New Energy Applications for Ports and Inland Waterway Shipping in the People’s Republic of China

Nicolás Dei Castelli  
Senior Transport Specialist  
Asian Development Bank

Richard van Lier  
Inland Waterway Transport and  
Green Energy Specialist  
STC-Nestra

Yang Jiaqi  
Port, Shipping, and Integrated Logistics  
Management Specialist  
Wuhan University of Technology

Yuan Chengqing  
Reliability and Green Technology of  
Ship Power Systems Specialist  
Wuhan University of Technology

Harrie de Leijer  
Ports and Inland Waterway  
Transport Specialist  
STC-Nestra

Yan Xinping  
Intelligent Transportation and  
Green Energy Specialist  
Wuhan University of Technology

Liu Qing  
Traffic Safety Engineering and  
Transportation System Optimization  
Decision Specialist  
Wuhan University of Technology

INTRODUCTION

This policy brief summarizes the policy recommendations prepared by a technical assistance project of the Asian Development Bank (ADB) that provided technical support and policy advice to accelerate the adoption of new energy technologies in ports and inland waterway shipping in the People’s Republic of China (PRC). The recommendations align with the country’s ambitions to reach peak carbon emissions by 2030 and achieve carbon neutrality by 2060.

The project assessed experiences and lessons learned from completed pilot projects—such as those involving the use of hydrogen–powered equipment in ports and the operation of all-electric barges—and reviewed international best practices.

Note: ADB recognizes “China” as the People’s Republic of China.
Regarding future investments, the project recommended research and policy directions for new energy applications in ports and inland waterway shipping in the PRC to meet the government’s decarbonization objectives.

This policy brief presents a road map and a framework of policy suggestions and incentives for accelerating the uptake of new energy technologies in ports and inland waterway shipping in the PRC. Both the road map and framework consider the views of relevant stakeholders obtained through interviews, surveys, and workshops.

**DECARBONIZING PORTS IN THE PEOPLE’S REPUBLIC OF CHINA**

**Setting the Scene for Energy and Port Activity**
The port industry in the PRC has experienced rapid expansion since 2000. At present, ports in the PRC are essential nodes on a global scale, managing large volumes of goods and services. In 2022, the cargo throughput in PRC ports reached 15.685 billion tons, of which 4.607 billion tons were in international trade. This included 283 million twenty-foot equivalent units (TEUs) in container flows, which rose to almost 296 million TEUs in 2022, an increase of 4.7%. Of the 20 largest ports in the world in 2022, 16 were in the PRC, and Ningbo Zhoushan Port maintained its position as the world’s largest port.

The long-standing reliance of PRC ports on fossil fuels has led to significant environmental challenges such as air pollution and greenhouse gas emissions. As a response to the global call for carbon-neutral sustainable growth, the PRC has established ambitious decarbonization goals and launched a world-class initiative to make ports “safe and convenient, intelligent and green, cost-effective and efficient, powerful and cutting-edge.” However, as the world is now being confronted with the adverse effects of climate change at a faster pace, there is a growing need for the PRC to diversify its energy sources and embrace new energy technologies. Ports play a vital role in the PRC’s energy transition process, as ports and related industries consume and generate a lot of energy. Also, ports are located at the interface between offshore renewable power-generation and energy networks for the land-based power needs of industries and private residences. In the future, ports can be part of the supply chain for decarbonizing industries and homes.

Renewable energy is gaining momentum in the PRC. Wind, solar, tidal, and wave energy generation, as well as energy-storage technologies (e.g., batteries), currently exceed fossil-based production capacity. Still, renewable energy accounts for less than 30% of total energy consumption, so it has yet to become the dominant component of the energy mix. With approximately 70% of energy demand still met by thermal plants, and with energy demand and production still growing, the pressure to adopt more renewable energy sources is evident.

**Renewable Energy in Ports**
Renewable energy sources will safeguard future port operations in a sustainable manner. Solar, wind, hydrogen, and tidal energy, as well as bioenergy, have been researched and introduced in the PRC to ensure a sufficient and resilient power supply for ports. At present, the multi-energy integration mode followed by the ports is primarily based on the utilization of electric energy. The use of various renewable energy sources could help achieve zero-pollution and zero-emission goals. In ports, they could supply onshore power to vessels, and power port facilities and equipment (e.g., through “oil-to-electricity” replacement policies), and other resources. However, despite the commendable initiatives taken thus far, the utilization of renewable energy sources in ports is still largely in the planning and trial stages.

---

With the recent developments in energy technology and expansion of the market scale, the costs of photovoltaic cells and modules have greatly diminished, to the point where they are competitive with thermal electricity production. In ports, various applications of solar panels can be found, including on rooftops for direct transmission to office buildings (e.g., in Qingdao Port), and on warehouses and solar farms, a popular solution for powering other port functions.

In addition, the government has encouraged the development of wind-generated power. Wind power has become an alternative to thermal power, with wind farms linked directly to the main grid or to a closed grid (i.e. a port’s microgrid). Government support for wind-power projects is expected to continue through 2030.

Tidal-generated power has also become more popular. In the PRC, a capacity of 21 million kilowatts could be developed especially in the southeast coastal provinces of Fujian and Zhejiang. Investments in tidal power amount to 2.5 times the cost of a hydropower or thermal power station, though the cost differences have diminished. On the positive side, tidal power stations are resilient against natural forces and can achieve financial recovery within about 10 years. The downside is the need for high up-front investments for research and for the selection and preparation of each site. In addition, tidal power stations are hindered by tidal variations, which can restrict their ability to generate sufficient power to meet the actual power demand of a port.

When excess wind, solar, or tidal power is generated, the surplus can be stored in batteries or as hydrogen through electrolysis. Battery technology is important, but to achieve a sustainable future the government must also prioritize the production of green hydrogen. For PRC ports, green hydrogen presents a strategic opportunity, as any surplus of renewable energy produced in or near a port could be stored as hydrogen. Other regions, especially Europe, will become net consumers of green hydrogen. The European Union’s import target for 2030 is 10 million tons, according to the European Commission. Green hydrogen could thus become a promising

---

**Figure 2: Estimated Costs of Energy from Renewable Sources**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Investment Cost</th>
<th>Transport Cost</th>
<th>Energy Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>660 MW installation</td>
<td>CNY2,500 million</td>
<td>CNY0.20–0.30/1,000 km</td>
<td>CNY0.30–0.40/kWh</td>
</tr>
<tr>
<td>Distributed generation</td>
<td>CNY8.10/W</td>
<td>Nearby used, short transmission lines, negligible</td>
<td>CNY0.36/kWh</td>
</tr>
<tr>
<td>3 MW equipment</td>
<td>CNY9.30 million CNY-3,100/kW</td>
<td>CNY0.20–0.30/1,000 km</td>
<td>CNY0.27–0.35/kWh</td>
</tr>
<tr>
<td>1,000 m³/h installation</td>
<td>CNY13 million</td>
<td>CNY20 MPa: 21/500 km/kg CNY50 MPa: 9.64/500 km/kg</td>
<td>Gray: CNY12.80/kg Green: CNY24.40/kg CNY0.38–0.73/kWh</td>
</tr>
<tr>
<td>1 MW installation</td>
<td>CNY33 million</td>
<td>Nearby used, short transmission lines, negligible</td>
<td>CNY0.45–1.40/kWh</td>
</tr>
</tbody>
</table>

h = hour, kg = kilogram, km = kilometer, kW = kilowatt, kWh = kilowatt-hour, m³ = cubic meter, MPa = megapascal, MW = megawatt, W = watt.

Notes:
1. This figure assumes that the lower heating value of hydrogen of 33.33 kWh/kg is applied.
2. A megapascal is a unit of pressure according to the International System of Units.

export for the PRC. It takes a lot of energy to produce green hydrogen, with energy losses at around 70%, hence the tendency of ports to prefer renewable energy they produce or that is produced nearby. However, green hydrogen production is becoming more efficient, so it may be worthwhile to increase the current modest levels of investment in this technology.

Pathways for New Energy Technology in Ports
The practical application of new energy technologies in PRC ports is demonstrated at (i) Tianjin Port’s zero-carbon terminal; and (ii) the utilization of hydrogen at Qingdao Port, known as the “‘Hydrogen + 5G’ Smart Ecological Terminal” (Box 1).

Overall, efforts to integrate green technologies into the PRC’s ports have resulted in a mosaic of several energy sources, each with its own benefits and challenges. After a strategic application and integration of these technologies, ports in the PRC will be able to help the country achieve a more sustainable future, while strengthening their operational resilience and economic vitality.

Box 1: Hydrogen Fuel Applications at Qingdao Port

HYDROGEN FUEL STATION
Qingdao Port

FUEL STATION FOR HYDROGEN GAS TRUCKS
On 29 December 2021, the hydrogen refueling station (350 bar) in the Qianwan Port Area was put into operation for trucks running on gaseous hydrogen. The refueling station has a capacity of 1,000 kilograms per day. The gaseous hydrogen refueling station had a total investment of CNY 12 million (approx. $1.7 million) and covers an area of about 4,000 square meters. Currently, the hydrogen produced is gray (industrial by-product).

In March 2022, the permit was obtained to start operations. The most cutting-edge safety technology was installed to manage the associated risks of refueling hydrogen gas. For example, there are six flame detectors and nine hydrogen detectors, which should uncover any problems at hand. In 2022, Qingdao Port conducted a study on the use of hydrogen fuel for container trucks. A number of trucks are in operation, and hydrogen-fueled truck producers announced a total production of 1,100 fuel cell trucks through 2026, including 4.5-, 18- and 49-ton trucks with outputs of 50–200 kilowatts.

HYDROGEN FUEL-CELL CRANE
Qingdao Port

The hydrogen fuel cell set that powers the automated rail-mounted stack crane reduces the equipment’s deadweight by about 10 tons. By means of the hydrogen fuel cell and lithium battery pack, the power consumption is reduced by approximately 3.6% per container. Cost savings on equipment purchased are recorded on the order of 20% per crane.


---

New Energy Applications for Ports and Inland Waterway Shipping

Figure 3: Zero-Carbon Terminal in Tianjin Port

KEY CHARACTERISTICS

Shore power
All berths equipped with shore power facilities; technically capable vessels can now be connected.

Electrification equipment
All terminal and handling equipment is electrified, with no fossil fuels or carbon emissions.

Renewable energy
Wind and solar energy sources generate 50 million kWh per year (more than the total terminal consumption of 45 million kWh), with 70% self-consumed and 30% sent to the main grid, where it is used during downtimes.

Power-generation system
New (internal) energy power-generation system avoids long-distance transmission lines, and reduces utility costs and energy loss.

KEY VALUE ADDED FOR VESSELS

• Shore power system suitable for variable voltages will serve many different types of (PRC-flagged) vessels. New vessels can usually connect to shore power.

• Preferential policies to enhance shore power use include “four priority measures”: priority berthing, priority gate crossing, priority passage, and priority loading and unloading operations.

• Shore power was free of charge for 3 years (2020–2022) for all vessels.

KEY CHALLENGES

• Zero-carbon terminal is in the exploratory phase, with no harmonized standards for expansion.

• Zero-emission intra-port traffic is a corporate responsibility, so it is not incentivized.

• Many existing vessels cannot connect to shore power.

• Vessel owners have to invest in competent marine engineers, who are limited in supply and thus increase operational costs.

• When oil prices are low, generating electricity is more expensive and that discourages shore power use.

kWh = kilowatt-hour, PRC = People’s Republic of China.

Based on world-class green and smart port policies, port scheduling and management, resource use, and port energy-saving and emission-reduction technologies, the following steps are suggested for the development of new energy infrastructure in PRC ports:

Step 1: This initial step focuses on improving the energy efficiency of existing terminals, shore power facilities, and port equipment. This includes upgrading infrastructure and systems to save energy and reduce emissions. The policy is designed to attract new green energy companies while reducing the cost of energy production and transportation.

Step 2: The second step, looking at the medium term, shifts the focus to implementing port automation and developing an advanced low-carbon-management platform. This includes integrating human, mechanical, and energy resources into port operations. Special attention should be paid to promoting renewable energy sources, such as solar and wind power, and to optimizing port energy consumption.

Step 3: In the long term, the PRC aims to achieve near-zero carbon status. This ambitious goal will be reached through close cooperation between port energy and logistical systems. Key port equipment will be fully electrified to end dependency on fossil fuels. In addition, hydrogen–storage and advanced power-generation technologies will be deployed to ensure a sustainable energy supply. Various energy–storage systems will be utilized to diversify the energy supply and ensure a reliable and continuous power supply without carbon emissions.

In line with the PRC’s guidelines on developing world-class smart and green ports, the key elements of the three-step carbon-reduction plan for port development are as follows:

**Port grid load layout optimization and a new energy power system.** The new energy technologies are in the early adoption phase. Short-term consumption will continue to be based mostly on fossil fuels and on the main power grid. The electrification of port equipment, as well as improvements in the monitoring of power demand and supply in ports (tailored to each port’s characteristics and activities), will be significant stepping stones to the development of carbon-neutral energy networks and storage systems in PRC ports.

**Integrated port energy systems with hydrogen production and storage.** Multi-energy–storage systems in ports will lead to energy conservation in the short term. Industries and logistics companies will benefit from each other’s production activities through a complementary cooperative model using electricity, heat, and gas. Overproduction of renewable energy sources can be stored as hydrogen (despite high energy losses) and later used for electricity or as a source for other types of energy. However, green hydrogen technology will require further development to significantly reduce application costs.

**Promotion of green port technology in parallel with intelligent systems.** In the long term, an intelligent port utilizing big data will be able to support the control, analysis, and optimization of port resources to achieve balanced centralized and decentralized energy generation. Such data–based decarbonization–management platforms will primarily monitor the supply and demand of energy in port environments to generate, conserve, and use clean energy supplies; tailor battery–storage capacity; quantify energy demand, the charging of equipment, and the onshore power supply; and optimize all active resources within the port energy grid. In the short term, more research and development (R&D) and testing will be required to promote and adopt decarbonization–management systems on a large scale.

**Adoption of shore power technology and clean fuels to significantly reduce the direct emissions of vessels berthed in ports and in proximity of the port-city domains.** Shore power technology has been strongly promoted, and thus tends to involve mature applications. However, the cost of equipment adaptation and the high prices of shore power for both vessels and ports remain obstacles to growth in shore power demand and consumption. Another issue concerns life-cycle emissions: the carbon-emission–reduction effect of shore power is not as big as it should be in the PRC, so the share of renewable energy sources in the port energy mix needs to grow.

---

**Figure 4: Three-Step Carbon-Reduction Plan for Ports in the People’s Republic of China**

Source: STC-Nestra.
Microgrids to accelerate the decarbonization processes in both sea and inland ports. Clean energy technologies, such as offshore wind and solar energy, will certainly play an important role in the future, and PRC ports will have to transform their power systems through new energy technologies. Retrofitting a multi-energy structure onto each port’s existing power system will be a big challenge. However, smart port microgrids, primarily transmitting various (renewable) energy sources, will help ports develop flexible integrated clean energy systems that may or may not be linked to the main power grid (e.g., for redundancies).

Suggested Policy Directions for New Energy Applications in Ports

PRC ports have certain tools for encouraging the application of new energy technologies. One is the use of preferential policies to prioritize green(er) vessels. Another is the promotion of shore power. However, more will be needed to accelerate the uptake of affordable new energy technologies and to address current decarbonization challenges. In consultation with the Ministry of Transport, three main categories of policies have been identified and analyzed to strengthen knowledge exchange and technical and safety standards, and to expedite the application of proven technologies:

Guiding policies include specific policy directives, specifications, and standards to encourage the adoption of new energy technologies in ports and inland waterway. As the transition to new energy technologies is still in its infancy, guiding policies should ensure the effective and safe introduction of these technologies, and prevent technologies with different specifications from being brought to market. Therefore, guiding policies are recommended to introduce (i) central guidance on integrating new energy power systems, transitioning from fossil-based power sources to multi-energy port microgrids (to supply industries, vessels, and equipment, with specifications based on R&D and demonstrations); (ii) technical standards for renewable power generation to accelerate the replacement of thermal-generated electricity, as well as standards for using hydrogen for port equipment and industrial purposes based on a surplus of electricity generated from renewable sources; and (iii) guidelines for integrated smart energy systems (distributed new energy + energy storage + microgrids) for optimized renewable energy use in ports and for exchanges within each port domain to improve the conservation of energy resources.

Organizational policies focus on coordination, cooperation, and R&D within the port and inland waterway sectors. They seek to establish platforms for technological innovation, promote interdisciplinary cooperation, and encourage joint research efforts. They also recommend harmonized standards and operating procedures to support a knowledge-based implementation of new energy technologies in a safe manner based on, and making effective use of, available R&D resources through (i) the establishment of multidisciplinary collaborative R&D platforms to drive innovation in core technologies and encourage ports to develop into a low-carbon environment (with relevant departments advised to engage in joint initiatives such as key research projects, continue R&D of basic technologies, and to develop a platform for smart green port innovations); (ii) the introduction of a real-time emission monitoring system.

Figure 5: Schematic Overview of a Multi-Energy Port

CHP = combined heat and power, ESS = energy storage system, PV = photovoltaic.

in ports to analyze the impacts of decarbonization measures; (iii) cooperation between ports and energy companies to introduce new energy-storage mechanisms involving energy-use planning and operation, cost recovery for investments, and assessments of required financial incentives to improve the business case; and (iv) the planning of multisource energy microgrids as part of new port energy systems. Further, port authorities need encouragement and technical support to develop multi-energy complementarity during the transition to carbon neutrality.

Market stimulation policies include incentives such as fee deductions and subsidies to reduce the costs of installing and operating low- or zero-carbon technologies. They also include constraint measures to be studied, such as carbon taxes and stricter emission control standards, to reduce polluting behavior and encourage the use of green technologies. More specifically, recommended market stimulation policies include (i) introducing tax incentives to encourage the adoption of new energy technologies, such as an alignment of price elasticities for renewable energy sources with those for fossil fuels, as well as various tax exemptions and rebates linked to investments in solar power, wind power, hydrogen production, etc.; (ii) establishing a “Smart and Green Port Guarantee Fund,” for example, that would be financed by a tax on fossil fuel use in ports to support investments in new energy technologies in ports (which are typically perceived as high-risk investments) or to provide dedicated low-interest or interest-free loans from the central or regional governments to ports investing in new energy technologies; (iii) financing R&D and demonstration platforms in ports (utilizing a platform for smart green port innovations); and (iv) introducing policies favoring vessel and port operators that participate in a voluntary green-port incentive scheme to certify clean, safe vessels. Regarding this last option, the benefits for the vessels could include, for instance, discounted port dues or priority handling; or a port tax credit could be introduced for cargo owners who prioritize the use of certified vessels.

TOWARD SUSTAINABLE INLAND WATERWAY SHIPPING SOLUTIONS IN THE PEOPLE’S REPUBLIC OF CHINA

A Look at Current Trends and Green Energy Initiatives

Like the port sector in the PRC, the inland waterway sector is the largest globally in terms of its network, fleets, and freight and passenger turnover. In 2022, almost 4.4 billion tons of cargo was transported through the extensive network of inland waterways on 109,500 vessels. Compared with global standards, the PRC’s inland waterway vessels are relatively young, but their environmental performance needs improvement to effectively contribute to the government’s carbon-neutrality goals.

While the European Union and the United States have introduced stricter emissions standards for fossil-fuel-based inland vessel engines, the PRC could consider stricter emission standards aligned with their carbon-neutrality goals (Figure 6).

However, significant progress has been made. Liquefied natural gas (LNG)-powered vessels, and hybrid-powered vessels have been operating in the PRC’s inland waterways, and the number of initiatives is increasing rapidly. There are currently more than 460 LNG-powered vessels; these are commonly larger inland cargo vessels that require more power and travel long distances. Also, more than 80 all-electric inland waterway vessels (greater than 20 meters in length) are in operation, of which 20 exceed 3,000 deadweight tons. Electric vessels are more frequently used for passenger transport, including day trips, and for dry cargo and container transports ranging up to approximately 300 kilometers (km) on a single charge, for instance in the Huzhou demonstration zone (Box 2).

Other new technologies are in pilot application, such as those involving hydrogen or methanol (with and without fuel-cell technology). But no single technology can serve the whole inland waterway transport sector due to the very different characteristics and operational profiles of the vessels; and the required infrastructure has not been built. However, most of the abovementioned alternatives to diesel engines do have one thing in common: There is no business case for switching to new energy solutions (except for LNG and, in some cases, all-electric vessels). As mentioned above, LNG and all-electric vessels have been put into operation in the PRC’s inland waterways. Bunkering facilities are available for LNG vessels, but the charging network for all-electric vessels needs to be planned and built.

The government expects much from electrification in the long run. The PRC could benefit from existing initiatives that aim to apply green solutions in inland waterway shipping. For instance, full-electric inland vessel technology is expected to generate nearly a trillion yuan in industrial output. Based on demonstration projects, such as those in Huzhou and on the Yangtze River, further scale-ups of proven designs are the logical next step. An example is COSCO SHIPPING Lines, which just launched a 700 TEU all-electric inland container vessel as part of a demonstration project for the electrification of inland waterway vessels on the Yangtze River. The vessel is expected to run distances of up to 1,100 km (with one or two stops for battery exchanges, depending on whether the vessel is traveling downstream or upstream); it is equipped with 36 placeholders for 20-foot battery containers, each having a capacity of 1,600 kilowatt-hours.

Suggested Pathways for Adopting New Energy Technologies for Inland waterway Shipping

In view of the acceleration of new energy solutions in inland waterway shipping, the following key elements are to be considered:

Inland waterway shipping market structure. Larger shipping companies in the PRC typically have sufficient capital to introduce new vessels or innovations, while the less-resourced smaller family-owned companies, which are a lot more numerous, do not have the financial means to transition. It is vital to ensure that small and medium-sized enterprises are not left behind during the transition to renewable energy sources.
**New Energy Applications for Ports and Inland Waterway Shipping**

### Figure 6: Comparative Overview of Global Emission Standards for Inland Vessel Engines

#### Marine Engine Emissions Standards

- **IMO Tier III** (speed ≥ 2,000 rpm)
- **IMO Tier II** (speed ≥ 2,000 rpm)
- **China Stage II**
  - 5–15 liters; power ≤ 2,000 kW
- **US Tier 4**
- **EU Stage V**

#### Emissions Limits

- **PM emissions limits (g/kWh)**
  - IMO Tier III
  - US Tier 4
  - EU Stage V
  - China Stage II
- **NOx (+HC) emissions limits (g/kWh)**
  - IMO Tier III
  - US Tier 4
  - EU Stage V
  - China Stage II

**Note:** Emission standards depend on the engine-rated speed, displacement per cylinder, or on the rated power.

- ^a Standards for PM and NOx + HC, which took effect in 2021.
- ^b Standards for PM and NOx, for engines with rated power ≥ 600 kW and < 3,700 kW, phased in 2014–2017.
- ^c Standards for PM and NOx, for engines with rated power > 300 kW, phased in 2019–2020.

**Source:** National Resources Defense Council. [https://www.nrdc.org/](https://www.nrdc.org/)

---

**Life span of the existing fleet.** One of the biggest challenges to decarbonization for the PRC’s inland fleet is the long life span of the existing vessels. Over the past few decades, various ship-standardization programs have replaced older, smaller ships with larger modern inland waterway vessels. Most of these vessels, have been equipped with conventional diesel engines that generate high emissions. New fossil-fuel-powered vessels have recently been in operation in the PRC. Although some incentive measures are in place to encourage the use of new energy sources and smart technologies, the question is how to meet future decarbonization objectives, given the existing investment envelope in the inland waterway shipping market.

**Required support infrastructure for bunkering and charging.** Despite the technical and financial maturity of technology solutions for inland waterway vessels, the support infrastructure for new energy sources is not yet in place. The construction of support infrastructure is needed, as are related business models for the financing of ports, the participation of shipping companies, and multilateral cooperation concerned with infrastructure construction. Knowledge exchanges and the harmonization of technical and service standards for energy infrastructure are important ways to take advantage of economies of scale in the PRC’s inland shipping market.

**Investment costs for new energy technology and win–win opportunities.** Vessel operators currently lack a comprehensive business case for applying cleaner technologies. Whether it is a question of LNG, all-electric systems, or another technology, the price difference between cleaner energy and gas oil needs to increase, with a reasonable financial recovery time in sight. Enhanced cooperation among technology suppliers, shipyards, and public and private research institutions can lead to breakthroughs in ship design, construction, and financing.

**Introducing harmonized standards.** The development of technical specifications has two primary goals: safety and a reduction in carbon emissions. Technical standards in the PRC covering the use of all-electric vessels need strengthening, and pilot applications of methanol and hydrogen fuels in the future will face similar challenges. Currently, insufficient practical experience with these alternative energy options is considered to be a safety concern, and thus a constraint on implementation.
In June 2022, the first 2,000-ton dual-purpose new energy carrier Dongxing 100 in the PRC was officially delivered and put into operation in Huzhou. With a length of 62.7 meters, a width of 12.4 meters, and a depth of 4.1 meters, the full loading displacement is 2,270 tons, and the maximum cargo carrying capacity is 1,800 tons. The maximum speed of the vessel is about 9 knots (16 km/h). The vessel houses a direct current integrated power system with lithium iron phosphate battery packs that drive two 150 kW magnet propulsion motors (direct drive). The 3,400 kWh batteries are charged in 4 to 5 hours and provide the vessel a range of 300 kilometers (on a single charge). By operating all-electric year round, the Dongxing 100 saves 100,000 liters of gas oil, equivalent to 288 tons of CO₂ emission. Furthermore, the vessel does not emit NOx, SOx, or PM; it vibrates less; and it makes no noise.

For assessing emission reduction, it is important to consider the entire supply chain of the energy source. Looking at engine-out emissions only (TTW), the production of energy is overlooked. In the table (below) a comparative overview is given between gas oil and electricity from various sources, including: thermal coal, natural gas, and renewables. The comparison underlines the urgency of investing in energy production from renewable sources.

<table>
<thead>
<tr>
<th>Power Source</th>
<th>Well to Tank</th>
<th>Tank to Wake</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAS</td>
<td>61</td>
<td>288</td>
</tr>
<tr>
<td>Coal</td>
<td>364</td>
<td>0</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>203</td>
<td>0</td>
</tr>
<tr>
<td>Renewables</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Savings Compared with Gas Oil**

+ = higher, – = lower, CO₂ = carbon dioxide, DC = direct current, GLEC = Global Logistics Emissions Council, h = hour, km = kilometer, kW = kilowatt, kWh = kilowatt-hour, PRC= People’s Republic of China, SOx = sulfur oxide, TTW = tank-to-wheel, WTT = well-to-tank, WTT = well-to-wheel.

Notes:
1. The total life cycle of the various technologies is not included in this comparison.
2. For electricity, the well is the source of production (thermal, gas, renewable energy), the tank is the main grid or intermediate storage unit, and the “wake” refers to the batteries installed in the vessel.
3. A blank cell indicates that the column head does not apply.

Internalizing external costs. In the PRC, no system has yet been introduced for carbon accounting. By contrast, the European Union uses its Emissions Trading System (ETS) to generate funds to decarbonize pollutive sectors. Maritime shipping is included as a sector, and inland waterway shipping is expected to join the ETS 2 in either 2027 or 2028. To implement such a credit system in the PRC, a proper taxonomy would have to be introduced for managing appropriate protocols for monitoring and reporting, based on a well-to-wake approach. The PRC has yet to establish a monitoring system to facilitate emission monitoring and reporting for inland waterway vessels.

To accelerate the “greening pathway,” the following suggestions are offered:

Intensify the application of LNG as a transition fuel and improve LNG engine technology. New LNG-powered inland waterway vessels have started operating in the PRC, and their number will grow. Also, existing vessels can be retrofitted for LNG use. Despite the high up-front costs (engine, cryogenic tank, piping system, etc.), the business case is positive for inland waterway vessels that travel longer distances.

There is scope for improvement in the application of pure natural gas marine engines (without diesel as the pilot fuel) and in the development of gas-electric hybrid technology (combining gas generators, electric engines, and a battery pack). The PRC has yet to produce LNG engines with higher power for larger inland waterway vessels with a capacity of roughly 2,000 deadweight tons or more. In addition, two serious concerns with PRC-manufactured LNG engines are methane slip and inadequate nitrogen oxide emissions control; they need to be addressed if LNG is to remain a better option than clean diesel-powered engines with after-treatment systems. Research is needed to determine whether the business case for cleaner LNG engines is still positive when compared with that for cleaner diesel engines.

Accelerate the development of full battery–electric inland waterway vessels. Such vessels have significant potential for travel over short and medium distances (up to 300 km based on current technology in the PRC). To accelerate the introduction of battery-electric drivelines, the power systems would require further attention, such as improvements in the battery-management system; development of a battery with greater safety, capacity, and density; and research into new battery types. Following a well-to-wake approach, the importance of an increased share of renewable energy for charging batteries is evident, but that should not detract from the current investments in other energy sources for inland waterway vessels. The capacity of technology providers requires attention to keep up with (future) demand for batteries. Support for battery-charging infrastructure is needed, along with facilities for exchanging battery containers.

Research, test, and promote the application of methanol, hydrogen, and other power technologies. Aside from the introduction of LNG-powered and all-electric inland waterway vessels, no green, zero-emission technology is readily available for inland waterway shipping. The potential of green methanol and hydrogen is recognized, with these technologies recently applied in inland waterway shipping (see Figure 8). Overall, R&D needs to be intensified to overcome the low-density, packaging, and operational challenges of all new energy solutions.

Suggested Policy Directions for New Energy Applications in Inland waterway Shipping

To promote the green development of the PRC’s inland waterway sector, the Ministry of Transport and regional authorities have issued a series of action plans and standards that have played
Figure 8: Examples of Innovative Green Vessels in the People’s Republic of China, including Key Information on Their Expected Development Pathways

**LNG as Transition Fuel**
- New LNG-powered vessels are used for long-distance operations.

**Changhang Cargo 001**: featuring various LNG-propulsion modes, such as PTI, PTO, and PTH.

**Suihang 906**: LNG-powered transformation ship under the “Green Pearl River” project. It uses LNG and features DC network technology for electric propulsion.

**Guochuang**: 64 TEU inland green intelligent container vessel designed for efficient battery-electric operation.

**Dongxing 100**: new dual-purpose carrier powered by lithium iron phosphate batteries and hydrogen fuel cells.

**Zhongtian Electric 001**: fully electric cargo ship with a 1,000-ton capacity. It operates on lithium iron phosphate batteries and supercapacitors.

**Three Gorges 1**: the world’s largest fully electric river cruise ship. It uses advanced DC-network control systems and high-voltage charging technology.

**H Three Gorges Hydrogen Boat 1**: the first 500 kW class hydrogen fuel cell–powered workboat.

**New Yangtze River 26007**: hybrid inland vessel capable of using different energy systems, including gas, oil, and electric, depending on operational requirements.

**The PRC’s first methanol-fueled vessel**: officially launched in Jianglong Boat Science and Technology Park.

**The PRC’s first methanol dual-fuel–powered green vessel**: delivered to and departed from launched in Nansha, Guangzhou.

**CIMC Runqing**: the PRC’s first new LNG single-fuel powered cement tanker, designed to transport powdered materials such as cement.

**Suihang /nine.lin/zero.lin/six.lin**: LNG-powered transformation ship under the “Green Pearl River” project. It uses LNG and features DC network technology for electric propulsion.

**Dongxing /one.lin/zero.lin/zero.lin**: new dual-purpose carrier powered by lithium iron phosphate batteries and hydrogen fuel cells.

**Three Gorges /one.lin/zero.lin/one.lin**: the world’s largest fully electric river cruise ship. It uses advanced DC-network control systems and high-voltage charging technology.

**HMETANOL**: the first 500 kW class hydrogen fuel cell–powered workboat.

**The PRC’s first methanol-fueled vessel**: officially launched in Jianglong Boat Science and Technology Park.

**The PRC’s first methanol dual-fuel–powered green vessel**: delivered to and departed from launched in Nansha, Guangzhou.

**CIMC Runqing**: the PRC’s first new LNG single-fuel powered cement tanker, designed to transport powdered materials such as cement.

**Suihang 906**: LNG-powered transformation ship under the “Green Pearl River” project. It uses LNG and features DC network technology for electric propulsion.

**Guochuang**: 64 TEU inland green intelligent container vessel designed for efficient battery-electric operation.

**Dongxing 100**: new dual-purpose carrier powered by lithium iron phosphate batteries and hydrogen fuel cells.

**Zhongtian Electric 001**: fully electric cargo ship with a 1,000-ton capacity. It operates on lithium iron phosphate batteries and supercapacitors.

**Three Gorges 1**: the world’s largest fully electric river cruise ship. It uses advanced DC-network control systems and high-voltage charging technology.

**H Three Gorges Hydrogen Boat 1**: the first 500 kW class hydrogen fuel cell–powered workboat.

**New Yangtze River 26007**: hybrid inland vessel capable of using different energy systems, including gas, oil, and electric, depending on operational requirements.

**The PRC’s first methanol-fueled vessel**: officially launched in Jianglong Boat Science and Technology Park.

**The PRC’s first methanol dual-fuel–powered green vessel**: delivered to and departed from launched in Nansha, Guangzhou.

**CIMC Runqing**: the PRC’s first new LNG single-fuel powered cement tanker, designed to transport powdered materials such as cement.

**Suihang 906**: LNG-powered transformation ship under the “Green Pearl River” project. It uses LNG and features DC network technology for electric propulsion.

**Guochuang**: 64 TEU inland green intelligent container vessel designed for efficient battery-electric operation.

**Dongxing 100**: new dual-purpose carrier powered by lithium iron phosphate batteries and hydrogen fuel cells.

**Zhongtian Electric 001**: fully electric cargo ship with a 1,000-ton capacity. It operates on lithium iron phosphate batteries and supercapacitors.

**Three Gorges 1**: the world’s largest fully electric river cruise ship. It uses advanced DC-network control systems and high-voltage charging technology.

**H Three Gorges Hydrogen Boat 1**: the first 500 kW class hydrogen fuel cell–powered workboat.

**New Yangtze River 26007**: hybrid inland vessel capable of using different energy systems, including gas, oil, and electric, depending on operational requirements.

**The PRC’s first methanol-fueled vessel**: officially launched in Jianglong Boat Science and Technology Park.

**The PRC’s first methanol dual-fuel–powered green vessel**: delivered to and departed from launched in Nansha, Guangzhou.

DC = direct current, kW = kilowatt, LNG = liquefied natural gas, PRC = People’s Republic of China, PTH = power take-home, PTI = power take-in, PTO = power take-off, R&D = research and development, TEU = twenty-foot equivalent unit.

New Energy Applications for Ports and Inland Waterway Shipping

an active role in guiding the reduction of pollutant emissions, utilization of clean fuels, introduction of green vessels, and construction of related infrastructure. In line with the PRC’s 5-year planning cycle, in conformity with central government policies and supported by various levels of government, dozens of policies have been introduced to promote the use of new energy technologies in inland shipping. All these policies are very relevant, but stronger policy directions are needed to address the problems related to inland waterway shipping (e.g., longevity of vessels, predominance of small vessel operators, and the high costs of new zero-emission energy technologies).

The urgent need for policies to create a greener inland shipping fleet is evident. With 109,500 vessels in operation, the scale of the challenge is evident. A framework of suggested guiding policies, organizational policies, and market stimulation policies would assist in identifying the best ways to accelerate the uptake of new energy technologies in the PRC’s inland waterway sector.

Guiding policies should consist of harmonized technical standards that can streamline technological development in the sector and promote the acceptance of new green solutions, including support for (i) the introduction of safety norms for electric, hydrogen, and other new technologies, combined with operational procedures for bunkering or charging (including guidelines for supervising inland waterway vessels with new energy technologies); and (ii) the updating of professional qualifications and certification processes for nautical crews working in inland waterway shipping to ensure their knowledge of new energy technologies.

Organizational policies such as central directives and a cooperative R&D model can create synergies among different actors in the sector and encourage the development of innovative technologies, focusing on support for (i) the establishment of an interdepartmental cooperation mechanism to strengthen collaborative research on new energy technologies for inland waterway vessels and (ii) the introduction of demonstration zones to support research on new core energy technologies for inland waterway shipping. The different demonstration zones would foster a greater understanding of operational characteristics, market demand and supply, economic factors, and different energy options for inland waterway vessels.

Market stimulation policies are crucial for strengthening the business case for an accelerated adoption of new energy technologies. Such policies could include subsidies and fee deductions for companies investing in green technologies, as well as strict emission standards for vessels still using fossil fuels, thereby creating financial incentives to switch to environment-friendly alternatives and help ensure equal treatment in the sector.

Three specific policies are especially recommended: The first is to offer financial incentives (e.g., subsidies) for inland waterway vessels to adopt new energy technologies at an accelerated pace, as mentioned above. These incentives could be based on turnover to support small operators, which usually lack sufficient resources. Instead of requiring operators to invest significant capital, smart funding solutions could be introduced, such as financial lease structures at shipyards backed by a government guarantee. The second policy is to have the relevant departments cooperate in the development of a green corridor project in combination with a zero-emission vessel design and energy infrastructure. Related price elasticities and subsidies for new energy sources (including shore power) could be researched and tested to improve the business case for using the new energy sources, compared with the case for using diesel engines. The third policy is to study market mechanisms and to introduce a voluntary (later mandatory) green certification system for inland waterway vessels, as a basis for providing incentives or enforcing (new) rules.

TRANSFERABILITY OF GOOD PRACTICES TO OTHER ADB DEVELOPING MEMBER COUNTRIES

Good Practices, Not a Blueprint

Overcoming barriers that date back to the 1960s and 1970s, the PRC has shown the potential of long-term central planning and unwavering support for the transformation of the port and inland waterway sectors. This technical assistance project emphasizes the point that, while the PRC’s experience cannot serve as a uniform blueprint for other developing countries, it can nevertheless provide valuable insights that can inform and inspire other ADB developing member countries (DMCs).

Long-term planning of sustainable growth. A key reason for the success of inland waterway development in the PRC is the commitment to long-term central planning. Unlike many developing and emerging economies that struggle with short-term policies and political instability, the PRC has benefited from its ability to formulate comprehensive plans for its port and inland waterway sectors. This planning has enabled the systematic and sustainable growth of these sectors and provided a strong foundation for future progress toward zero emissions.

Benefits of public financing for ports and inland waterway shipping. Another crucial lesson from the PRC’s experience is the importance of public financing for the revitalization of the port and inland navigation sectors. These sectors have suffered from years of neglect, but they were rejuvenated through strategic investments and government funding initiatives. This highlights the importance of dedicated financial support for initiating and sustaining systemic improvements in ports and inland waterway shipping.

Investment in infrastructure research and development. Innovation and technological progress are essential for keeping the PRC’s port and inland shipping facilities clean, safe, and competitive on a global scale. The PRC has recognized this, and invested in strengthening its R&D capacity. By fostering a culture of innovation and encouraging collaboration between research institutions and industry players, the PRC has been able to develop breakthrough solutions that have strengthened the efficiency and sustainability of inland waterway shipping.
Standardization as a way to reduce costs. Driven by the scale of operations in both the port and inland waterway sectors, the PRC has introduced standardized inland waterway vessels, combined with effective classification and monitoring mechanisms. These actions have played a crucial role in replacing old and inefficient vessels. Standardization has not only improved safety, it has also streamlined operations and reduced costs. Moreover, robust control systems have ensured regulatory compliance and promoted accountability within the inland waterway sector. More responsibilities are now delegated to subnational governments than was the case in earlier decades, but the central government is expected to further strengthen its policies on new energy technologies and its guiding principles for the decarbonization of ports and inland waterway shipping.

**Recommendations**

Based on these good practices in the PRC and the abovementioned suggestions for accelerating the adoption of new energy technologies in ports and inland waterways, the following recommendations can be considered by other ADB DMCs:

(i) Study and introduce multi-energy port microgrids to supply renewable energy to industries, vessels, and equipment. Each microgrid should be connected to the main power grid, but should also be capable of operating independently.

(ii) Study and introduce preferential policies for clean port and shipping operations. There are currently no market incentives to introduce green solutions, except for the electrification of certain services (e.g., electric ferries), when fossil-based equipment has fully depreciated or new services are introduced. On the contrary, investments in green solutions usually entail higher costs. Therefore, front-runners introducing clean operations in ports and inland waterway shipping should receive advantages over fossil-fuel-based operators. This is something that port authorities can introduce themselves, or that can be organized through a centrally organized green port or shipping award system.

(iii) From the perspective of the operator, the technical and economic viability of new energy solutions will be key for accelerated adoption. A central financial guarantee system could help de-risk commercial investments in ports and (especially) in inland waterway shipping. For other DMCs, international financing institutions could support the creation of such financing mechanisms, along with technical assistance for introducing new (standardized) energy technologies in the port and inland waterway sectors.