Analysis on the energy-saving and emission-reduction benefits of new energy engineering machinery: A vertical and horizontal study based on XCMG Group

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Abstract. With the rapid development of the economy and society and the dual drive of carbon neutrality, the demand for new energy engineering machinery is becoming more and more vigorous, accelerating the replacement of traditional diesel equipment. Infrastructure construction cannot be separated from the use of engineering machinery. New energy equipment promotes green development and energy conservation and emission reduction. This paper will take XCMG Group as the research object, through the vertical comparison of the evolution of XCMG's own diesel engines and new energy equipment, and the horizontal benchmarking of the product spectrum, fuel saving and emission reduction, life cycle cost and business model of the same industry (XCMG VS Sany, Carter), a comprehensive analysis of market demand, market capacity, future market development direction, etc., to analyze the practical significance of new energy engineering machinery for energy conservation and emission reduction and the trend of future green development.

Keywords: New Energy Equipment, XCMG, Emission reduction, Green development, market competitiveness.

Introduction

The global construction machinery industry accounts for about 12% of industrial carbon emissions (IEA 2023), with diesel traditional equipment being the main source of particulate matter (PM2.5) and carbon oxides (NOx) emissions. With the implementation of China's Phase IV emission standards for non-motorized mobile equipment, the shift to new energy demand is accelerating (DAE, 2022)

XCMG, as a leader and pioneer in China's construction machinery industry, is a model of this shift. Its new energy product line, covering new energy electric, hybrid and hydrogen fuel cell systems, achieved year-on-year growth of 217% in 2023, accounting for 35% of the domestic market in China. However, challenges such as high upfront costs (hydrogen energy equipment costs 2.8 times more than diesel) and infrastructure gaps (only 19% of construction sites in China are equipped with fast charging stations) have hindered the widespread application of new energy construction machinery.

The use of green energy accelerates environmental protection. Countries around the world are promoting energy transformation. Traditional energy is not conducive to the normal development of the environment. The rise of new energy is an inevitable trend in energy development. The Indonesian government is also actively promoting the development of the use of new energy. Since the signing of the Paris Agreement in 2015 (Ban, 2016), green energy has developed rapidly around the world. In 2023, global green energy investment has exceeded 1.7 trillion US dollars, surpassing traditional energy for the first time. The field of construction machinery has also gradually shifted from high energy consumption and high emissions to electric, intelligent, and low-carbon modes. The new energy of construction machinery is an emerging scenario for the application of green energy. It has brought measurable positive impacts in carbon emission reduction, urban environmental protection, and operational safety, and has gradually become an important support for the green transformation of infrastructure.

Background

The background of the use of new energy in construction machinery is a multi-dimensional and systematic proposition, which includes not only the external pressure of energy security and global climate governance, but also the endogenous power of the manufacturing industry to reduce costs and

increase efficiency, iterate technology and update policies. China has pledged to "peak carbon in 20230 and achieve carbon neutrality in 2060", and Western countries and other economies have also set a goal of achieving carbon neutrality around 2050. As non-road mobile machinery, construction machinery consumes 55 million tons of diesel annually, and carbon dioxide emissions account for 18% of the country's non-road sources (State Council, 2024). The fluctuations in energy prices and fossil fuel prices have brought about the explicitness of economic risks. Taking a 25-ton XCMG truck crane as an example, the monthly fuel consumption is about 5,000 yuan, accounting for 1/3 of the operating cost; under the background of high oil prices and inverted rents, the electricity/oil cost ratio of new energy equipment is 1:5, which can make an additional profit of 14 US dollars per day, and the cash flow in the four-year financing period will turn from negative to positive. The maturity of industrial technology and the decline in the price of power batteries have promoted the economic efficiency of construction machinery to exceed the break-even point ahead of schedule. The technology has strong adaptability, and the electricity consumption cost of pure electric equipment and other medium- and short-term, indirect operation scenarios is only 1/3-1/5 of the diesel version. It also reflects the advantages of new energy in the market application scenario segmentation, supports night work, is noise-free and green, and is convenient to charge. At present, the night operation scene has achieved a penetration rate of 71%. Thanks to fixed lines and centralized energy replenishment, XCMG's business model is to launch a battery leasing plan, reduce users' down payments by 30%-40%, and solve the endurance problem through a network of swap stations. In 2024, the penetration rate of new energy in construction machinery has reached 13.4%, and the sales volume of electric loaders has increased by 361% year-on-year, and the operating costs such as maintenance have been greatly reduced. The use of new energy and green energy ensures the implementation of the entire life cycle of mechanical equipment and makes new contributions to energy conservation and emission reduction.

The Comparison of between the traditional energy and green new energy

Indicator	Traditional diesel equipment (score)	New energy equipment (score)	Description
Carbon emissions	80	30	New energy significantly reduces carbon emissions
Energy consumption	85	40	Electricity consumption is much lower than fuel consumption
Noise	90	35	Electric drive is quieter
Maintenance frequency	70	45	New energy equipment has a simpler structure and fewer failures
Operating costs	75	50	Lower energy and maintenance costs

Source: interview the manager XCMG Indonesia

Carbon emissions: XCMG's XE270E electric excavator can reduce carbon dioxide emissions by 62 tons per year, which is equivalent to the carbon sequestration of 3,400 trees. This shows the positive effects of XCMG's new energy equipment in reducing carbon emissions. Electric equipment directly eliminates exhaust emissions and has a significant effect on energy conservation and emission reduction.

Energy consumption: The energy consumption cost of XCMG's electric loader LW500FN is only US$3 per hour, which is 74% lower than that of the traditional diesel version. The actual energy saving effect depends on the influence of actual working conditions (such as the accelerated attenuation of new energy batteries during continuous heavy load operation).

Noise: The operating noise of XCMG's electric equipment is 68dB, while the traditional diesel version is about 82dB. The noise of electric equipment is close to the urban daytime environmental noise standard (65dB), which is suitable for work in sensitive areas such as hospitals and schools. It also has commercial value. Some European cities impose surcharges on equipment with excessive noise (such as Berlin charges 15 euros per hour for noise exceeding 75dB), and electric equipment can avoid such costs.

Maintenance frequency: The moving parts of electric equipment are reduced by 80% (no engine, gearbox, exhaust treatment system). XCMG's report shows that the annual maintenance cost of its electric loaders has been reduced by 44%. Battery health monitoring has become a new focus (for example, XCMG uses a cloud BMS system to predict battery life with an accuracy of 92%).

Operating Costs: New energy equipment has obvious advantages in operating costs. Taking XCMG loaders as an example, the 5-year operating cost of diesel equipment is about 170,000 US dollars, and the 5-year operating cost of pure electric equipment is about 100,000 US dollars. Energy costs and maintenance costs are greatly reduced.

Methodology

This study will use qualitative analysis and quantitative analysis. Quantitative analysis will use vertical analysis and horizontal analysis. Vertical analysis refers to the comparison of XCMG's own new energy equipment, from the average energy consumption, carbon dioxide emissions and fuel equipment and new energy equipment comparison, sample energy efficiency and emission data comparison, the relevant data collection comes from XCMG's equipment parameter manual, ESG report, industry report, empirical evaluation data, corporate annual financial report and other materials. Horizontal analysis refers to the comparison with its business competitors, through the energy consumption and carbon emissions of the same model of equipment, compared with competitors, whether XCMG has more advantages in new energy. Qualitative analysis refers to direct interviews with XCMG's internal senior leaders, giving a SWOT analysis of XCMG's new energy equipment in energy conservation and emission reduction and future market forecasts for new energy equipment.

XCMG's own technological evolution

XCMG Group's transformation of equipment technology from traditional fuel equipment to new energy reflects its strategic response to the global decarbonization trend and carbon neutrality and carbon peak goals. This evolution can be divided into three key stages and is supported by specific milestones and market application data.

Source: XCMG official website

Comparison between electric excavator XE270E and diesel engine XE270D - Comparative analysis of sample energy efficiency and emission data, selected a representative equipment of the same tonnage for analysis.

Index	XE270E（EV）	XE270D（Diesel）	Change
Average energy consumption	22.3 kWh/h	15.2 L/h	-35.6%（based on CO_2 emissions）
Unit carbon emissions	18.5 kg CO_2/h	29.8 kg CO_2/h	-37.90%
Operation and maintenance costs	14.6 yuan/h	33.5 yuan/h	-56.40%

Failure rate (year))	0.8 times	1.6 times	↓50%

Source: XCMG internal data

By comparing the four core indicators of XCMG's XE270E electric excavator and XE270D diesel excavator, the table clearly shows the significant advantages of new energy construction machinery in energy conservation, emission reduction and economic benefits. From the perspective of energy consumption, the average energy consumption of the XE270E is 22.3 kWh/h, which is 35.6% lower than the diesel version's 15.2 L/h, based on carbon dioxide emissions. This data shows that electric equipment has a significant improvement in energy efficiency. The fundamental reason is that the energy conversion efficiency of electric motors (usually over 85%) is much higher than that of diesel engines (about 35-45%), and the electric system avoids the energy loss links of traditional internal combustion engines, such as heat loss and mechanical friction. In terms of carbon emissions, the unit carbon emissions of the XE270E are 18.5 kg CO_2/h, which is 37.9% lower than the diesel version's 29.8 kg CO_2/h. This is mainly due to the direct elimination of tail gas emissions by electric equipment, while the clean progress of China's power grid (such as the increase in the proportion of renewable energy) has further reduced indirect emissions. It is worth noting that if green electricity (such as photovoltaic or wind power) is used, carbon emissions can be close to zero.

In terms of operating costs, the hourly cost of XE270E is only 14.6 yuan, which is 56.4% lower than the 33.5 yuan of the diesel version. This advantage comes from the stability of electricity prices and the simplification of electric system maintenance. The high cost of diesel equipment is mainly affected by fuel price fluctuations and complex mechanical structures (such as regular maintenance of engines and gearboxes), while electric equipment only needs to focus on battery and motor maintenance, and the number of lubrication points is reduced by more than 80%. The failure rate data also confirms this: the annual failure rate of XE270E is 0.8 times, which is 50% lower than the 1.6 times of the diesel version. This is attributed to the significant reduction of moving parts in the electric system (such as no fuel injection system, exhaust gas after-treatment device), thereby reducing mechanical wear and failure risks.

Overall, the table not only verifies the superiority of new energy engineering machinery in environmental protection indicators, but also reveals its economic potential. However, it should be noted that the actual performance of electric equipment is subject to external conditions. For example, battery performance degradation in low temperature environments may affect energy consumption, and the degree of perfection of charging infrastructure will also determine equipment utilization. In addition, hidden costs not reflected in the table (such as battery replacement costs) need to be included in the full life cycle assessment. XCMG's data provides an important reference for the industry, but in the future, it needs to be combined with more field tests (such as performance in different climates and working conditions) to fully quantify the comprehensive value of new energy equipment.

Horizontal comparative analysis between XCMG Group and its competitors in the field of new energy engineering machinery

Description of main comparison dimensions and indicators				
Comparison Dimensions	**Key Indicators**	**XCMG**	**SANY**	**Caterpillar**
Product type	New energy model type (electric, hydrogen, etc.)	Electric, hydrogen	Electric mainly	Hybrid, electric
Technical path	Electric drive system, fuel cell integration	Independent platform + cooperative optimization	Self-developed three-electric system	Mature hybrid technology

Annual sales growth rate（2019–2024）	CAGR（New energy equipment）	65% ↑	48% ↑	30% ↑
Reducing carbon emissions from bicycles	Annual reduction in carbon dioxide emissions (tons/unit)	38T	35T	32T
Life cycle cost savings	Compared with traditional equipment	reduce 25%	reduce 20%	reduce 18%
Intelligence level	Remote monitoring, energy management system	High (cooperation with Huawei)	Medium-high	Mature platform
Export share (new energy equipment)	Share of total sales	23%	15%	45%
New energy-related patents (2020–2024)	Number of authorizations	326items	210items	180items

Source: second data

XCMG, SANY and Caterpillar have shown significant differences in their development paths and emission reduction benefits in the field of new energy engineering machinery. XCMG has achieved a comprehensive layout in the field of electric and hydrogen energy equipment with its independent R&D platform + cooperatively optimized technical route. Its new energy vehicle model has an annual compound growth rate of 65%, far exceeding SANY (48%) and Caterpillar (30%). A single device reduces CO_2 emissions by 38 tons per year, leading the industry. Although SANY is mainly electrified, its self-developed three-electric system has outstanding performance in cost control, reducing life cycle costs by 20%; Caterpillar relies on mature hybrid technology, and its emission reduction effect (32 tons/unit) and cost advantage (reduced by 18%) are slightly inferior, but its export share is as high as 45%, reflecting the first-mover advantage in the global market.

The core significance of new energy equipment for energy conservation and emission reduction lies in the significant reduction of carbon footprint throughout the life cycle. Taking XCMG as an example, a single piece of equipment can reduce CO_2 emissions by 38 tons per year. If it is extended to its sales of new energy equipment in 2023 (about 12,000 units), the total annual emission reduction can reach 456,000 tons, which is equivalent to the carbon sequestration of 250,000 trees in one year. In addition, electric and hydrogen energy equipment not only reduce direct pollution but also reduce dependence on fossil energy through zero tail gas emissions and efficient energy conversion (electric motor efficiency>85% vs diesel engine 40%). Intelligent functions (such as the energy management system cooperated by XCMG and Huawei) further optimize energy consumption and improve emission reduction efficiency.

The key to future competition lies in the speed of technology iteration and industrial chain synergy. The gap between XCMG's 326 new energy patents (2020-2024) and Sany's 210 reflects that Chinese companies are seizing the right to set standards through innovation. However, Carter's advantage in the export market (45% share) shows that international customers still value brand trust and the transition value of hybrid power. At the policy level, China's "dual carbon" goals will accelerate the penetration of electric/hydrogen equipment, while European and American carbon tariffs (such as CBAM) may force companies to give priority to low-carbon equipment, further amplifying the dual benefits of new energy in terms of emission reduction and economy.

Finding and discussion

The study found that XCMG's development in the field of new energy engineering machinery has shown significant technological breakthroughs and market growth, and its energy-saving and emission-reduction benefits have been fully verified through vertical and horizontal comparisons. Vertical comparisons show that XCMG's new energy equipment has achieved significant optimization in carbon emissions, energy consumption, operating costs and maintenance efficiency compared to traditional fuel equipment. Taking the XE270E electric excavator as an example, its unit operating energy consumption is 22.3 kWh/h, which is 35.6% lower than the 15.2 L/h of the diesel version XE270D (based on carbon emissions conversion), and unit carbon emissions have dropped from 29.8 kg CO_2/h to 18.5 kg CO_2/h, a reduction of 37.9%. Operating costs have dropped from 33.5 yuan/h to 14.6 yuan/h, a decrease of 56.4%, and the annual failure rate has dropped from 1.6 times to 0.8 times, a decrease of 50%. Hydrogen energy equipment such as the XCT25_FCEV crane achieves zero tail gas emissions, with an annual emission reduction of 120 tons of CO_2 per unit, noise levels reduced from 85 dB to 72 dB, and low-temperature adaptability improved to -30°C. These data show that new energy equipment not only meets environmental protection requirements, but also has competitive advantages in terms of economy and reliability.

Horizontal comparative analysis reveals that XCMG has differentiated advantages over domestic and foreign competitors in terms of new energy technology paths and market performance. Compared with Sany Heavy Industry, XCMG's new energy vehicle models cover a wider range (electric + hydrogen energy), with an annual sales compound growth rate of 65% (48% for Sany), an annual emission reduction of 38 tons per unit (35 tons for Sany), and a life cycle cost reduction of 25% (20% for Sany). At the technical level, XCMG's independent R&D platform and the intelligent system in cooperation with Huawei achieve efficient energy management, and the number of patent authorizations (326) is significantly higher than Sany (210) and Caterpillar (180). Compared with the international giant Caterpillar, XCMG has laid out its layout in the field of pure electric and hydrogen energy earlier, but Caterpillar has a 45% export share (XCMG 23%) with its mature hybrid technology and global channels, highlighting its adaptability advantage in the transition stage. It is worth noting that the fast charging technology of XCMG XE270E (1.5 hours) is ahead of Sany SY19E (2 hours), and the emission reduction potential of hydrogen energy equipment in the field of heavy machinery (such as XCA1800 hydrogen energy crane) is close to the performance of diesel engines, but cost is still the main bottleneck (the purchase price of hydrogen energy equipment is 2.8 times that of diesel engines).

The discussion part needs to focus on the deep significance of new energy equipment for energy conservation and emission reduction and the challenges of industry transformation. From the perspective of environmental benefits, if the annual emission reduction of XCMG's new energy machinery (62 tons for electric/120 tons for hydrogen energy) is promoted on a large scale, it will greatly reduce the carbon footprint of the construction machinery industry. Based on the sales volume in 2023, the total annual emission reduction of its electric excavators is equivalent to planting 34 million trees, and hydrogen energy equipment can achieve a zero-emission breakthrough in the field of heavy machinery. In terms of economy, the TCO of electric equipment has been lower than that of diesel engines within three years, but hydrogen energy equipment depends on the price reduction of green hydrogen (target 20 yuan/kg in 2030) and the improvement of hydrogen refueling infrastructure. In terms of policy drive, China's "non-road National IV" standard and the EU CBAM carbon tariff form internal and external pressures, forcing companies to adopt new energy equipment. However, low-temperature endurance attenuation (-20℃ battery capacity drops by 30%), charging pile coverage (only 19% of construction sites) and shortcomings in the hydrogen energy industry chain (green hydrogen accounts for less than 5%) are still the key points of technical breakthroughs. The core of future competition lies in the breakthrough of battery energy density (XCMG's target is 400 Wh/kg solid-state battery) and hydrogen energy storage and transportation technology, and the joint construction of the "battery bank" model or integrated photovoltaic storage and charging power station by government and enterprises will become the key to large-scale application. In summary, XCMG's case proves that new energy engineering machinery has entered the stage of market competition from policy guidance, and its emission reduction benefits and economic value will provide a replicable Chinese solution for the low-carbon transformation of the global engineering machinery industry.

Limitation

Limitations of data coverage

The study mainly relies on XCMG public data and some third-party test reports, which may not cover all performance under actual working conditions (such as extreme climate, high-load continuous operation, etc.).

In horizontal comparison, the data of competitors (such as Sany and Caterpillar) mostly come from public reports, lacking unified testing standards, which may lead to reduced comparability of indicators.

Limitations of time span

The vertical analysis only covers 2015-2023, and the environmental impact of the entire life cycle (more than 10 years) of new energy equipment (especially hydrogen energy) has not yet fully emerged.

Technology iteration is rapid (such as solid-state batteries, hydrogen internal combustion engines), and the current conclusions may become outdated in the next 3-5 years due to technological breakthroughs.

Limitations of assumptions

The carbon emission calculation is based on China's average grid factor (0.583kg CO_2/kWh). If the regional power structure is very different (such as the high proportion of renewable energy in the northwest), the actual emission reduction benefits may be underestimated or overestimated.

The economic analysis does not consider the impact of policy fluctuations (such as subsidy reduction and carbon price increase) on TCO.

Limitations of application scenarios

The study focuses on mainstream equipment such as excavators and cranes, but the emission reduction paths of micro-machines (such as forklifts) or ultra-heavy machinery (such as mining trucks) may be different.

Infrastructure constraints (such as the coverage rate of charging piles/hydrogen refueling stations) are insufficient to quantify the actual emission reduction effect.

Limitations of international differences

The conclusion is mainly applicable to the Chinese market, while the emission reduction benefits of new energy equipment in the European and American markets may be significantly different due to differences in energy structure (proportion of green electricity) and regulations (carbon tariffs).

Suggestions for improvement

Expand data sources: include more field monitoring data (such as real-time energy consumption of IoT terminals).

Extend the research cycle: track the 10-year durability data of the first batch of hydrogen energy equipment (such as XCT25_FCEV).

Dynamic model construction: introduce policy sensitivity analysis to simulate the impact of variables such as carbon price and hydrogen price on economic efficiency.

Conclusion

XCMG's new energy engineering machinery has demonstrated its dual value in energy conservation and emission reduction and economic feasibility through electrification and hydrogen energy technologies, becoming the core solution for the low-carbon transformation of the engineering machinery industry. In the future, it is necessary to further expand the scale of emission reduction through policy support (such as charging/hydrogenation infrastructure subsidies), technological innovation (solid-state batteries, hydrogen internal combustion engines) and industrial chain collaboration (battery recycling, green hydrogen production) to help achieve the global carbon neutrality goal.