management systems capable of forecasting vessel arrivals and optimising load distribution. Peak shaving and demand-side management should be prioritised through mechanisms such as maximum demand constraints and demand response programmes.

In addition, ports should explore advanced system flexibility solutions, including Vehicle-to-Grid (V2G) applications where electric AGVs function as mobile storage units capable of providing ancillary services to the grid. These measures will reduce reliance on costly peak-driven grid expansion while enhancing system resilience and operational efficiency.

## 3. Deploy blended finance, fiscal incentives and demand-side market creation

Strong demand signals and financial de-risking mechanisms are key to overcoming high upfront costs and coordination gaps. To address the high capital expenditure and long payback periods associated with port electrification, a comprehensive blended finance framework should be established to de-risk investment and mobilise private capital. This includes leveraging existing schemes such as the Enterprise Financing Scheme-Green (EFS-Green), expanding access to green bonds, green loans, and blue bonds, and introducing enhanced fiscal incentives such as accelerated depreciation and investment allowances.

At the same time, strong demand-side signals must be created to break the "chicken-and-egg" dilemma. The logic here mirrors the policy causal chain: demand-side signals reduce investment uncertainty, which in turn improves the bankability of infrastructure projects and lowers the cost of capital. The existing Green Ship Programme should be strengthened and extended beyond its current horizon, offering more substantial and long-term port dues concessions for vessels actively utilising OPS. Carbon pricing mechanisms and port-related surcharges can further reinforce the economic case for electrification.

In the near term, transitional instruments such as Renewable Energy Certificates (RECs) and Virtual Power Purchase Agreements (VPPAs) can be leveraged to enable ports to achieve net-zero emissions ahead of full grid decarbonisation. Public funding should also be directed towards pilot and first-mover projects to catalyse early adoption and build investor confidence.

## 4. Bolster cross-sector demand aggregation and innovative business models

Shared investment, aggregated demand, and new service models improve bankability and facilitate early adoption. A viable and scalable business case for port electrification requires moving beyond a siloed, port-centric approach towards co-development of cross-sector demand. Singapore could facilitate the formation of multi-stakeholder consortia that bring together port operators, shipping companies, power generators, and its major trading partners on a bilateral or multilateral framework on supply chain decarbonisation. This model enables shared investment, aggregated demand for decarbonised port services, and improved utilisation of infrastructure, thereby enhancing overall project bankability.

Innovative business models should be actively promoted to reduce upfront capital burdens and improve financial viability. These include Energy-as-a-Service, Equipment-as-a-Service, and even tailored emission allowance trading across supply chains or trading routes, which allow infrastructure and equipment costs to be recovered through long-term service agreements rather than initial capital expenditure with potential revenue streams from emission allowance trading within the supply chain.

In addition, operational innovations such as equipment leasing, battery–vehicle separation, and standardised battery swapping systems should be encouraged to improve lifecycle cost efficiency and operational flexibility. Such models not only lower barriers to entry but also create new market opportunities across the value chain.

## 5. Catalyse innovation, pilot projects, and first-mover deployment

Public-private testbeds accelerate technology validation and exportable solutions. Targeted public funding and coordinated innovation efforts are essential to accelerate next-generation technologies for port electrification. Singapore could consider establishing a public-private innovation platform to develop, testbed, and commercialise advanced solutions, positioning Singapore as a “living lab” for smart and sustainable port technologies.

Key areas of focus should include high-power automated charging systems such as robotic connection arms and pantographs, inductive (wireless) charging technologies, and integrated digital platforms for energy management and operational optimisation. Pilot projects and demonstration sites, particularly within Tuas Port and Pasir Panjang Port, should be used to validate these technologies under real-world conditions.

By supporting first-mover deployments and reducing technological uncertainty, Singapore can develop exportable solutions and standards for the global maritime industry while accelerating domestic adoption.

## 6. Future-proofing through energy diversification and system flexibility

Balance short-term flexibility with long-term direction toward scalable zero-emission solutions. Given the uncertainty surrounding future energy pathways, port electrification strategies should be designed to remain flexible and technology and vendor neutral. Singapore should avoid over-reliance on a single energy carrier and instead support a diversified approach that balances green electrons with green molecules.

Electrification is most suited to port operations and short-distance harbour craft, where it offers clear efficiency and cost advantages. For long-distance international shipping, alternative zero-emission fuels — including green hydrogen, ammonia, and methanol — are likely to play the primary role. These two pathways are complementary: a strong electrification foundation at ports supports the broader ecosystem needed to develop and supply zero-emission fuels for deep-sea shipping. While electrification will play a central role, alternative energy carriers such as hydrogen and other low-carbon fuels may be better suited for certain applications, including heavy-duty vehicles and specialised port equipment. Supporting the development of hydrogen-based systems, including fuel cell-powered vehicles, can complement electrification efforts while enhancing energy security and resilience.

For an import-dependent country such as Singapore, diversification of energy carriers also reduces exposure to supply risks. A flexible, multi-pathway approach ensures that port decarbonisation remains robust under evolving technological, economic, and geopolitical conditions.

## 7. Promote regional integration, green corridors, and standard export

Harmonised standards and green corridors generate economies of scale and reinforce Singapore's regional leadership. The realisation of scale effects in port electrification depends on regional coordination and international interoperability. Singapore should take a leadership role in promoting the harmonisation of technical standards, regulatory frameworks, and operational protocols across ASEAN. This includes alignment of voltage levels, connection systems, and safety requirements to reduce retrofit costs and enhance vessel compatibility across regional ports.

At the same time, the development of green shipping corridors should be accelerated to enable coordinated deployment of OPS and other low-carbon solutions along key trade routes. These corridors can serve as early adoption pathways, creating concentrated demand and enabling economies of scale.

By exporting its standards, regulatory frameworks, and best practices, Singapore can strengthen its influence in global green maritime governance while enhancing regional competitiveness and integration.

## 8. Implement emission re-attribution, pricing, and market design for shore power

Singapore can set global standards in emissions accounting, ensuring incentives align with OPS deployment and enabling scalable international adoption. While shore power reduces vessel emissions at berth, it creates a structural accounting challenge which shifts emissions from ships to the host country's port or indirectly power sector, increasing national GHG inventories. This is not merely a technical issue: without clear attribution frameworks, countries like Singapore face a structural disincentive to invest in OPS, undermining the global deployment of shore power. Singapore is well-positioned to lead internationally on resolving this challenge.

There is a need to establish clear emission accounting, attribution and pricing frameworks. This includes standardised measurement and reporting of shore power usage at berth, and national grid emission factors, alongside mechanisms to reattribute OPS-related emissions to ship operators through verifiable contractual arrangements and/or carbon accounting systems.

Electricity pricing for OPS should incorporate both energy and carbon costs, using structured tariffs (e.g. energy charges, connection fees, and carbon-adjusted pricing) to ensure cost recovery and incentivise adoption.

In the near term, bilateral and/or multilateral agreements between ports and shipping lines can operationalise these approaches. Over time, international standardisation, potentially under the IMO, will be essential to ensure consistent emission accounting, align incentives, and enable scalable global deployment of OPS.

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# Biography

**Dr Victor Nian** is a Founding Co-Chairman of the Centre for Strategic Energy and Resources. His expertise spans energy systems analysis, long-term planning, industrial and climate policy, and sustainability strategy. He is a recognised authority on nuclear energy, digital transformation, and sustainability governance in Southeast Asia. He advises public and private organisations on the geopolitics and market dynamics of strategic technologies. Dr Nian leads efforts in energy policy development, technology commercialisation, value chain development, and private-public collaboration to accelerate the energy transition in emerging Asian economies. He holds a PhD in Mechanical Engineering and a BEng (Hons) in Electrical Engineering with a Minor in Management of Technology from the National University of Singapore.

**Victor Nian**

Founding Co-Chairman, Centre for Strategic Energy and Resources, Singapore

**Dr Jun Yuan** is an Associate Professor at Shanghai Maritime University and an affiliated expert of CSER. He is a recipient of the Shanghai Oriental Young Scholar award and serves as an expert at the Shanghai International Data Port Research Institute. His research focuses on the modelling and optimisation of port and shipping energy systems, integrated energy systems, port operations, and advanced simulation methodologies. He has contributed to more than ten national and provincial research projects, including those funded by the National Natural Science Foundation of China and the Shanghai Municipal Government. He also works closely with industry and government stakeholders on policy and planning related to energy efficiency, emissions reduction, electric vessels, and port infrastructure. Dr Yuan holds a PhD from the National University of Singapore and a Bachelor of Engineering from Shanghai Jiao Tong University.

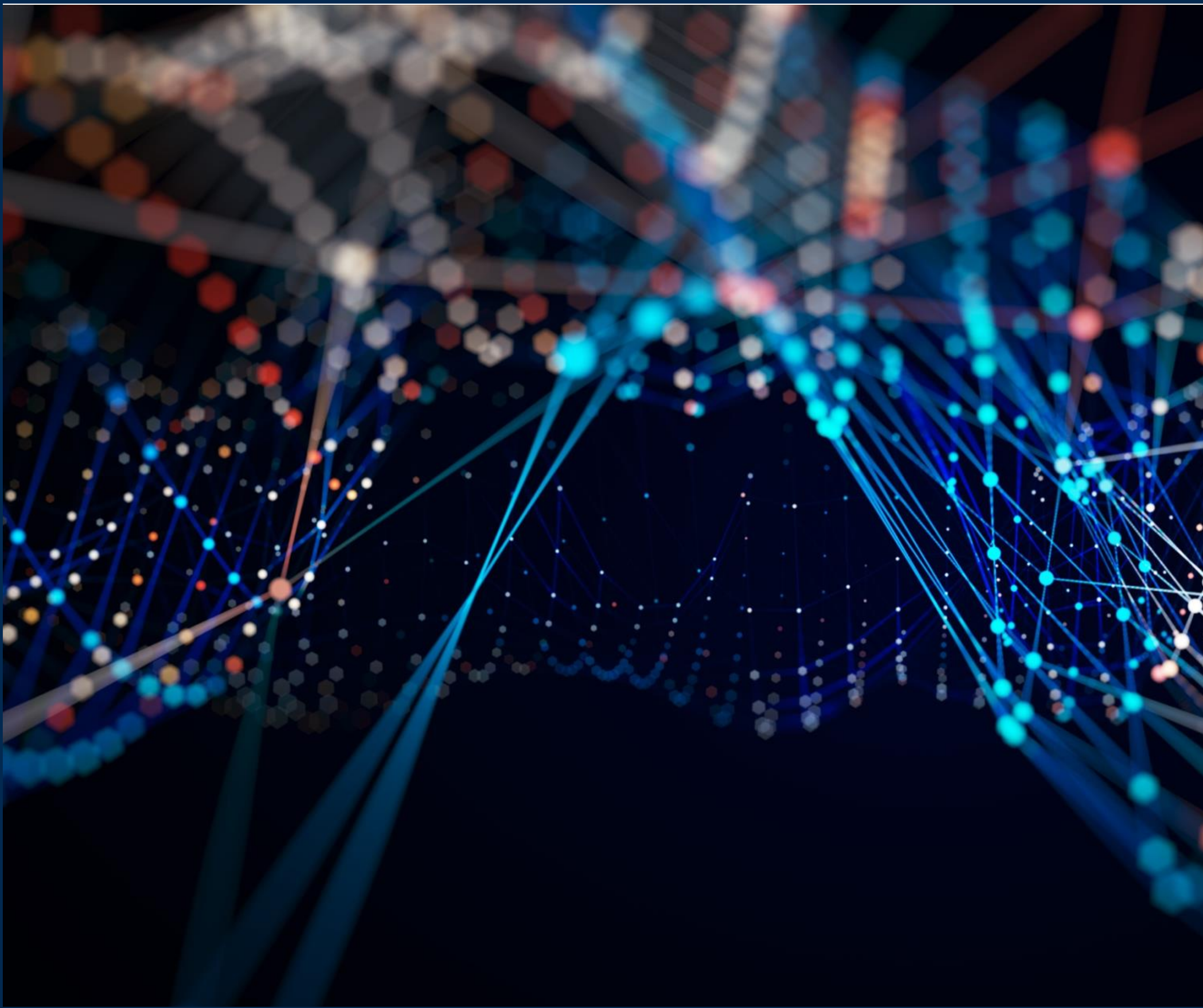
**Jun Yuan**

Associate Professor, China Institute of FTZ Supply Chain, Shanghai Maritime University, China

**Jude Lee** is the Regional Policy and Program Director for Asia-Pacific at Transport & Environment (T&E), where she leads the organisation's regional expansion and strategy. Based in Australia, she oversees T&E's work on shipping, aviation, road transport decarbonisation, and energy transition, with Singapore serving as a key hub. She collaborates with NGOs, funders, and policymakers to align Asia's transport and energy decarbonisation with global climate frameworks.

**Jude Lee**

Regional Policy and Program Director for Asia-Pacific, Australia




**Contact info**

CSER Secretariat
Email: secretariat@cser.energy
Website: www.cser.energy
Address: 50 Bukit Batok Street 23, #08-15,
Singapore 659578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