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China electric off-road machinery casebook

JINJIAN LI, HUI HE, AND YIFEI MA
International Council on Clean Transportation

DIAN CHU AND YUQI DENG
Chengdu Tianfu Innovative Environmental Science and Technology Research Institute

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International Council on Clean Transportation
1500 K Street NW, Suite 650
Washington, DC 20005

communications@theicct.org | www.theicct.org | @TheICCT

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1. INTRODUCTION

China's off-road mobile machinery sector is a critical but often overlooked mobile emission source. While regulatory efforts have largely targeted on-road vehicles with increasingly stringent standards, off-road construction machinery, such as excavators, loaders, forklifts, and drilling rigs, accounts for a growing share of urban air pollution due to underdeveloped mitigation policies. According to the *China Mobile Source Environmental Management Annual Report* (Ministry of Ecology and Environment of the People's Republic of China [MEE], 2024), non-road sources including construction and agricultural machinery, ships, locomotives, and aircrafts are approaching or surpassing on-road sources as the primary contributor of key air pollutants in the transportation sector. In 2023, for instance, non-road sources emitted 4.53 million tons of nitrogen oxides (NO_x), nearly matching the 4.73 million tons from on-road sources, and produced 224,000 tons of particulate matter (PM), far exceeding the 44,000 tons from on-road vehicles. Construction machinery alone was responsible for 13% of national mobile-source NO_x emissions and 26% of PM emissions (MEE, 2024).

Often operating in densely populated areas and construction hotspots, off-road construction machinery poses serious environmental and health risks to frontline workers and surrounding communities, while also contributing to climate change through black carbon and carbon dioxide (CO_2) emissions. As cities strive to meet air quality goals and carbon reduction targets, the transition to zero-emission construction machinery has emerged as a key strategy. Zero-emission alternatives not only eliminate tailpipe NO_x and PM emissions but also offer environmental benefits through significantly lower greenhouse gas (GHG) emissions and noise.

In recent years, leading Chinese manufacturers have developed a broad portfolio of zero-emission construction machinery across equipment categories, sizes, and power segments. As of 2024, excavators led the market with 81 available electric models, followed closely by loaders with 76 models, along with dozens of other electric construction machinery types. Battery electric powertrains have become the dominant configuration, alongside other solutions such as wired electric models. Battery electric systems are supported by improvements in fast-charging capabilities and, in some cases, battery swapping. As the largest producer, consumer, and exporter of construction machinery, China is well positioned to leapfrog to clean technologies and lead the global shift toward emission-free construction.

To better understand how zero-emission construction machinery performs in practice and showcase early successes that could inspire broader adoption, this casebook draws on extensive on-the-ground research across six Chinese cities (Figure 1). Our team systematically studied the use of zero-emission machinery at a variety of industrial and construction sites. We engaged with equipment operators, site managers, rental firms, and manufacturers to gather first-hand insights into the deployment of electric off-road machinery in real working conditions. By observing daily operations, documenting charging practices, collecting technical specifications, and analyzing cost data, we built a first-of-its-kind, evidence-based profile of the real-world performance of zero-emission construction machinery. The casebook highlights representative cases of excavators, loaders, and rotary drilling rigs, and offers detailed evaluations of their operational viability, energy savings, and financial implications.

Figure 1. Locations of zero-emission construction machinery deployment in six Chinese cities

2. ELECTRIC EXCAVATORS

2.1. ELECTRIC EXCAVATOR BOOSTS SAFETY AND PRODUCTIVITY IN A CHENGDU DISTILLERY

In a traditional distillery in Chengdu, where scooping and moving lees was once done entirely by hand, the introduction of a zero-emission electric excavator has transformed daily operations. Like many similar facilities, this distillery had never used diesel equipment due to two key concerns: safety regulations that prohibit open flames and fears that diesel exhaust could compromise product quality.

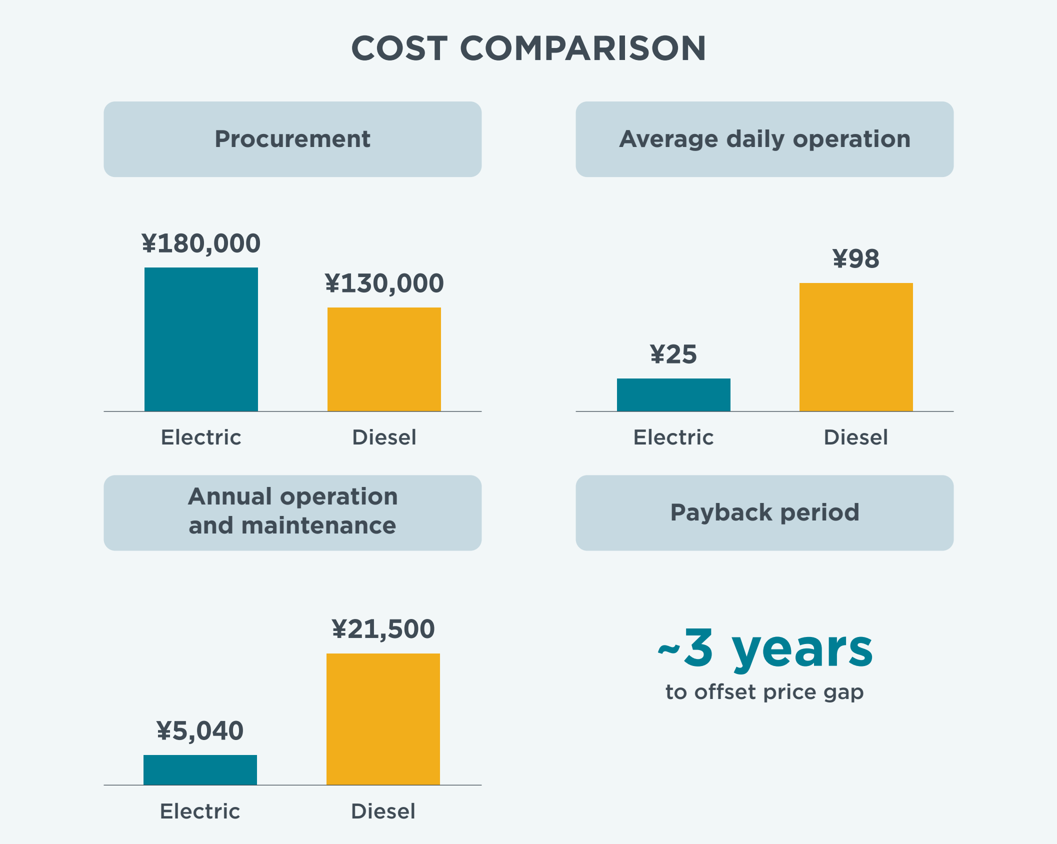
The electric excavator, equipped with a 0.04 m^3 bucket, offered a solution tailored to the distillery's needs. Operationally, the excavator proved more efficient than manual labor, completing each scooping cycle in just a few seconds, twice as fast as the previous two-person team. In operation for 3 hours each in the morning and afternoon, the machine is recharged during lunch and performs reliably throughout the day. Its low noise levels also make it ideal for enclosed indoor work, improving comfort without generating health risks for nearby staff. While the crawler design results in slower movement compared with wheeled equipment across smooth cement floors, its steady, controlled operation is well-suited to the distillery's operations.

In terms of project economics, the payback period of the electric excavator relative to the diesel alternative—that is, the time required to offset the higher upfront cost of the electric model—was approximately 3 years.

Figure 2.1.1. Specifications and application of the SY19E electric excavator in the Chengdu distillery

Electric excavator specifications	
SANY SY19E	Bucket 0.04 m^3
Rated power 10 kW	Battery capacity 22 kWh
Average daily use 6 h	On-site charging 7 kW

Figure 2.1.2. Cost comparison of electric and diesel excavators in the Chengdu distillery



LESSONS LEARNED

PROS	CONS
• Zero emissions: Eliminates air pollution risks in sensitive production environments. • No combustion engine: Safe for areas where open flames are banned. • Boosts productivity: Completes tasks twice as fast as manual labor. • Low noise: Ideal for enclosed spaces and improves working conditions. • Operationally efficient: Easily meets daily workload with midday charging.	• Mobility limitation: Crawler design makes movement slower on smooth indoor surfaces.

2.2. ELECTRIC EXCAVATOR SHOWS PROMISE AMID INFRASTRUCTURE CONSTRAINTS IN WUXI

At a large construction site in Wuxi, the project team initiated a comprehensive electrification pilot program targeting both construction machinery and transport vehicles. As part of this broader initiative, one SANY SY215E electric excavator was deployed for around 180,000 m^3 of earthworks, operating 3–4 hours per day over a project period of approximately 2.5 months. In heavy clay excavation and earth-moving operations, the electric excavator demonstrated performance on par with diesel models, with comparable digging force and cycle times. The daily energy cost of the electric excavator was only CNY 140 for electricity, less than one-third the fuel cost of a comparable diesel unit.

However, the project struggled to overcome charging barriers. Efforts to install high-power chargers on-site stalled due to local grid capacity limits and a lengthy, multi-agency approval process for upgrading grid access. Portable charging solutions such as mobile power containers were not feasible due to inadequate advance planning and site preparation. As a workaround, the team temporarily towed the excavator to nearby public charging stations, such as those used by electric buses. This approach proved labor-intensive and time-consuming, and was eventually abandoned. With only slow charging available, the team had to scale back to one electric excavator instead of the two originally planned, resulting in reduced daily productivity. More critically, the electric excavator's rental price of CNY 40,000 per month amounted to a total of about CNY 100,000 over the duration of the project, roughly CNY 57,500 more than a diesel unit. The energy savings were not enough to close the cost gap during the construction project.

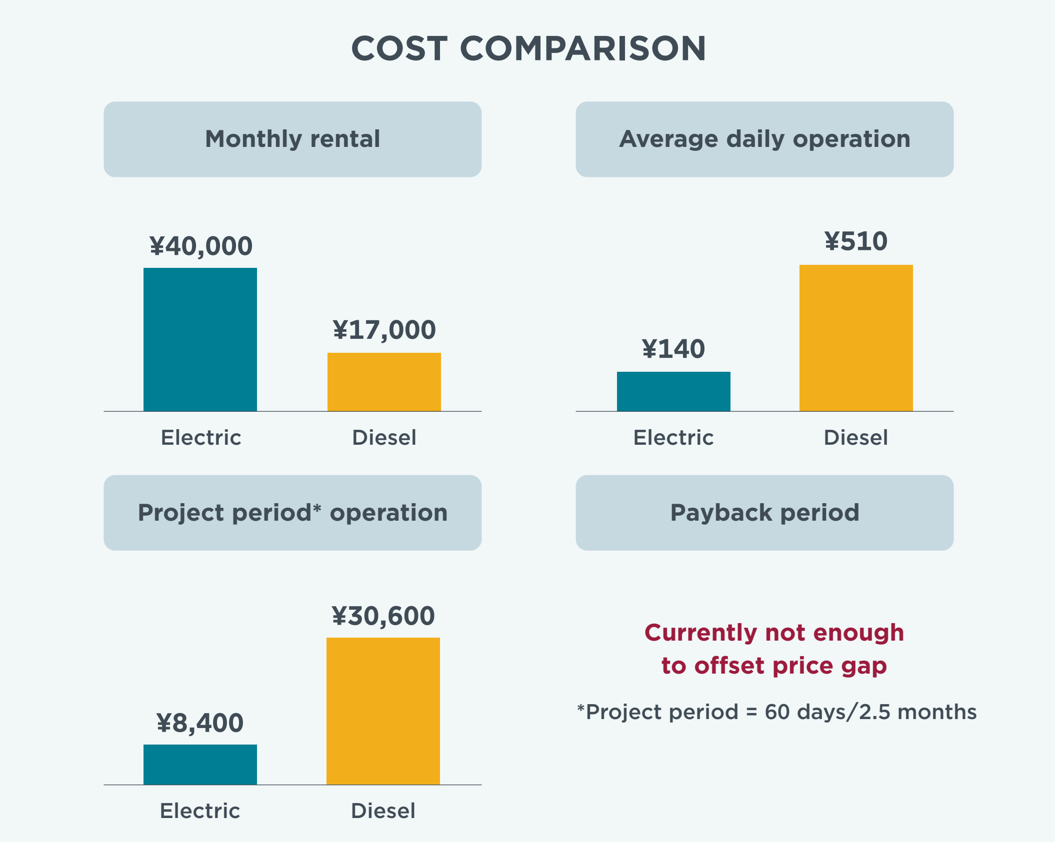
Still, the experience confirmed that electric excavators can perform tough, real-world construction work, provided that charging infrastructure and cost barriers are addressed.

Figure 2.2.1. Specifications and application of the SY215E electric excavator at the building construction site in Wuxi

Electric excavator specifications

SANY SY215E	Bucket 1.1 m^3
Rated power 150 kW	Battery capacity 423 kWh
Average daily use 3–4 h	Public slow charging

Figure 2.2.2. Cost comparison of electric and diesel excavators at the building construction site in Wuxi



LESSONS LEARNED

PROS	CONS
• Lower energy cost: One-third lower energy costs compared with diesel engines. • Zero emissions: Reduced air pollution, ideal for urban or regulated sites. • Lower noise: Improved on-site working conditions. • Proof of concept: Electric excavator performed reliably within charge limits.	• Limited daily runtime: 3–4 hours/day due to slow charging. • Charging infrastructure gaps: No on-site fast charging; public charging restricted. • Higher rental cost: Nearly CNY 60,000 more than diesel over project duration.

2.3. ELECTRIC CONSTRUCTION MACHINERY PILOTS ON THE NATION'S FIRST NEAR-ZERO CARBON CONSTRUCTION SITE

The Tianfu Yongxing Laboratory Park in Chengdu shows how cleaner technology can transform traditional building practices. As part of the city's first near-zero construction pilot, the project has benefitted from strong government backing through a task force established by the city's Ecological Environment Bureau and Housing and Urban-Rural Development Bureau. This enabled coordination among equipment makers, contractors, and environmental experts focused on reducing emissions from one of Chengdu's biggest pollution sources, construction machinery. Electric dump trucks, cement mixers, excavators, and other equipment replaced diesel models for tasks like digging, hauling, and dust control. Of 8,116 dump truck trips, 26% used electric vehicles; electric mixers handled 93.5% of deliveries. Solar panels and solar-powered streetlights supplied part of the site's electricity and lighting needs.

This project provided an opportunity to observe the real-world performance and cost of electric machinery. For example, early attempts at earth excavation with a 20-ton electric excavator revealed operational limitations when handling the site's rocky, high-clay soil, requiring a switch to a 40-ton diesel excavator. During the relatively less demanding earthwork backfilling stage, the team tested a prototype electric excavator made available by KOBELCO through a collaborative agreement that traded equipment access for real-world performance data and user feedback. The machine recorded daily operating costs 12% lower than a diesel equivalent, saving CNY 6,640 over the 80-day project period. This showed how strategic partnerships can enhance the viability of emerging electric construction equipment.

The project's success was also made possible by charging infrastructure support from the local government. Dedicated charging lanes were set up for electric dump trucks, and a 150 kW charging station with dual charging ports was installed on-site, providing 1–1.5 hours of charging time for 7 hours of equipment operation.

This case showed that it is possible to run a large-scale construction project with mostly electric machinery, if supported by smart planning and local leadership. Looking ahead, more heavy electric equipment rental options, better logistics planning, and stronger data tracking are key for wider adoption. The city plans to expand the model to other types of construction, including road infrastructure, and to develop a system to evaluate the environmental performance of such projects.

Figure 2.3.1. Specifications and application of the SK210E electric excavator at the near-zero carbon construction site in Chengdu

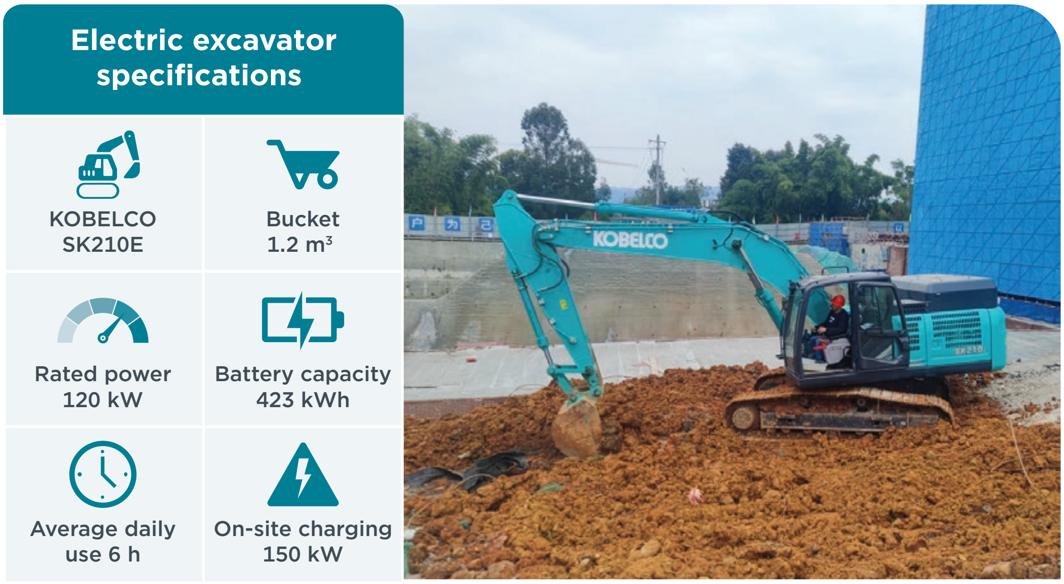
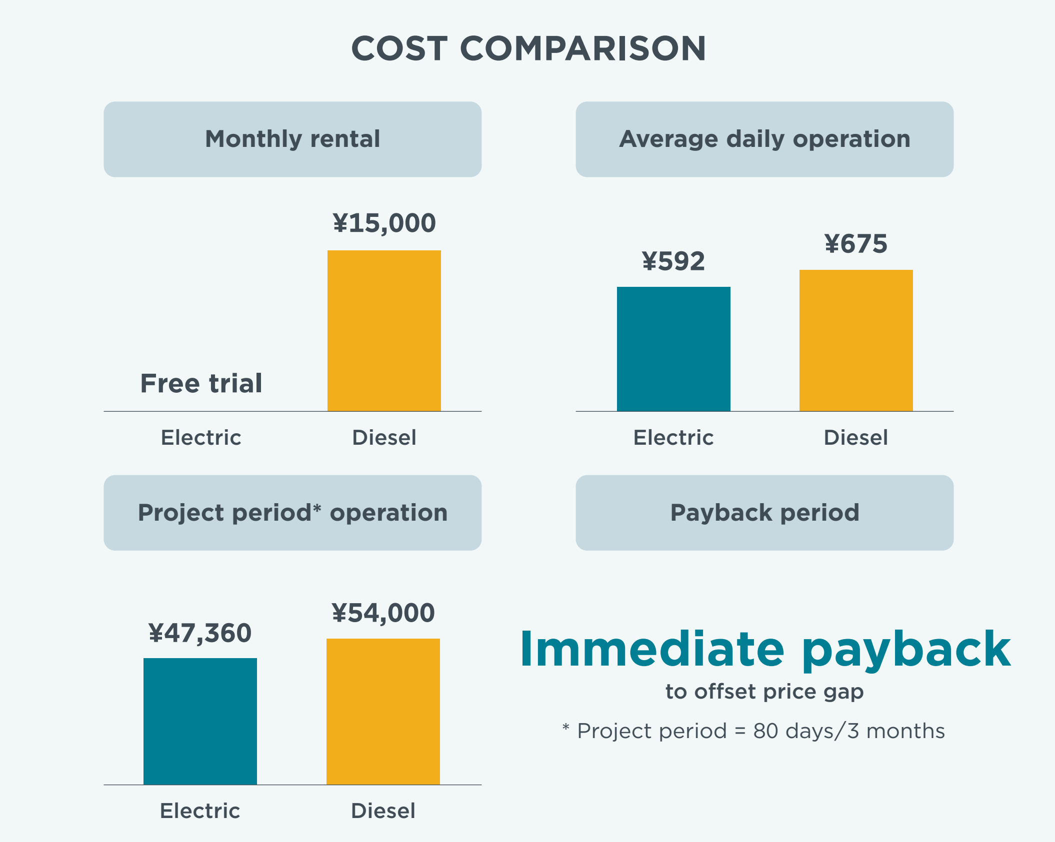


Figure 2.3.2. **Cost comparison of electric and diesel excavators at the near-zero carbon construction site in Chengdu**



LESSONS LEARNED

PROS	CONS
• Major GHG emission reductions: CO_2 reduced by 272.5 tons (58%) during the foundation phase; full project cycle expected to reduce CO_2 by 65%. • Significant reductions in air pollutants: SO_2 by 37%, NO_x by 22%, PM_{10} and $PM_{2.5}$ by 19%, volatile organic compounds by 17%. • Strong government coordination helped solve infrastructure and supply challenges. • Strategic partnerships demonstrated how collaborative pilots can lower adoption barriers and foster greater confidence in the viability of electric machinery. • High visibility of clean technology boosted public awareness and industry confidence.	• The availability of large electric machines remains limited, with no rental options. • Smaller load capacities and limited supply sources increased transport and logistics costs. • Without careful planning, electric vehicles' shorter range and longer charging times can delay progress. • Tracking emissions and performance in real time was difficult, making post-project assessment less accurate.

2.4. ELECTRIC EXCAVATOR IMPROVES AIR QUALITY AND WORKER SAFETY IN XICHANG TUNNEL CONSTRUCTION PROJECT

In Xichang's construction project in a mountainous highway tunnel, maintaining air quality posed a critical challenge due to the confined workspace and limited ventilation. Traditional diesel excavators were deemed unsuitable as their exhaust emissions would compromise air quality and occupational health and safety. The project team opted for an electric excavator, which provided a zero-emission alternative that eliminated harmful pollutant emissions, thereby reducing ventilation demands while enhancing workplace safety. Additionally, electric machines operate more quietly and with fewer vibrations, lowering the risk of accidents and enhancing worker communication in the acoustic-sensitive tunnel structure.

The SANY SY215E excavator operated efficiently for approximately 6 hours daily, aligning with conventional work shift cycles. Charging was facilitated by a mobile 240 kW fast-charging unit connected to the 380 V grid, enabling consistent daily use while maintaining the project timeline.

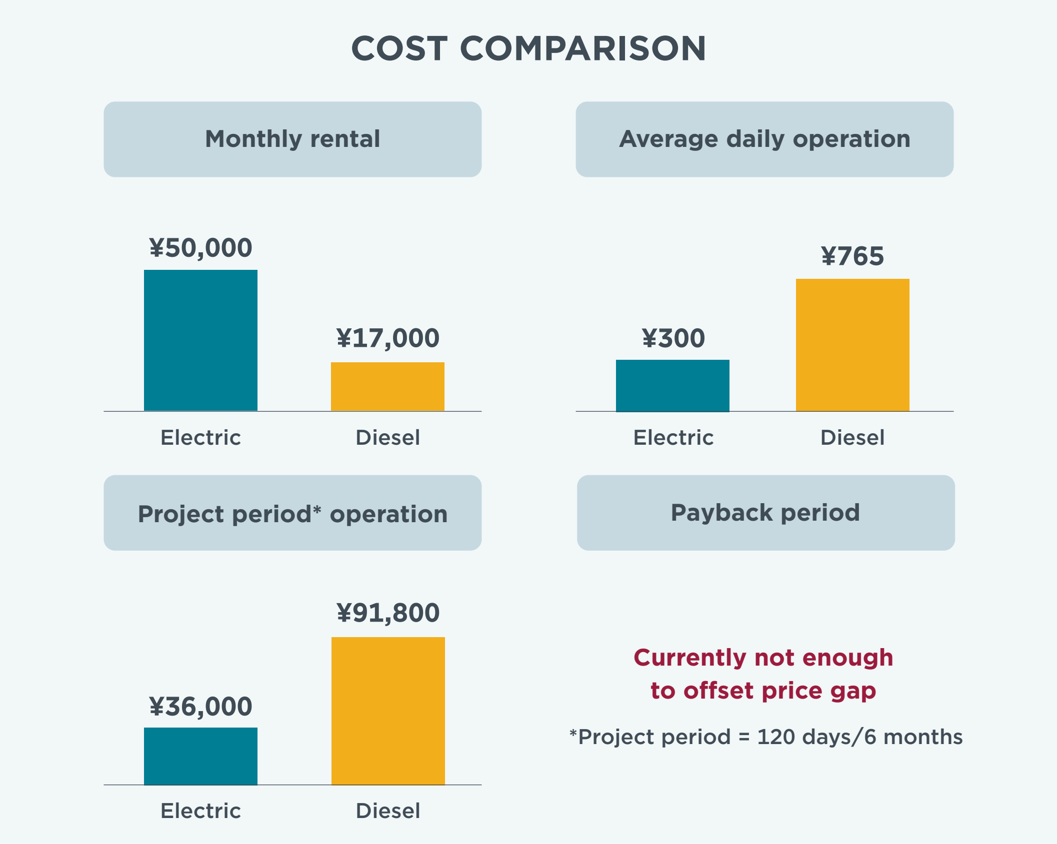
However, the electric excavator's rental rate was nearly 3 times that of a diesel unit. Additionally, under high-intensity working conditions, battery endurance could drop to 4 hours, forcing charge interruptions. While the operational savings of the electric model relative to the diesel model totaled CNY 55,800 over the 6-month period, this was not enough to close the gap against a CNY 33,000 monthly premium.

Even so, project managers reported greater compliance with occupational health standards and avoided heat-related incidents. While the electric excavator is not yet at cost parity with the diesel model, the Xichang case thus offers a strong environmental and safety case for electrification in confined-space applications.

Figure 2.4.1. Specifications and application of the SY215E electric excavator in Xichang tunnel project

Electric excavator specifications	
SANY SY215E	Bucket 1.1 m^3
Rated power 150 kW	Battery capacity 423 kWh
Average daily use 6 h	On-site charging 240 kW

Figure 2.4.2. Cost comparison of electric and diesel excavators in Xichang tunnel project



LESSONS LEARNED

PROS	CONS
• Zero emissions: Eliminated harmful exhaust pollutants, critical for confined tunnel environments. • Lower noise: Improved communication and reduced acoustic stress in enclosed spaces. • Reduced vibrations: Minimized structural disturbance in sensitive tunnel environments. • Lower energy cost: Saved 60% in energy costs compared with diesel engines. • Proof of concept: Electric excavator generally delivered 6-hour operational duration per charge, matching typical work shift demands.	• High rental cost: Cost around CNY 200,000 more than diesel over project period, which cannot be offset by operational savings. • Battery limitation: Runtime dropped to 4 hours under high-intensity working conditions.

2.5. BATTERY-SWAPPING ELECTRIC EXCAVATOR PROVES VIABLE IN MINING OPERATIONS IN HONGHE PREFECTURE

The Honghe Prefecture mining site in Yunnan Province demonstrates a pioneering application of battery-swapping technology for heavy-duty excavators in continuous mining applications. Since November 2023, the site has operated a SANY SY375E electric excavator, which features a 200 kW rated power output and 1.9 m^3 bucket capacity, along with 600 kWh swappable battery packs. This configuration enabled 15 hours of daily operation.

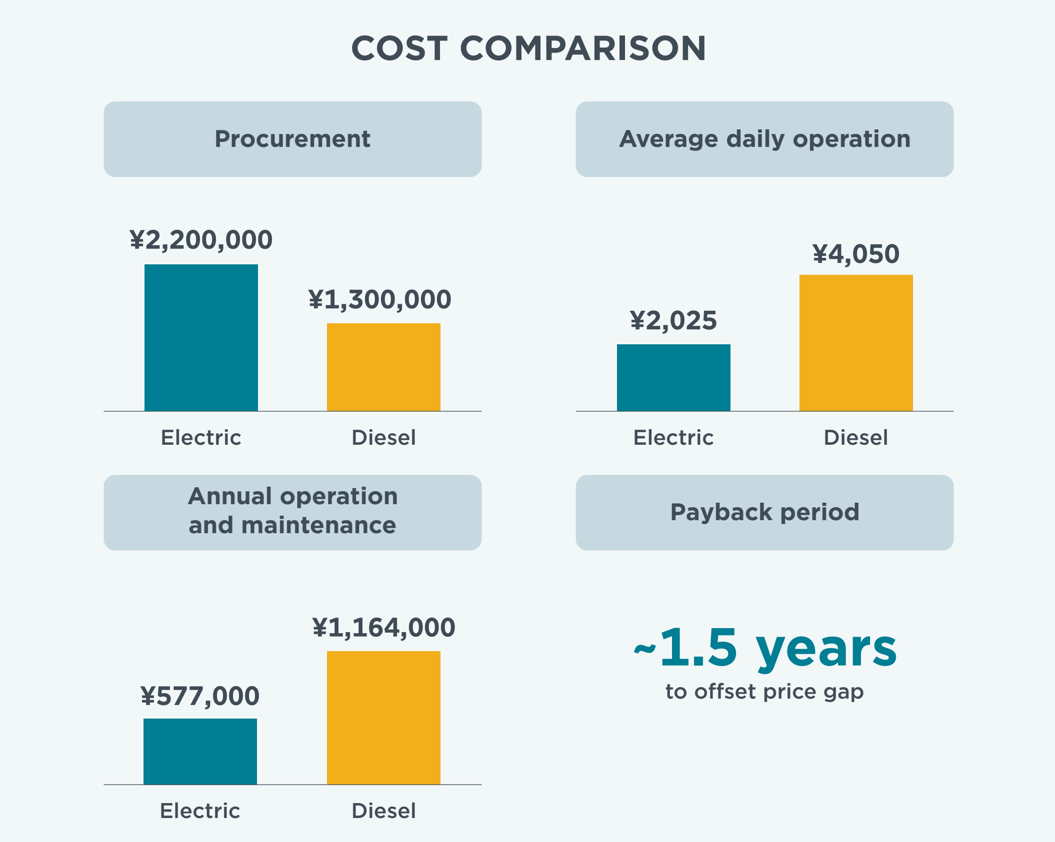
The battery-swap system enabled continuous mining operations through rapid 10-minute power replenishment. To meet demands for uninterrupted operation, the system incorporated a specialized battery transport vehicle with three pre-charged packs. These batteries were charged at a dedicated charging facility and delivered using the same type of transport vehicle already in service for the mine's electric trucks. This approach maintained high productivity while addressing the rigorous needs of heavy-duty mining applications.

This case also proved economically advantageous. The electric excavator reduced energy costs by 50% compared with diesel equivalents, generating annual savings of approximately CNY 590,000 from lower fuel and maintenance expenses. Despite a higher upfront cost (of CNY 2.2 million, against CNY 1.3 million for conventional excavators), the 1.5-year payback period demonstrates cost-competitiveness for high-utilization scenarios.

This case established three critical success factors for mining electrification: shared battery-swap infrastructure to reduce capital costs, sustained high utilization (15+ hours daily) to achieve quick payback, and 10-minute replenishment to maintain productivity on par with diesel equipment. In this way, the Honghe project provides a replicable model for large-scale mining operations pursuing both environmental and economic benefits through electrification.

Figure 2.5.1. Specifications and application of the SY375E electric excavator at the mining site in Honghe Prefecture

Figure 2.5.2. Cost comparison of electric and diesel excavators at the mining site in Honghe Prefecture



LESSONS LEARNED

PROS	CONS
• Long-term heavy-duty performance: Maintained 15-hour daily operation through rapid 10-minute battery swaps. • Infrastructure efficiency: Utilized existing electric truck battery-swapping stations (no additional infrastructure cost). • Proven economic viability: Saved 50% in energy costs compared with diesel models and achieved a 1.5-year payback period.	• None observed.

2.6. ELECTRIC EXCAVATOR CUTS EMISSIONS AND COSTS IN NORTHERN CHINA'S LARGEST INLAND RIVER PORT

At Liangshan Port in Jining, Shandong Province—Northern China's largest inland river port and a key logistics hub connecting western coal-producing regions with the Yangtze River Delta—electrification is being integrated into bulk material handling. As part of the port's efforts to build a near-zero-emission demonstration zone, electric excavators have been introduced to replace diesel models in daily operations, especially in enclosed coal storage facilities where pollution control and worker safety are essential.

A Shantui EE215 electric excavator was deployed for continuous coal scooping and stacking. Powered by a 423 kWh lithium iron phosphate battery and supported by 360 amp dual-port fast charging, the machine can operate for 4.5 to 8.5 hours after a 1.5-hour charge, meeting full-shift demands. Operators highlighted its high energy efficiency, quiet operation, and minimal vibration, while the sealed cabin with filtration systems offered protection from coal dust, which contributed to smoother workflows and improved conditions in the dusty, semi-enclosed environment. The daily operating cost was CNY 330, compared with CNY 1,080 for a diesel unit, generating daily savings of CNY 750 and annual savings of around CNY 270,000. The estimated payback period to offset the price gap with a diesel excavator was approximately 3.6 years.

Environmental benefits were also evident. The electric excavator consumed about 150,000 kWh of electricity annually, which corresponds to 84 tons of CO_2 emissions. A comparable diesel excavator would consume 44 tons of fuel and emit roughly 137 tons of CO_2. This translates to an annual CO_2 reduction of about 54 tons per machine. The Liangshan Port case illustrates that electric excavators can deliver both financial and environmental gains in high-utilization industrial settings, especially when supported by reliable charging access and consistent equipment use.

Figure 2.6.1. Specifications and application of the EE215 electric excavator at Liangshan Port

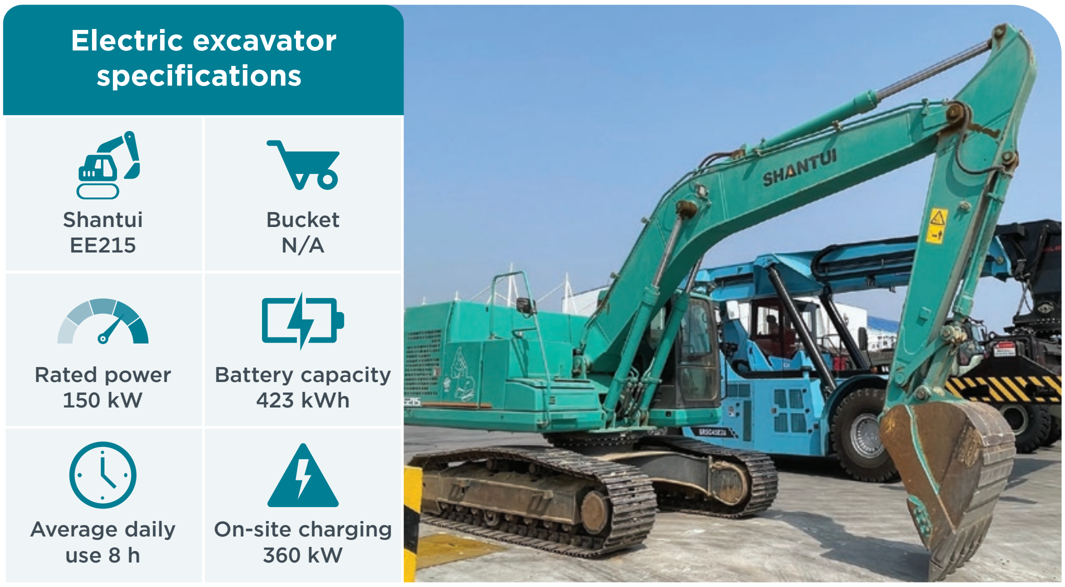
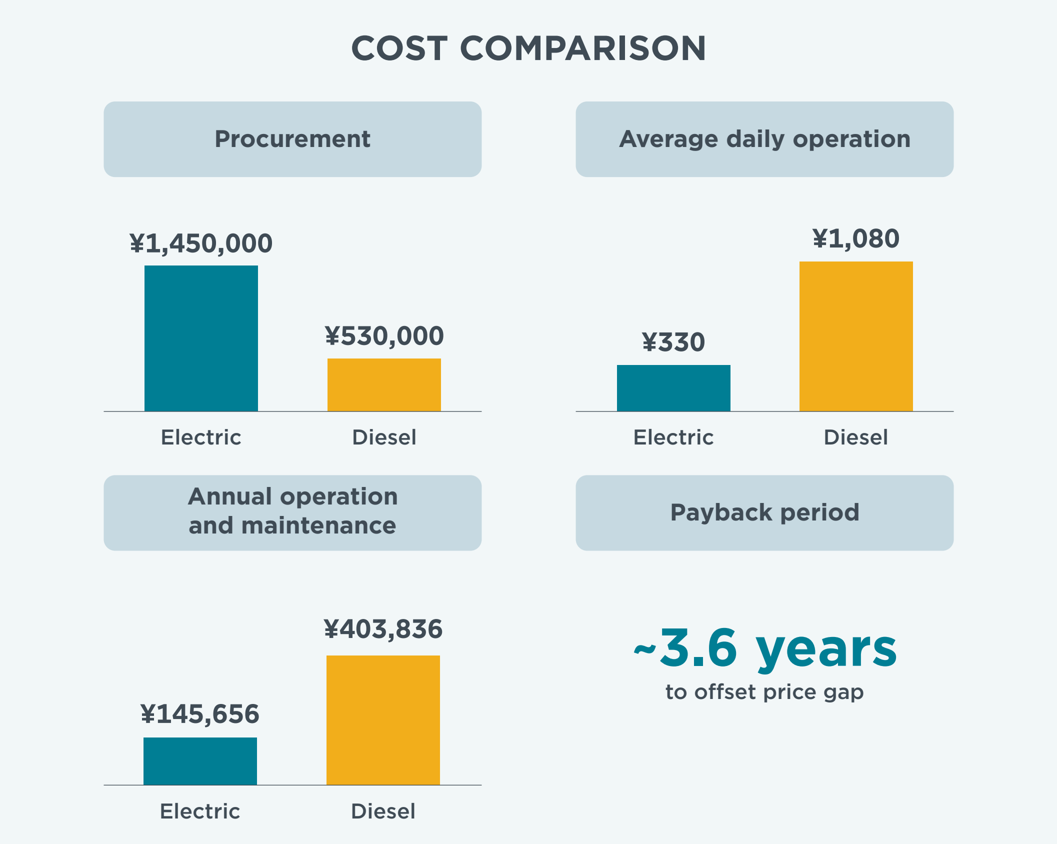


Figure 2.6.2. Cost comparison of electric and diesel excavators at Liangshan Port



LESSONS LEARNED

PROS	CONS
• Lower operating cost: Daily energy cost was 70% lower than the diesel unit, saving approximately CNY 260,000 annually per unit. • Sufficient runtime: A 1.5-hour charge supported 4.5 to 8.5 hours of operation, meeting full-shift needs. • Improved worksite conditions: Low noise, vibration, and zero emissions improved safety and comfort in enclosed areas. • Emission reduction: Each unit cut CO_2 emissions by around 54 tons per year, supporting the port's near-zero emission goals.	• High capital barrier extended payback period: The CNY 1.45 million unit price extended the payback period to around 3.6 years.

3. ELECTRIC LOADERS

3.1. ELECTRIC LOADERS ACHIEVE RAPID PAYBACK IN A HIGH-INTENSITY CEMENT PLANT IN CHENGDU

Operating under a continuous three-shift schedule, a high-intensity cement plant in Chengdu required machinery that was both reliable and environmentally friendly. Beginning in 2022, three LiuGong 856HE electric loaders were introduced to support daily material handling. Each unit typically operated an average of 13 hours per day. Charging was scheduled during operator breaks using two in-plant 240 kW fast-charging stations, which were installed by the equipment dealer as part of their service package. By coordinating charging sessions with shift breaks, the plant maintained high productivity despite the loaders' runtime per charge of approximately 5.5 hours.

The financial case was particularly compelling. Although the purchase price of each electric loader was CNY 800,000, which was CNY 200,000 more than a comparable diesel model, the electric units saved nearly CNY 300,000 per year in energy and maintenance expenses. This resulted in a payback period of only around 8 months.

Operators also reported a noticeable improvement in work conditions. Sealed cabins with filtration systems reduced dust exposure, and reduced noise and vibration helped lower physical strain. Diesel machines remained available to provide extended runtime during emergency or peak operations, but electric loaders became the default choice for regular tasks.

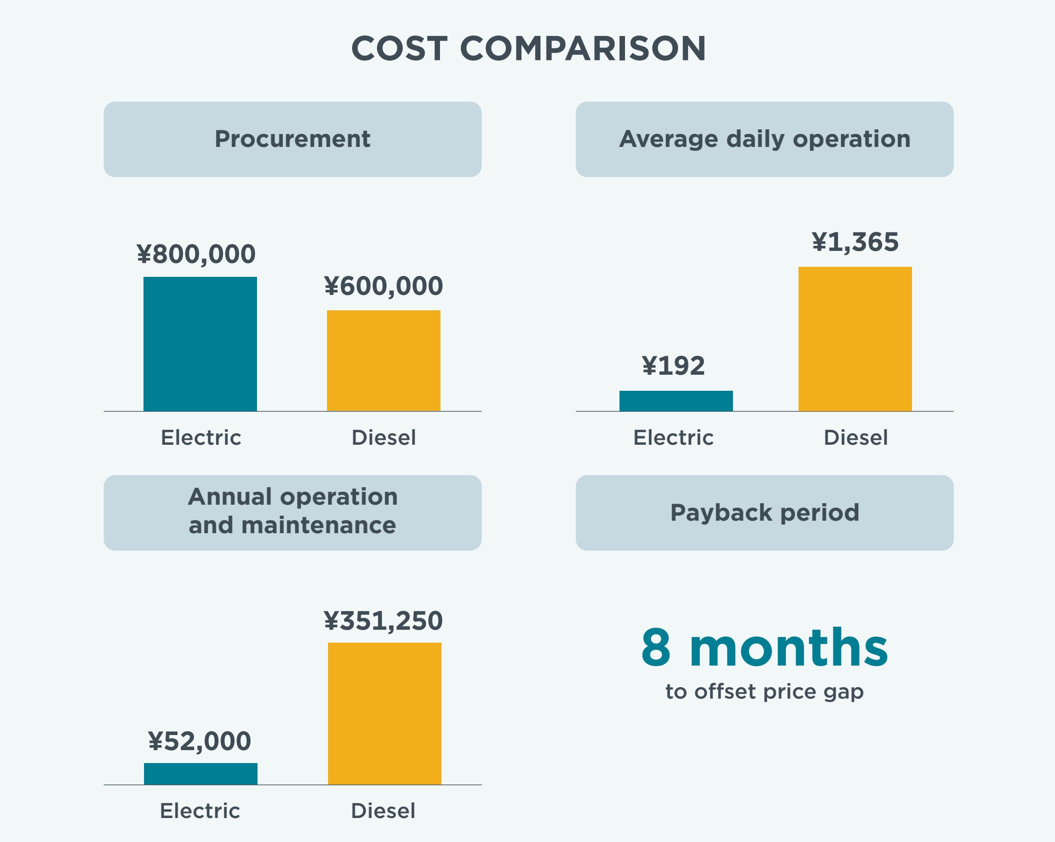
This case demonstrated that when paired with proper infrastructure, high daily operating hours, and effective planning, electric loaders could not only outperform diesel machines in environmental performance but also achieve rapid payback within a single operational year.

Figure 3.1.1. Specifications and application of 856HE electric loaders in the cement plant in Chengdu

Electric loader specifications

LiuGong 856HE	Load capacity 5.8 t
Rated power 180 kW	Battery capacity 282 kWh
Average daily use 13 h	On-site charging 240 kW

Figure 3.1.2. Cost comparison of electric and diesel loaders in the cement plant in Chengdu



LESSONS LEARNED

PROS	CONS
• Lower operating cost: Saved 86% in energy costs compared with diesel engines. • Rapid payback: Less than 1 year payback due to nearly CNY 300,000 in annual savings under high daily operating hours. • Improved health and safety: Low noise and filtered cabins created better working conditions. • Operational fit: Charging cycles aligned smoothly with three-shift work schedules.	• Relatively shorter runtime per charge: Around 5.5 hours compared with more than 10 hours for diesel.

3.2. ELECTRIC LOADERS LEVERAGE ON-SITE RENEWABLE POWER FOR COST-EFFECTIVE OPERATION IN A BIOMASS POWER PLANT IN LIUZHOU

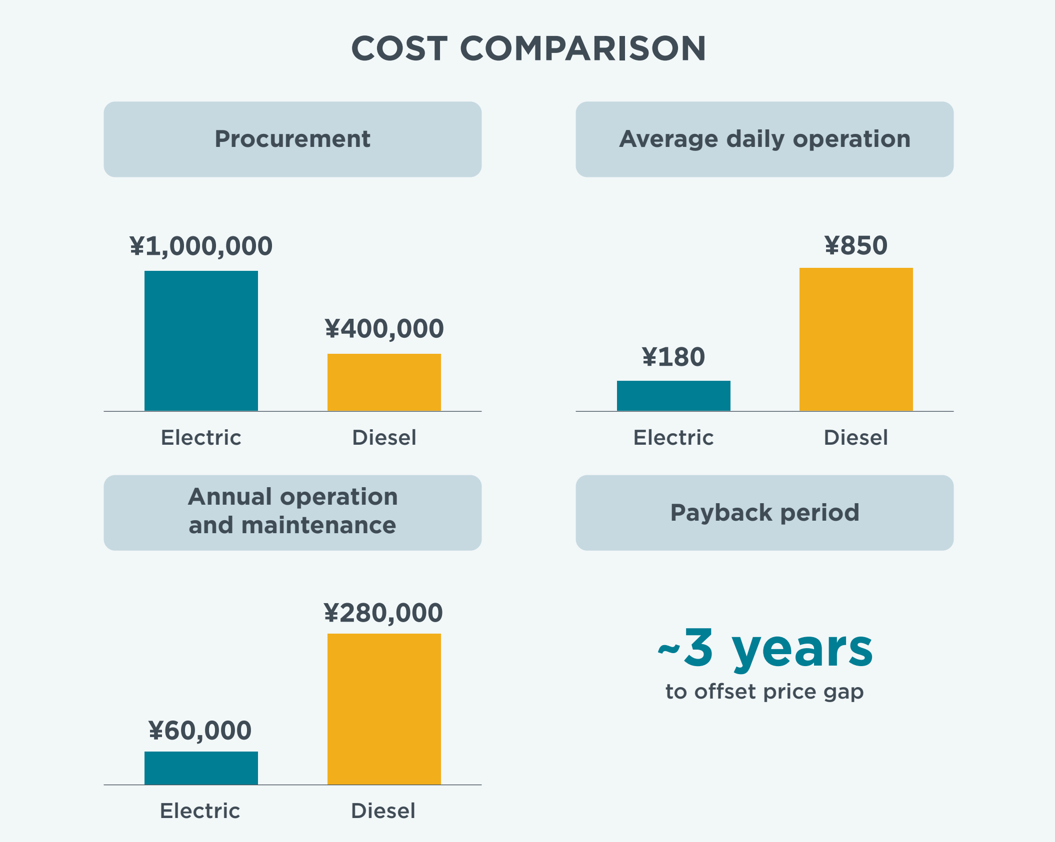
At a high-throughput biomass power plant in Liuzhou, Guangxi, electric loaders played a central role in handling nearly 900 tons of agricultural and forestry waste daily, including sugarcane leaves, straw, and tree bark. These materials were shredded and combusted to generate electricity. To support continuous operations, beginning in 2021, the plant introduced three LiuGong 856H-E MAX electric loaders equipped with specialized grapple attachments for biomass handling. Each unit, equipped with a 5.8-ton rated capacity and 282 kWh battery, operated in shifts for around 15 hours per day, recharging 3 to 4 times during meal and shift breaks. With a 240 kW dual-port charger, each 1-hour charge provided 5 to 8 hours of runtime. The plant primarily used its self-generated renewable electricity to power the loaders and resorted to external sources only during outages or maintenance.

The electric loaders performed reliably and efficiently under demanding working conditions. Compared with diesel models, they offered strong power output with smoother handling, lower vibration, and greater resistance to dust and moisture. In-cab noise was limited to 65 dB, improving operator comfort during extended shifts. Battery performance data showed one unit retaining over 93% capacity after 6,000 cumulative operating hours. The manufacturer's 5-year warranty provided further assurance, including complimentary battery replacement if degradation exceeded 20%. In the high-temperature and high-humidity environment of biomass material handling operations, dust accumulation in air intake filters initially reduced cooling airflow and caused thermal management issues, but subsequent cooling system modifications addressed these challenges, illustrating the iterative improvement process typical of emerging electric machinery technology adoption.

The electric transition brought clear cost benefits while aligning with the plant's zero-emission goals. Although each electric loader cost approximately 2.5 times as much as the diesel alternative, annual savings in energy and maintenance reached CNY 220,000 per unit. With average machine usage exceeding 5,000 hours annually, the additional capital cost could be recovered within 3 years.

Figure 3.2.1. Specifications and application of 856H-E MAX electric loaders in the Liuzhou biomass power plant

Figure 3.2.2. **Cost comparison of electric and diesel loaders in the Liuzhou biomass power plant**



LESSONS LEARNED

PROS	CONS
• Low operating costs and short payback period enabled by on-site clean energy: Annual energy and maintenance savings of approximately CNY 220,000 per unit allowed cost recovery within 3 years under high utilization. • Reliable performance in harsh conditions: Operated dependably under dust-heavy, high-load conditions, with strong resistance to environmental stress. • Improved operator comfort: Lower in-cab noise and minimal vibration enhanced the work environment during long shifts. • Strong after-sales and design support: The manufacturer provided a 5-year warranty and worked closely with the user to address site-specific issues.	• Initial thermal management challenge under dusty conditions: Cooling system required redesign to ensure reliable operation, which was resolved through close collaboration with the manufacturer.

3.3. ELECTRIC LOADERS REPLACE AGING DIESEL FLEET AND DRIVE LOW-CARBON TRANSITION AT LIANGSHAN PORT

In response to a citywide push for cleaner off-road machinery, Liangshan Port retired six aging diesel loaders and invested CNY 2.8 million to purchase three fully electric loaders, including one L956HEV unit and two L968HEV units, for bulk coal handling inside enclosed coal storage sheds.

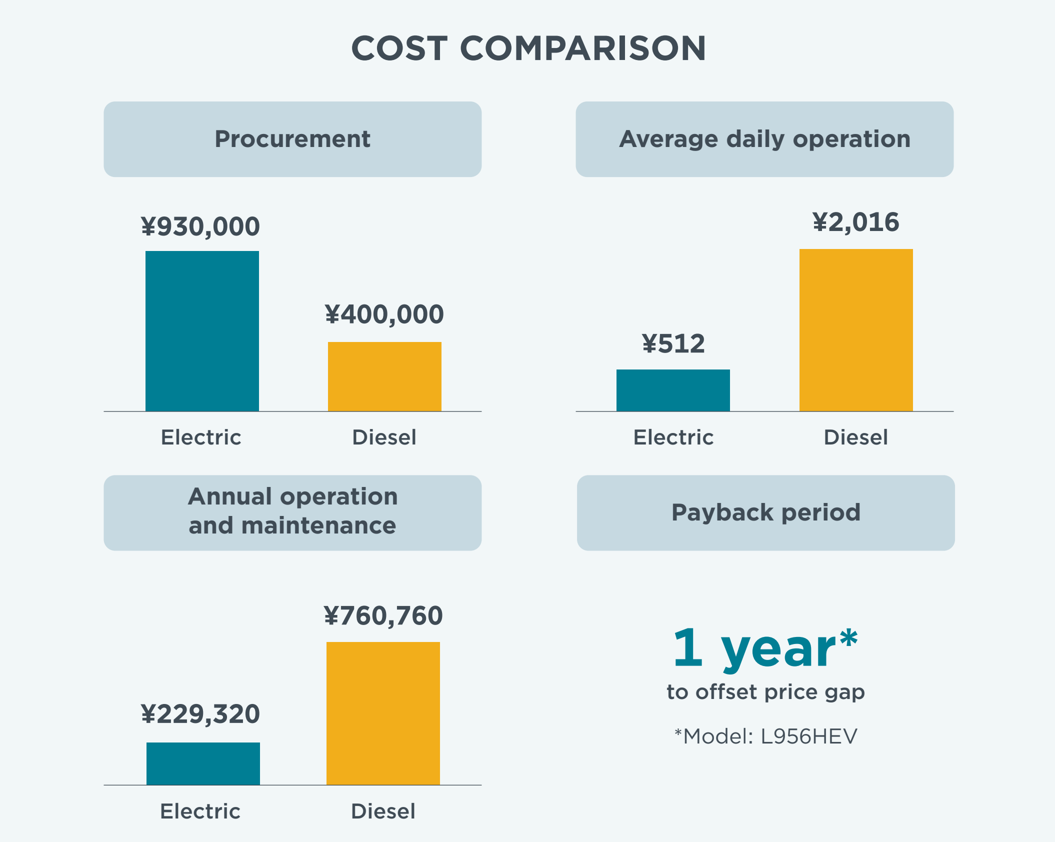
Each loader was powered by a 350 kWh lithium iron phosphate battery and used 360 amp dual-port fast charging. A 1-hour charge supported up to 6 hours of continuous operation, allowing for two-shift coverage with minimal downtime. Compared with diesel machines, operators reported smoother handling, less noise, and lower fatigue. Daily operating costs averaged CNY 512, far below the CNY 2,016 cost of diesel loaders. Over 360 workdays per year, the port saved roughly CNY 1.6 million across the three electric units.

Environmental benefits further reinforced the transition. Annual electricity use led to an estimated reduction of 440 tons of CO_2 emissions compared with diesel. This effort was complemented by the installation of a 5 MW rooftop solar system on the port's coal shed, which generates 5.5 million kWh per year. This system reduces electricity costs and cuts CO_2 emissions by more than 3,000 tons annually. In 2023, Liangshan Port became the first inland port in China to receive national dual certification for carbon footprint and carbon neutrality.

This case demonstrated how replacing legacy diesel fleets with electric alternatives can yield clear economic and environmental gains, particularly when paired with renewable power systems. For high-utilization ports seeking to reduce emissions and long-term costs, electric loaders provide a practical and scalable solution.

Figure 3.3.1. Specifications and application of L956HEV and L968HEV electric loaders at Liangshan Port

Figure 3.3.2. Cost comparison of electric and diesel loaders at Liangshan Port



LESSONS LEARNED

PROS	CONS
• Substantial cost savings: Daily energy costs were reduced by 75%, saving about CNY 1.6 million annually for three units. • Reliable performance: 1 hour of charging supported two full shifts with minimal disruption. • Improved working conditions: Low noise and zero emissions enhanced safety and comfort in enclosed workspaces. • Synergy with on-site solar power: Integration with rooftop solar amplified contribution to the port's carbon reduction goals.	• High cost of full fleet transition: Significantly higher upfront costs of electric models may pose a challenge for the full replacement of the diesel fleet.

4. ELECTRIC DRILLING RIGS

4.1. ELECTRIC DRILLING RIGS DELIVER MEASURABLE COST SAVINGS IN CHENGDU URBAN CONSTRUCTION PROJECT

In urban construction projects, where emission control and noise restrictions are increasingly strict, electric rotary drilling rigs are emerging as a practical alternative to conventional diesel equipment. At a construction site in Chengdu, two Yutong electric rotary drilling rigs, the YTE306HE and YTR266HES, were deployed for a 1-month foundation piling operation. By eliminating on-site exhaust and significantly reducing noise, the use of electric power supported compliance with local environmental and acoustic standards. Both machines operated for approximately 6 hours per day and drew electricity from the grid through cable connections (i.e., wired electric systems), enabling steady performance throughout the project.

In addition to their environmental benefits, the electric rigs offered notable cost advantages under consistent operating schedules. Daily energy costs averaged around CNY 675 per unit, compared with over CNY 2,800 for diesel models consuming approximately 375 liters of fuel per day. The purchase prices of the electric models were 20% higher than those of their diesel counterparts. Over a 20-day project period, each electric rig saved about CNY 43,000 in energy costs. Based on this performance, full cost recovery could be achieved within five to seven project cycles. For contractors with consistent workloads, the payback period could be as short as half a year.

Both drilling rigs maintained stable performance throughout the project, despite some minor component issues during the initial deployment phase. These faults were resolved promptly through on-site technical support during the warranty period at no additional cost. No disruption to construction progress was reported.

This project showed that electric drilling rigs can effectively meet urban construction demands and deliver cost benefits. With daily energy savings of over CNY 2,000 per unit and payback periods under 1 year for consistent operators, they represent a practical solution for foundation projects in dense urban areas.

Figure 4.1.1. Specifications and application of YTE306HE and YTR266HES drilling rigs at the construction site in Chengdu

Electric drilling rig specifications

Yutong YTE306HE	Yutong YTR266HES
Rated power 230 kW; 185 kW	Battery capacity N/A
Average daily use 6 h	Wired electric

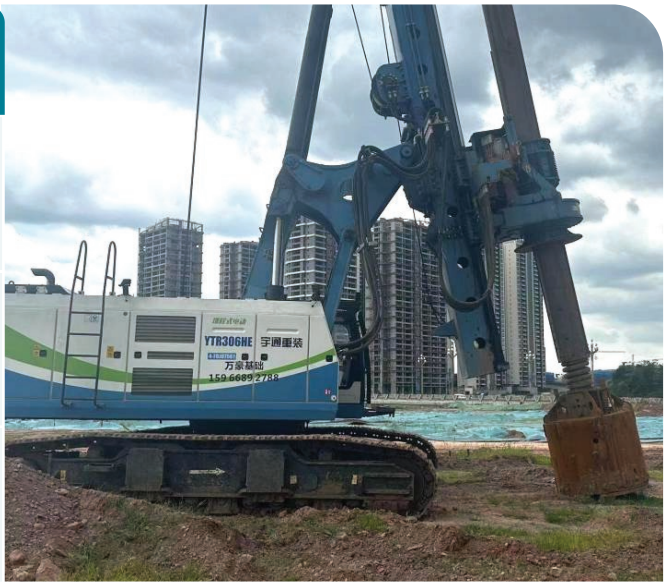
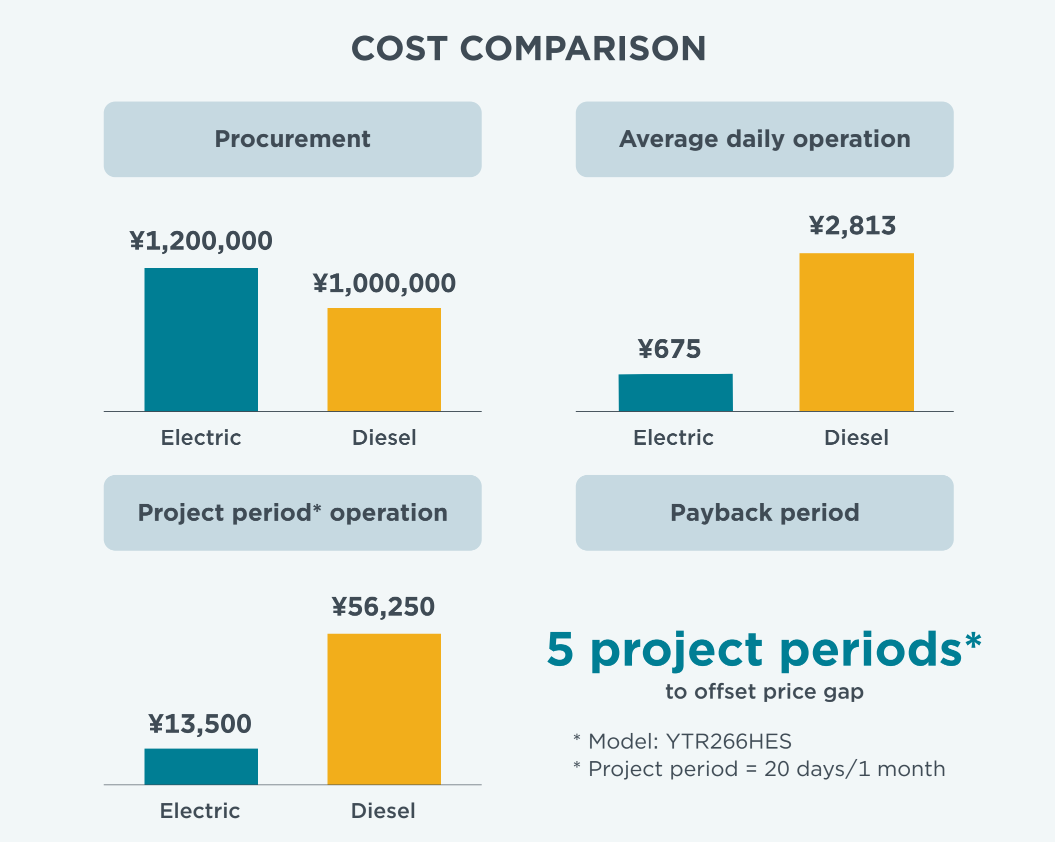


Figure 4.1.2. Cost comparison of electric and diesel drilling rigs at the construction site in Chengdu



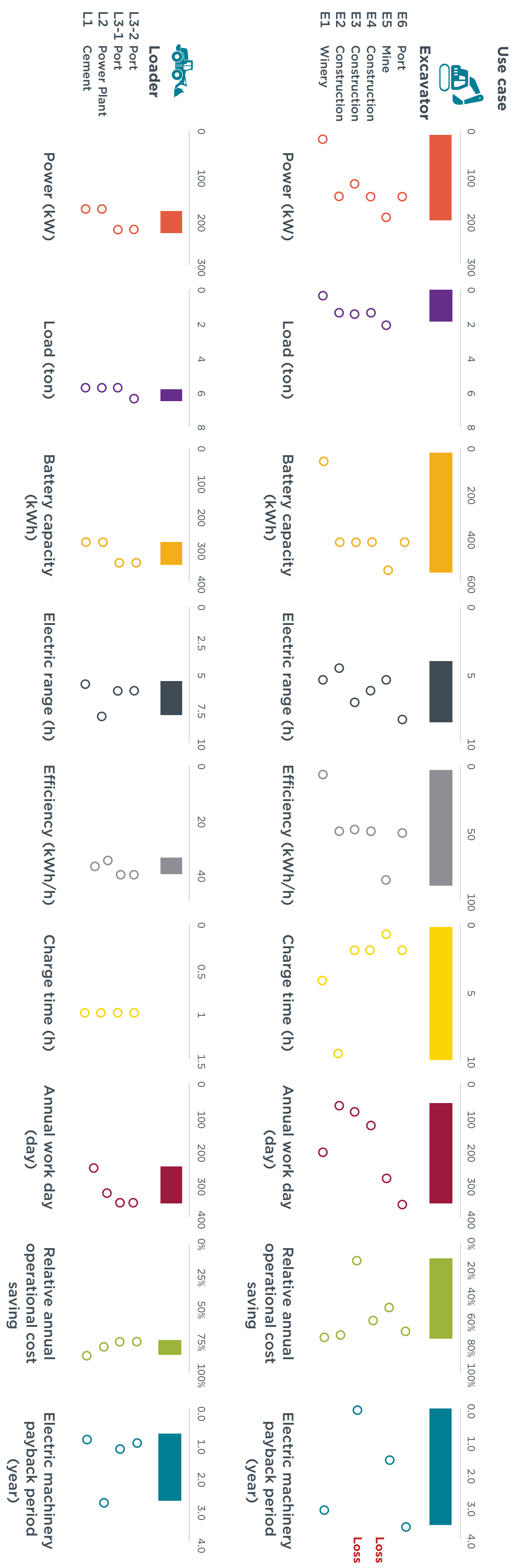
LESSONS LEARNED

PROS	CONS
• Short payback period under steady use: Reduced daily energy expenses by 76% compared with diesel models, suggesting possible cost recovery within a year for users with consistent workloads. • Environmental and acoustic compliance: Zero on-site emissions and lower noise supported adherence to tightening urban standards. • Stable performance: Operated reliably throughout the project period. • Responsive manufacturer support: Minor early faults were promptly resolved under warranty by on-site technicians.	• Minor component faults during early deployment: Initial issues required technical intervention and highlighted the need for reliable after-sales support.

5. GENERAL LESSONS LEARNED

In this casebook, we examined six electric excavator cases, three electric loader cases, and one electric drilling rig case across diverse real-world settings, including urban construction sites, tunnel projects, mining sites, cement and power plants, and distilleries. Figure 5 summarizes the deployment scenarios, model specifications, and cost parity considerations for electric excavator and loader applications. (Drilling rigs are excluded from the figure due to incomparable performance parameters.) These use cases offer practical insights into the performance, operational suitability, and cost-effectiveness of electric off-road machinery in China, discussed below.

Figure 5. Summary of deployment settings, technical specifications, and cost parity outcomes for electric excavator and loader applications



Electric excavators examined in this study ranged from 2 to 41 tons in machine weight, with power outputs between 10 and 200 kW, bucket capacities spanning 0.04 to 1.9 m^3, and battery sizes ranging from 22 to 560 kWh. Depending on machine size and workload, they operated electrically for 4 to 8.5 hours per charge. Average daily operating use varied from 4 to 15 hours. Payback periods ranged from 1.5 to 3.6 years in the three most economically advantageous cases, with the most cost-effective case—a battery-swapping excavator deployed at Honghe Prefecture's continuous mining operation—achieving full cost recovery in just under 1.5 years.

Electric loaders spanned from 18 to 22 tons in weight and 180 to 230 kW in power output, with load capacities between 5.8 and 6.5 m^3. Battery capacity ranged from 282 to 350 kWh, supporting 5.5 to 8 hours of runtime per charge. Annual operating hours ranged widely, from around 3,000 to more than 5,700. Most loader use cases demonstrated significant fuel savings, with payback periods ranging from within 1 to 2.7 years. In Chengdu's high-intensity cement plant, electric loaders operating across three shifts achieved a payback period of around 8 months.

Electric drilling rigs had power outputs ranging from 185 to 230 kW. Unlike electric excavators and loaders, which are often powered by battery-electric systems, electric drilling rigs commonly rely on wired electricity due to their limited mobility requirements during operation. This setup enables continuous power supply without the need for frequent recharging. In contrast to equipment used in industrial plants, cement facilities, or mining sites, where operations are conducted year-round, rotary drilling rigs are mainly deployed in short-term construction projects. In an urban construction site in Chengdu, grid-connected electric drilling rigs met strict environmental requirements while reaching near-term cost parity through reduced energy use and stable performance.

The diverse cases in this study highlight the following common strengths and key challenges of deploying electric machinery in real-world settings:

Common strengths

» Clear environmental benefits: Electric machinery eliminates tailpipe emissions, making it especially suitable for enclosed environments (e.g., tunnels and distilleries), urban construction sites, and areas with strict environmental controls. This positions electric equipment as a compliance-ready solution under tightening air quality and noise regulations.

» Improved worksite conditions: Many cases were characterized by significantly lower noise, vibration, and emissions, leading to safer, healthier, and more comfortable working environments, particularly in enclosed, high-exposure, or urban settings.

» Lower operating costs and rapid payback in high-utilization scenarios: In projects with high daily usage, electric machines consistently delivered 50%–86% energy cost savings. In several cases, payback periods were achieved in under 2 years, offering a compelling economic case where utilization is stable and intensive.

» Demonstrated operational functionality comparable to diesel counterparts: Across case types, electric equipment proved capable of meeting core productivity needs (especially repetitive task- and shift-based work) when charging or battery-swapping solutions were in place.

Key challenges

» High upfront and leasing costs: The purchase or leasing costs of electric machinery in our cases were 1.3 to 3 times those of their diesel counterparts. In several cases, rental premiums tended to be higher than purchase premiums due to provider risk margins, logistics and service costs, and limited competition in the emerging electric machinery rental market. Without financial policies or strategic industry partnerships, this price gap may deter adoption, especially among smaller operators.

» Charging infrastructure gaps limit runtime: Many machines achieved only 4–6 hours of operation per charge, which fell short of diesel-equivalent runtimes. The lack of on-site fast-charging options or scalable battery-swapping systems often disrupted workflows or required labor-intensive solutions. Grid constraints and long approval timelines for increased grid capacity hindered the deployment of fast chargers in several construction cases. Inadequate planning for charger locations or swap logistics reduced operational efficiency. This challenge may be particularly pronounced for smaller construction sites where individual grid capacity often cannot support full electrification. Large-scale construction sites and dense construction zones may present better opportunities for shared charging infrastructure and economically viable grid upgrades.

» Limited model availability and market maturity: Access to electric heavy-duty machinery remains constrained by a small number of models and suppliers, and this equipment often requires technological customization. Lack of information disclosure and access to available models prior to purchase further hampers adoption. Some machines are only available for purchase, not rental, limiting flexibility for pilot users and small fleets.

» Economic viability depends on utilization: The business case for electric machinery is highly sensitive to usage intensity. For low-frequency or small-scale operators, extended payback periods may reduce willingness to invest without external incentives or shared-use mechanisms.

» Concerns over long-term durability and value: Some users remain cautious about battery life and resale value, especially beyond warranty periods.

Key success factors and enablers for scaling zero-emission off-road machinery

Based on the case studies we examined, we identified the following key factors or enablers for policymakers, fleet operators, and manufacturers to consider as they work together on scaling zero-emission off-road machinery.

» At the current stage of technology development, zero-emission equipment performs best in applications with high utilization (long working hours), moderate-duty or repetitive tasks, reliable access to charging and power supply, and high electric efficiency. These conditions create the most favorable environment for successful deployment of zero-emission machinery.

» Policy and regulatory drivers can play a critical role in catalyzing adoption. Environmental standards related to air pollution, GHG emissions, and noise have created demand for cleaner and quieter equipment in urban, industrial, and enclosed environments. Emerging policy tools from our cases include local zero (or near-zero) emission zones or construction sites, requirements for the use of clean machinery in heavy industries during air pollution episodes, and indoor air quality standards in certain manufacturing sectors. In some cases, even where financial payback was slower, the need to comply with safety and environmental requirements prompted early adoption.

» Public-private collaboration is essential. Manufacturer-backed pilot projects allowed users to evaluate electric machinery performance without bearing the full financial risk, while simultaneously generating real-world data to inform future investments. These partnerships not only reduced early barriers but also helped build public and industry confidence.

- Early and proactive planning is critical to operational success. In the cases we examined, grid access, permitting, and charging options and coordination (such as dedicated charging lanes, temporary mobile chargers, or lasting fast chargers) had to be addressed upfront. Operational and logistical adjustments are also essential. Effective use of electric machinery depends on careful coordination of work shifts and charging schedules. Deployment can also be more complex when model options are limited or charging systems lack compatibility, requiring advanced planning and flexible logistics.
- Strong post-sales support from manufacturers, including extended warranties, tailored technical assistance, and on-site troubleshooting, proved vital to resolving site-specific issues and ensuring long-term performance.

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www.theicct.org

communications@theicct.org

@theicct.org

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