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Review

Electric Tractors in China: Current Situation, Trends, and Potential

Hongguang Yang [1], Feng Wu [1], Fengwei Gu [1], Hongbo Xu [1], Lili Shi [1], Xinsheng Zhou [2,*], Jiangtao Wang [3,4] and Zhichao Hu [1,*]

[1] Nanjing Institute of Agricultural Mechanization, Ministry of Agriculture and Rural Affairs, Nanjing 210014, China
[2] Suiping Rural Social Development Service Center, Zhumadian 463100, China
[3] Henan Province Planting and Harvesting Agricultural Equipment Co., Ltd., Zhumadian 463100, China
[4] Henan Nongyouwang Agricultural Equipment Technology Co., Ltd., Zhumadian 463100, China
* Correspondence: spxnjz2014@163.com (X.Z.); huzhichao@caas.cn (Z.H.)

Abstract

Tractors are widely used self-propelled power machinery. Electrification is one of the main directions for the green and low-carbon development of tractors. Currently, electric tractors have become one of the main research hotspots in countries around the world. This study provides a comprehensive review of the research progress on electric tractors in China. Firstly, a brief analysis is conducted on the development history of electric tractors, the current research status in other countries around the world, and the situation regarding China's tractor industry. Secondly, the classifications and characteristics of electric tractors are summarized. We focused on the research progress of electric tractor motors and their drive transmission systems, batteries, and energy management technology, as well as other key technologies. Finally, some opportunities and challenges faced by the development of electric tractors in China are pointed out from the aspects of market demand, national policies, and standard setting.

Keywords: electric tractor; off-road vehicles; new energy; carbon emission

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1. Introduction

As is well known, tractors are one of the main power machinery technologies widely used in agriculture, forestry, and industrial production, especially playing an important role in agricultural production practice. However, the issue of carbon emissions during tractor operation is not easily overlooked. It has become one of the main sources of carbon emissions in the agricultural sector [1–3].

The tractors currently in use are generally powered by internal combustion engines that consume diesel or gasoline. Diesel or gasoline engines typically have higher levels of pollutants in their combustion emissions [4,5]. Electric tractors have the advantages of lower emissions and higher energy savings compared to traditional tractors driven by internal combustion engines [6–9]. Pascuzzi et al. [10] found that the fuel consumption and carbon dioxide emissions of hybrid electric tractors are ten times and five times lower than those of internal combustion engine driven tractors, respectively. Mousazadeh et al. [11] found that a solar-assisted plug-in hybrid electric tractor can reduce carbon dioxide emissions by 14 tons per year compared to traditional internal combustion engine-driven tractors. Ueka et al. [12] found that electric tractors reduce the energy consumption and carbon

dioxide emissions required for field operations by about 70% compared to traditional internal combustion engine-driven tractors.

In recent years, with the increasingly severe global energy and environmental pollution problems, many countries such as China [6], the United States [13], India [8,14,15], Italy [10,16,17], Brazil [18,19], Japan [12,20], Belarus [21], South Korea [22–24], Russia [25], Australia [26], the United Kingdom [27], Romania [28], Iran [11], Sweden [29,30], and Canada [31,32] have begun to vigorously develop electric tractors. These research results will make important contributions to global energy conservation and emissions reduction.

To further understand the current status of research and application of electric tractors in China, this study conducted a comprehensive review. The research results can provide a reference for the development of the electric tractor industry in China and other countries.

2. Development of Electric Tractors in Other Countries Around the World

To be precise, the electrification of tractors is not a new phenomenon. Electric tractors have been around for over 130 years, since the late 1880s [33]. Throughout the development history of electric tractors, they can be divided into two stages: power-grid-powered and battery-powered.

2.1. Electric Tractors Powered by Power Grids

Electric tractors powered by the power grid were mainly developed before the 1950s and require power supply through overhead power lines and long cables. They first appeared in Germany in the early 20th century and in Russia and the United Kingdom in the 1930s and 1940s [34]. Figure 1 shows some representative agricultural electric tractors produced by Germany, the United Kingdom, and the Soviet Union.

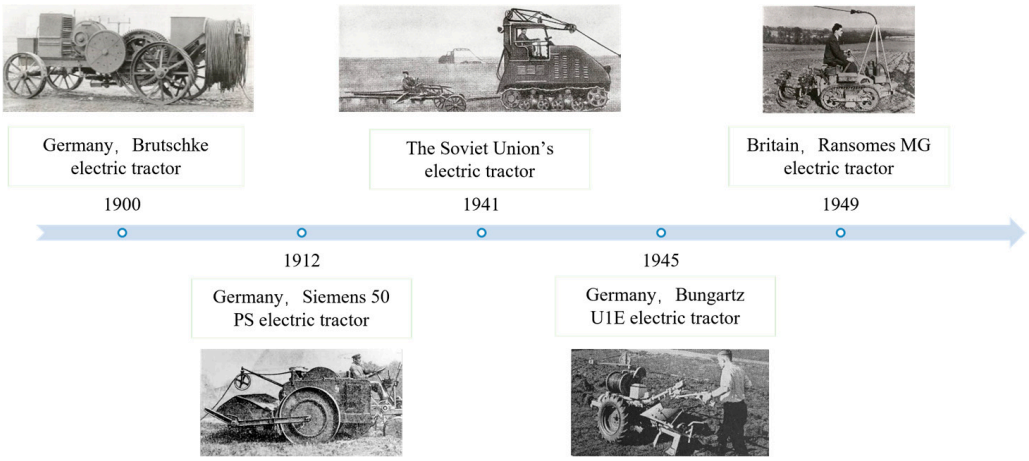


Figure 1. Historical timeline of electric tractors powered by power grids being used in agriculture [34,35].

However, practice has shown that the biggest problem faced by tractors powered by the power grid is how to handle the power cables. Moreover, there is a risk of wear and tear when dragging cables on the soil's surface, and they are prone to entanglement with tractor wheels when turning at headlands. At the same time, oil prices were cheap at that time, and environmental pollution issues were not taken seriously, so this electric tractor did not achieve large-scale replacement applications for traditional tractors.

In recent years, the American manufacturer John Deere has proposed a plan to develop cable-driven electric tractors, and successfully developed a prototype by the end of 2018 [36]. Although the electric tractor developed by John Deere uses a robotic arm to release and retract the power cable, it to some extent avoids the problem of cable entanglement with

tractor wheels. But it is still unknown whether electric tractors powered by cables can be widely used in the future.

2.2. Electric Tractors Powered by Batteries

In fact, the development of battery-powered electric tractors comes with energy and environmental issues, alongside the rapid development of electric vehicles. In particular, the energy crisis that emerged in the 1970s greatly propelled the development of electric tractors in countries around the world. And, at this stage, electric tractors are no longer constrained by power cables, and are powered by batteries.

In 1954, the International Harvester Company launched the Farmall 400 tractor. The world's first fuel-cell electric tractor was manufactured by Allis Chalmers Manufacturing Company in 1959. This tractor is equipped with 1008 independent fuel cells, which generate electricity to drive a 20 horsepower DC motor. In the 1960s and 1970s, General Electric in the United States launched the Elec Trak electric tractor driven by lead-acid batteries and permanent magnet DC brushless motors, which further promoted the development of battery-powered tractors. Subsequently, many countries around the world conducted research and development on electric tractors powered by batteries. Figure 2 shows some representative battery-powered electric tractors.

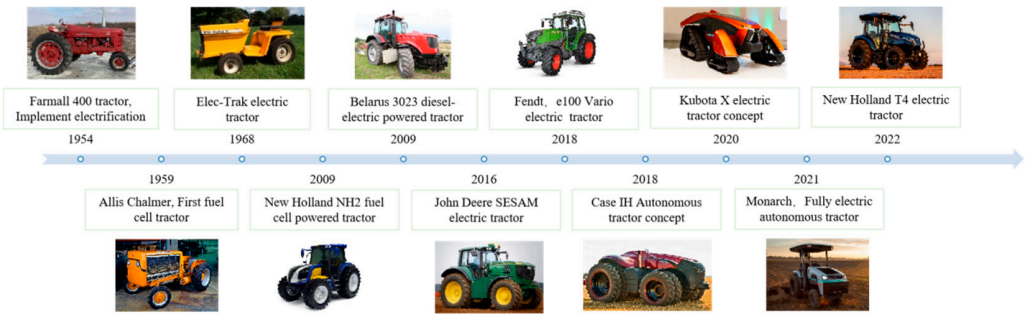


Figure 2. Historical timeline of some battery-powered electric tractors in other countries [37,38].

3. Current Situation of China's Tractor Industry

Tractors are the most important power machinery for agricultural production. As shown in Figure 3, tractors play an important role in agricultural production processes such as plowing, planting, managing, harvesting, and transportation.

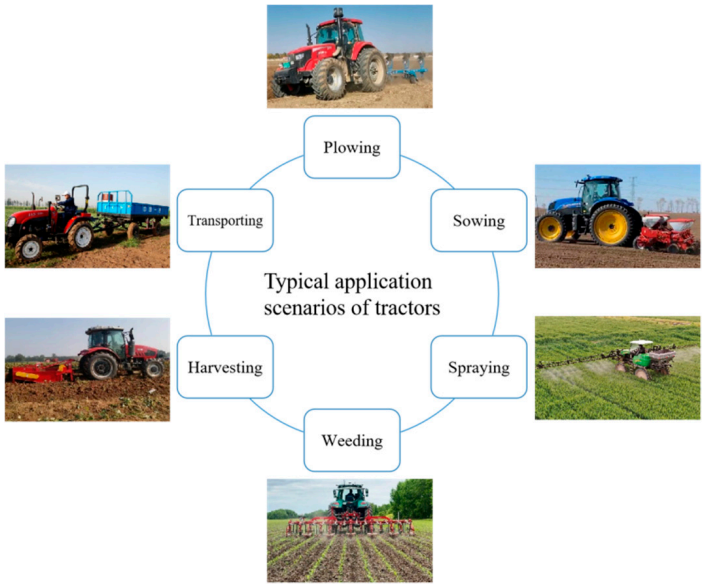


Figure 3. Schematic diagram of typical application scenarios for tractors.

The ownership of tractors is one of the important indicators of a country's level of agricultural mechanization development. Figure 4 shows tractor ownership in China over the past 48 years. According to Figure 4, by the end of 2022, the ownership of tractors in China exceeded 21 million. The ownership of tractors in 2022 is 278 times that of 1965. Among them, the ownership of large- and medium-sized tractors exceeds 5 million. The ownership of large- and medium-sized tractors remained relatively stable from 1978 to 2005. It surpassed 1 million in 2004 and 2 million in 2007. After 2007, it showed a rapid growing trend and reached a peak of 6.7 million in 2017. The ownership of small tractors had been on the rise until 2011. In 1997, it exceeded 10 million, and reached 18 million in 2011. After that, it gradually decreased year by year.

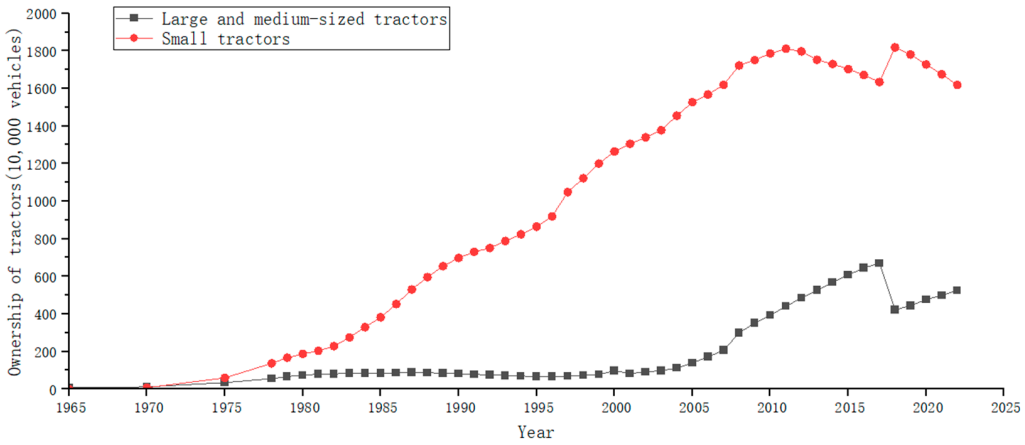


Figure 4. Ownership of tractors in China over the past 48 years. Note: The data are obtained from *China Rural Statistical Yearbook*, Beijing, 1980–2023, China Statistics Press. The classification standard for large- and medium-sized tractors and small tractors after 2018 has been changed from an engine power of 14.7 kW to 22.1 kW.

We need to point out that the classification criteria for tractors changed in 2018. Specifically, the upper limit of power for small tractors was changed from 14.7 kW to 22.1 kW. This means that, according to this standard, the ownership of small tractors will inevitably increase, while the ownership of large- and medium-sized tractors will inevitably decrease because, according to previous standards, tractors ranging from 14.7 to 22.1 kW would be classified as large- and medium-sized tractors. However, in 2018 and beyond, they will be classified as small tractors. Therefore, this can also explain why the ownership of small tractors in 2018 suddenly increased compared to the previous year. The ownership of large- and medium-sized tractors will suddenly decrease this year. However, with the development of agriculture in China, the demand for small tractors has weakened, and farmers generally purchase large- and medium-sized tractors. So even though the classification rules for tractors changed in 2018, the ownership of small tractors in the following years has been on a downward trend. On the contrary, the ownership of large- and medium-sized tractors is increasing. This phenomenon is consistent with the trend of the large-scale and high-efficiency development of agricultural machinery in China.

In addition, the export quantity of tractors from China in 2023 is about 150,000 units. This will play an important role in promoting the development of agricultural mechanization in other countries around the world, especially in developing countries along the Belt and Road.

4. Classification and Characteristics of Electric Tractors in China

As is well known, the main characteristic of electric tractors is that the walking system is driven by an electric motor. At present, electric tractors mainly include three types:

pure electric tractors, hybrid electric tractors, and fuel cell electric tractors. We refer to the relevant standards [39,40] and provide a brief analysis of the concepts and characteristics of three types of electric tractors below.

A pure electric tractor refers to a tractor whose operating power comes entirely from the onboard electrical energy storage device or the power grid. It has a simple structure and does not require an engine or gearbox. A fuel cell electric tractor refers to a tractor that uses a fuel cell system as a single power source or a hybrid power source of a fuel cell system and a rechargeable energy storage system. It can be further divided into two categories: pure fuel cell electric tractors and fuel cell hybrid electric tractors. A hybrid electric tractor refers to a tractor that can obtain power from at least two types of onboard energy storage devices. As shown in Figure 5, hybrid electric tractors can be divided into multiple types.

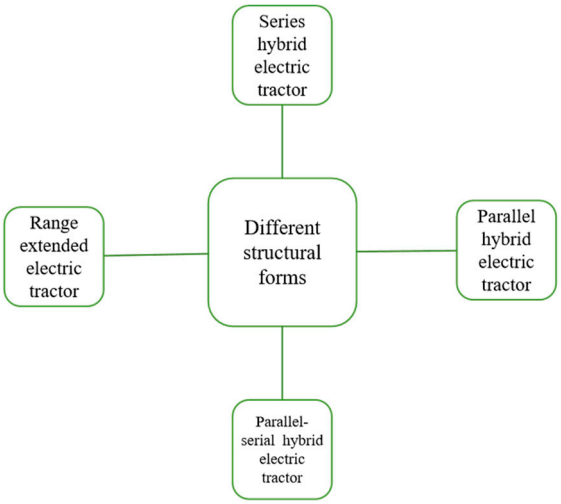


Figure 5. Classification of hybrid electric tractors.

The driving force of a series hybrid electric tractor only comes from the motor, and different types of energy are mixed using electrical coupling. The driving force of a parallel hybrid electric tractor is supplied simultaneously or separately by the motor and engine, and different types of energy are mixed using mechanical coupling. The parallel-serial hybrid electric tractor has both series and parallel drive modes, and different types of energy mixing modes can be switched between electrical coupling and mechanical coupling. The structural principles of extended-range electric tractors and series hybrid electric tractors are similar. The difference is that extended-range electric tractors generally operate in pure electric mode, and only turn on the auxiliary power supply device to provide electrical energy to the drive motor when the on-board rechargeable energy storage system cannot meet the operating mileage.

As shown in Table 1, after the previous analysis, we can summarize the advantages and disadvantages of these types of electric tractors.

Table 1. Advantages and disadvantages of different types of electric tractors.

Types	Advantages	Disadvantages
Pure electric tractors	Energy saving, environmentally friendly, stable and smooth.	Short driving distance and excessive reliance on charging facilities.
Hybrid electric tractors	High fuel economy and good power performance.	Production cost is high and there is still pollution to the environment.
Fuel cell electric tractors	High energy conversion efficiency and long service life.	Hydrogen fuel storage and transportation are difficult.

5. Development History and Recent Progress Regarding Electric Tractors in China

5.1. Development History of Electric Tractors

The development history of electric tractors in China is consistent with that of other countries in the world. Electric tractors have also gone through two main stages: power grid supply and battery-powered supply.

In the 1950s, Chinese researchers developed the first grid-powered wheeled electric tractor based on the imitation of Soviet electric tractors. Due to its power of 28 kW, it was named Electric Bull 28. Later, after improvement, the second wheeled electric tractor Electric Bull 33 and the first tracked electric tractor Electric Bull 55 were produced. These three electric tractors were powered by the power grid and long cables. Due to various factors, these electric tractors have not been widely used.

Entering the 21st century, with the development of China's electric vehicle industry, electrification improvement of tractors has also been on the agenda. Many companies and academic institutions in China have conducted research on battery-powered electric tractors and their key technologies. In particular, in 2007, Chinese scholar Gao Huisong wrote and published a review article titled 'Development of electric tractor and key technologies' [33]. This paper presents, in detail, the current research status of electric tractors in the world at that time, which also accelerated the process of electric tractor research in China.

5.2. Research Progress Regarding Electric Tractors

5.2.1. Production Status of Electric Tractors

In the production and manufacturing of electric tractors, Hiboridd (Beijing, China) Automotive Technology Co., Ltd., developed a battery powered electric tractor in 2011. In 2012, China Yituo Group Co., Ltd. (Luoyang, China), developed the ET1400 and ET1400-1 electric tractors. In the same year, Northwest Agriculture and Forestry University developed a small electric crawler tractor. In 2018, the National Agricultural Machinery Equipment Innovation Center successively developed China's first unmanned electric tractor. In 2020, Shandong Shifeng (Group) Co., Ltd. (Liaocheng, China), developed 25 horsepower and 35 horsepower electric tractors. In 2021, Jiangsu Yueda Intelligent Agricultural Equipment Co., Ltd. (Yancheng, China), developed the YL series electric tractor. In 2022, China Yituo Group Co., Ltd., developed a high-power diesel electric hybrid tractor. In 2024, Lingong Agricultural Equipment Co., Ltd. (Linyi, China), developed the world's largest horsepower hybrid electric tractor. Since 2020, the Engineering Laboratory of Intelligent Agricultural Machinery Equipment, Chinese Academy of Sciences, has successively developed the Honghu T series unmanned electric tractors. The representative electric tractors currently developed and produced in China are shown in Table 2.

Table 2. Typical electric tractors in China.

Manufacturers	Models	Physical Photo	Characteristics	Year	Notes
Hiboridd (Beijing) Automotive Technology Co., Ltd.	/		Powered by batteries, the electricity can plow 0.13 hectares of farmland.	2011	Functional prototype
China Yituo Group Co., Ltd.	ET1400		Dual motor drive, the power of lithium iron phosphate battery is 14.4 kW.	2012	Functional prototype

Table 2. *Cont.*

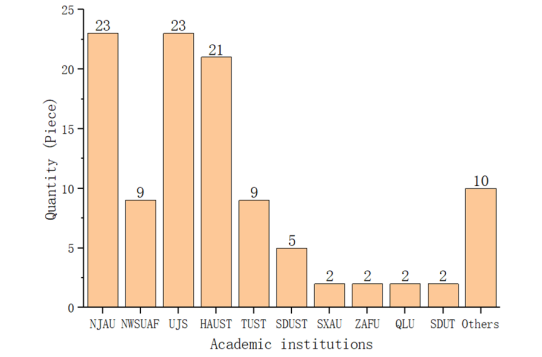
Manufacturers	Models	Physical Photo	Characteristics	Year	Notes
China Yituo Group Co., Ltd.	ET1400-1		Dual power supply system. Lead acid batteries are used for road transfer, and grid power is used for greenhouse work.	2012	Functional prototype
Northwest Agriculture and Forestry University	/		Adopting remote control operation. Powered by a 1.8 kW·h lead-acid battery.	2012	Functional prototype
National Agricultural Machinery Equipment Innovation Center	ET504		China's first electric tractor without a cab. Powered by a 55 kW·h lithium battery.	2018	Functional prototype
National Agricultural Machinery Equipment Innovation Center	ET504-H		Equipped with 5G mobile communication technology. Mainly powered by hydrogen fuel cells.	2020	Functional prototype
National Agricultural Machinery Equipment Innovation Center	ET1004-W		China's first four-wheel drive unmanned electric tractor.	2020	Functional prototype
Engineering Laboratory of Intelligent Agricultural Machinery Equipment, Chinese Academy of Sciences	Honghu T30		Pure electric unmanned tractor. Using lithium batteries and permanent magnet synchronous motors as power sources.	2020	Functional prototype
Engineering Laboratory of Intelligent Agricultural Machinery Equipment, Chinese Academy of Sciences	Honghu T150		China's first 200 horsepower unmanned electric tractor. There are 330 kW·h lithium iron phosphate batteries.	2021	Functional prototype
Shandong Shifeng (Group) Co., Ltd.	SF350E		Dual motor independent drive, battery capacity can work continuously for 6 h.	2020	Functional prototype
Jiangsu Yueda Intelligent Agricultural Equipment Co., Ltd.	YL254ET		A 25 horsepower four-wheel drive electric tractor. Powered by lithium iron phosphate batteries.	2021	Mass-market commercial sale
China Yituo Group Co., Ltd.	HB2204		A 220 horsepower hybrid tractor. It can achieve continuously variable speed travel from 0 to 40 km/h.	2022	Small lot production

Table 2. *Cont.*

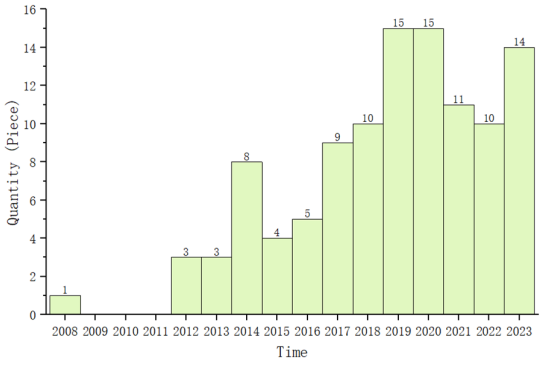
Manufacturers	Models	Physical Photo	Characteristics	Year	Notes
Lingong Agricultural Equipment Co., Ltd.	9E series		The world's most powerful hybrid tractor. Adopting a series hybrid technology route, the power exceeds 600 horsepower.	2024	Small lot production

5.2.2. Analysis of the Relevant Literature on Electric Tractors

We conducted a search for graduate theses using the keyword "electric tractor" on two data knowledge service platforms, China National Knowledge Infrastructure (CNKI) and Wanfang Data. After comprehensive analysis, there were 108 graduate theses directly related to electric tractors as of 2023. Among them, there are 6 doctoral theses and 102 master's theses. As shown in Figure 6, the classification is based on the academic institution, completion time, and research content of the graduate thesis.



(**a**)



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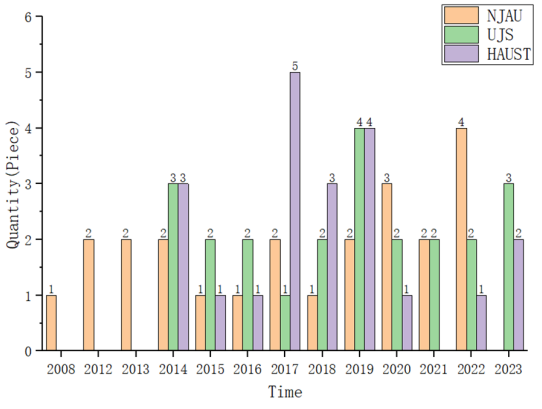

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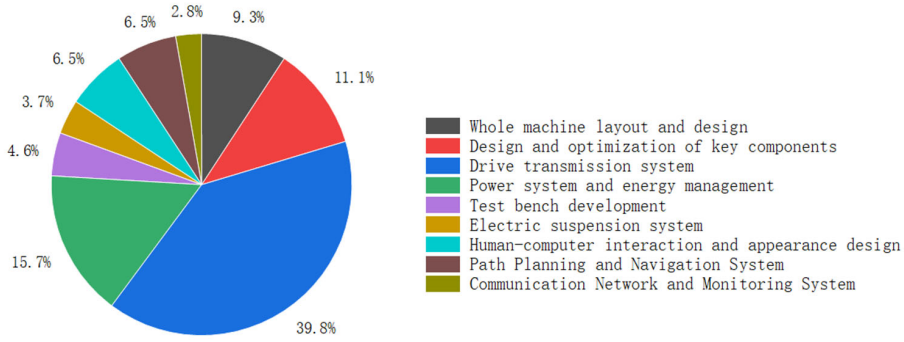

(**d**)

Figure 6. Classification of hybrid electric tractors. Note: NJAU is the abbreviation of Nanjing Agricultural University. NWSUAF is Northwest Agriculture and Forestry University. UJS is Jiangsu University. HAUST is Henan University of Science & Technology. TUST is Tianjin University of Science & Technology. SDUST is Shandong University of Science & Technology. SXAU is Shanxi Agricultural University. ZAFU is Zhejiang Agriculture and Forestry University. QLU is Qilu University of Technology. SDUT is Shandong University of Technology. Others mainly refer to China Agricultural University, Tianjin University of Technology and Education, Chinese Academy of Agricultural Sciences, Shihezi University, Chongqing Three Gorges University, Hubei University of Technology, Xi'an University of Technology, Hunan University, Liaoning University of Technology, and Zhongkai University of Agriculture and Engineering. (**a**) The number of graduate theses from different academic institutions. (**b**) The number of graduate theses at different times. (**c**) Analysis of the top three institutions in terms of the number of graduate theses. (**d**) The number of graduate theses divided by research content.

According to Figure 6a, the top three academic institutions with the highest number of graduate theses are NJAU, UJS, and HAUST. The sum of graduate theses from these three institutions accounts for 62% of the total. According to Figure 6b,c, the earliest graduate thesis was published in 2008 at NJAU. In both 2019 and 2020, there were 15 graduate students engaged in research on electric tractors. As shown in Figure 6d, the research content of these graduate theses mainly involves the drive transmission system and power energy management of electric tractors. Their proportion has reached over 50%. This indirectly indicates that the drive transmission system and power energy management are hot and difficult topics in the research of electric tractors. Overall, there are many graduate students in China engaged in research on electric tractors.

Similarly, these academic institutions have conducted extensive research on different types of electric tractors and their key technologies since 2007, and have achieved fruitful results.

5.2.3. Research Progress on the Key Technologies of Electric Tractors

Motor and Drive Transmission Systems

The use of electric motors for driving is one of the main differences between electric tractors and traditional tractors [41–43]. Research on electric motors and their drive transmission systems is also one of the hot topics for electric tractors [44–46]. Figure 7 shows the type of motors used in electric tractors.

At present, the drive transmission systems used for electric tractors mainly include single-motor drives, dual-motor independent or coupled drives, and four-motor independent drives [47–50]. Table 3 matches drive systems with different numbers of motors and agricultural scenarios.

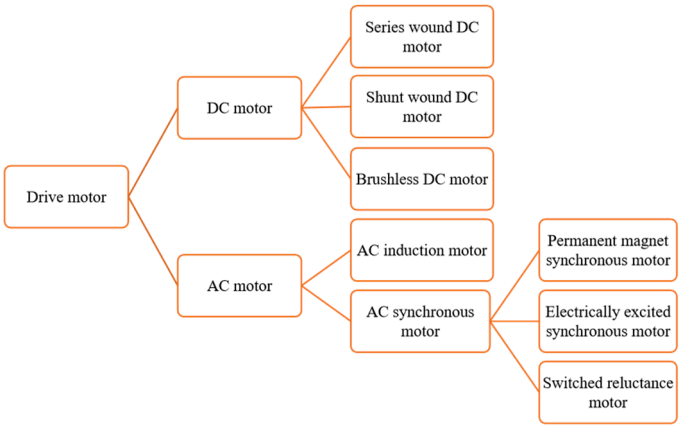

Figure 7. Types of motors used in electric tractors.

Table 3. Matching different driving systems and agricultural scenarios.

Drive System Type	Tractor Applications	Characteristics
Single motor drive	Transporting	Low torque
Dual-motor drive	Sowing, harvesting	Moderate torque
Four-motor drive	Plowing	High torque
	Spraying, weeding	High maneuverability

Meanwhile, Chinese scholars have conducted extensive research on these motor drive systems and their parameter matching.

(1) Single-motor drive

A single-motor drive refers to the use of one motor to drive the two rear wheels or both tracks of a tractor. Figure 8 shows a typical structural schematic diagram of pure electric tractors driven by a single motor.

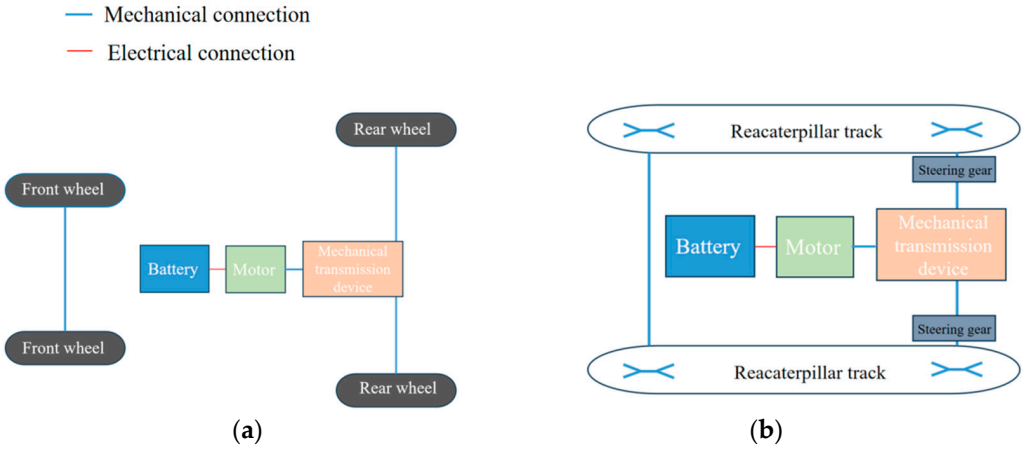

Figure 8. Schematic diagram of an electric tractor driven by a single motor: (**a**) wheeled electric tractor; (**b**) crawler-type electric tractor. Note: Mechanical transmission device mainly refers to the combination of gearbox, clutch, reducer, differential, etc.

The single-motor driven electric tractors is the earliest and simplest type of drive transmission system, widely used in various types of electric tractors.

① Single-motor-driven wheeled pure electric tractor

Nanjing Agricultural University was one of the earliest institutions to conduct research on wheeled pure electric tractors driven by a single motor. They systematically studied the design theory, driving force, and transmission efficiency of single-motor drive

transmission [51,52]. They conducted simulation experiments on motor drive systems using ADVISOR software [53,54], and developed a test bench for performance testing [55]. Shi et al. proposed a drive system scheme for a hand-held pure electric tractor [56]. Chen et al. studied a single-motor drive system for pure electric tractors suitable for hilly and mountainous areas [57]. Xie et al. designed a motor controller for wheeled pure electric tractors [58]. Ning et al. developed a pure electric tractor with an adjustable battery position driven by a single motor [59].

② Single-motor-driven crawler-type electric tractor

Northwest Agriculture and Forestry University conducted research on pure electric tractors driven by a single motor. They developed a crawler-type pure electric tractor for use in greenhouses [60,61]. The results of the plowing experiment conducted show a reduction of over 80% in energy consumption costs [62]. Jiangsu University has also conducted a series of studies on crawler-type pure electric tractors used in facility greenhouses [63–65]. They matched the parameters of the electric tractor transmission system and constructed corresponding control strategies based on the motor power requirements under different operating modes.

③ Hybrid electric tractor driven by a single motor

In recent years, many scholars in China have conducted research on series, parallel, and extended-range hybrid electric tractors and their drive transmission systems driven by a single motor. Shi [66] and Xu [67] et al. designed a transmission system for a series hybrid tractor driven by a single motor. Deng [68] and Xie [69] et al. analyzed a transmission system of a parallel hybrid tractor driven by a single motor. Zhao [70] and Wang [71,72] et al. conducted experimental tests on the drive systems of extended-range electric tractors driven by a single motor.

(2) Dual-motor drive

A dual-motor drive refers to the use of two motors to independently drive the two rear wheels or both tracks of a tractor. Alternatively, two motors can be coupled together to drive the two rear wheels or both tracks of the tractor. Figure 9 shows a schematic diagram of the structure of a typical electric tractor driven independently by dual motors.

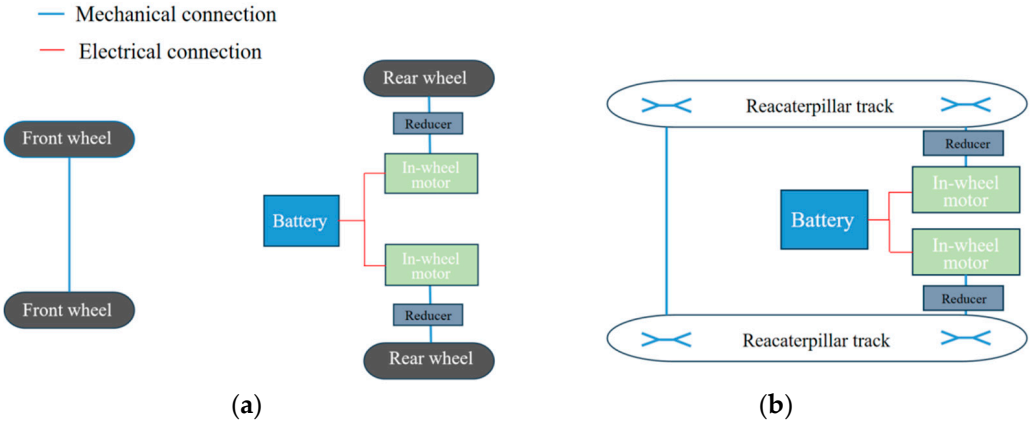

Figure 9. Schematic diagram of an electric tractor driven independently by dual motors: (**a**) wheeled electric tractor; (**b**) crawler-type electric tractor.

Lu et al. [73] studied a rear-wheel dual-motor independent drive system for a series of hybrid tractors and conducted plowing experiments. Mao et al. [74] constructed a dual-motor drive system for electric tractors and conducted simulation experiments. Zhao et al. [75] developed a mode-switching method for the dual-motor drive system of

an electric tractor. Xie et al. [76–78] studied the transmission performance of dual motor drive in electric tractors. Li et al. [79,80] conducted a systematic study on the transmission characteristics of a dual-motor coupled drive system for electric tractors. Chen et al. [81] designed and analyzed a torque-distribution strategy for a dual-motor coupled drive electric tractor. Zhang et al. [82] studied a fuzzy PI control strategy for dual-motor coupled drive electric tractors.

(3) Four-motor drive

A four-motor drive refers to the use of four motors to independently drive the four wheels of a tractor [23,83]. Figure 10 shows a wheeled electric tractor driven independently by four motors. An et al. [84] studied the differential steering characteristics of a four-wheel independent-drive electric tractor. Deng et al. [85] analyzed the dynamic characteristics of a four-motor independent-drive electric tractor. Zhou et al. [86] studied the torque-distribution problem of a four-motor independently driven electric tractor.

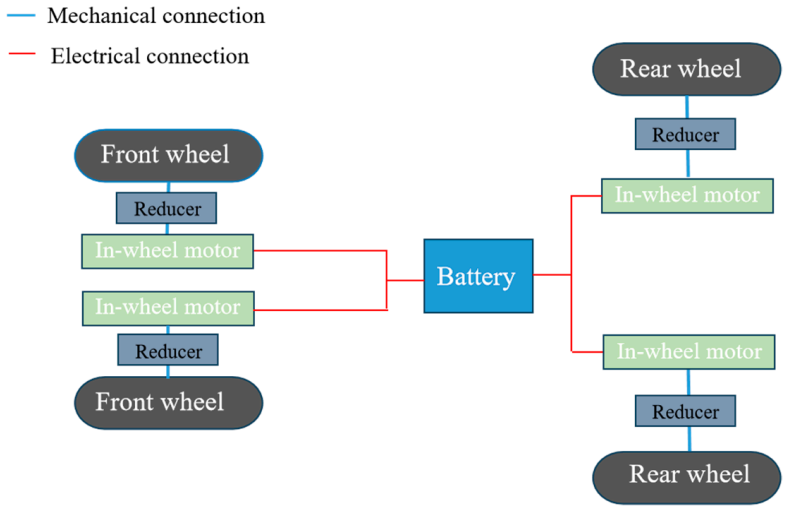

Figure 10. Schematic diagram of an electric tractor driven independently by four motors.

Battery and Energy Management Technology

The battery is the power source of electric tractors, and its selection and energy management technology are of great significance for improving the performance and service life of electric tractors [87–90]. Early electric tractors used lead-acid batteries as their power source. Currently, electric tractors commonly use lithium-ion batteries, supercapacitors, and fuel cells as power sources.

Currently, Chinese scholars have conducted extensive research on the battery and energy management technologies used in electric tractors. Li et al. [91] analyzed the issues of adaptive energy management and capacity configuration in the power supply systems of pure electric tractors. Wang et al. [92] constructed an energy management model for extended-range electric tractors. Xu and Wu et al. [93,94] studied energy management control algorithms for extended-range electric tractors. Zhao et al. [95] studied the energy management strategies of hybrid electric tractors. Li et al. [96] studied a real-time adaptive energy management strategy for dual-motor-driven electric tractors. Li et al. [97] analyzed the energy control strategies of electric tractors based on dynamic programming. Sheng et al. [98] studied energy management strategies for electric tractors based on demand power prediction. Xia et al. [99] studied an energy management strategy for electric tractors based on lithium-ion electronics and supercapacitors. Researchers from HAUST [100–103] and UJS [104,105] conducted a systematic study on the energy manage-

ment strategies of fuel cell electric tractors, which has made important contributions to promoting the energy utilization of fuel-cell electric tractors.

Test Bench Development and Other Key Technologies

The development of a test bench for the performance testing of electric tractors and their key components is of great significance. Wang et al. [106] built a series hybrid electric tractor test platform and conducted rotary tillage tests under pure electric and hybrid power modes. Xu et al. [107] designed a comprehensive test bench for electric tractors using a modular approach. The performance test results conducted on the test bench showed that the error compared to the previous simulation analysis was within 10%.

In addition, there have been many studies on the design of key components for electric tractors [108,109], overall performance testing [110–112], operation path planning [113,114], and unmanned driving [115,116]. These research results further promote the technological progress and intelligence level of electric tractors in China.

6. Development Prospects Regarding Electric Tractors in China

A large amount of practice has proven that electric tractors have many advantages, such as environmental protection, energy savings, simple operation, and easy implementation of intelligence [117–121]. Table 4 shows performance comparison results between electric tractors and traditional tractors.

Table 4. Comparison of performance between electric tractors and traditional tractors.

Work Scenario	Tractor Type		Performance Comparison Under the Same Condition	Reference
	Electric Tractor	Traditional Tractor		
Plowing	Parallel hybrid	Fuel powered tractor	The hybrid power saves 24% energy.	[68]
Plowing	Pure electric		The traction efficiency has increased by 3.7%, slip has decreased by 15.05%, and energy consumption has decreased by 4.9%.	[117]
Rotary tillage	Pure electric		The vehicle speed has increased by 14% and fuel consumption has decreased by 34.4%.	[122]
Simulation	Range extended		The maximum climbing slope has increased by 6.12%, and the maximum traction force has increased by 4.3%, the overall fuel consumption has been reduced by 5.37%.	[70]
Plowing	Pure electric		The average efficiency has increased by 0 38%, the energy consumption of the driving motor has been reduced by 7.53%.	[83]
Plowing	Pure electric		The energy consumption per unit mileage has decreased by 2.17%.	[98]

Therefore, research and applications of electric tractors are of great significance, especially for agricultural production and tractor-using countries like China. However, there are also many opportunities and challenges around the development of electric tractors.

The main opportunities are listed as follows:

(1) Currently, China is the world's largest producer and user of tractors. At the end of 2022, the ownership of tractors in use exceeded 21 million. The development and application of electric tractors have broad market prospects. Meanwhile, China has developed various electric tractors in recent years. Table 5 shows a comparison between electric tractors developed in China and those developed in other countries around the world. From Table 5, we can see that the electric tractors developed in

China are synchronized with the international advanced level and outperform other countries in terms of working horsepower.

(2) China's new energy vehicles have been widely promoted and used. In 2024, the production and sales of new energy vehicles in China were 12.888 million and 12.866 million, respectively, an increase of 34.4% and 35.5% year-on-year. Figure 11 shows the market penetration rate of new energy electric vehicles in China. We can see that it has been continuously growing in recent years. Especially in 2021, there was an increase of 8 percentage points compared to the previous year. The motors, batteries, and electronic control technologies used in new energy vehicles can be directly applied to electric tractors. The rapid development of electric vehicles in China will undoubtedly greatly promote the electrification process of tractors.

(3) In recent years, the Chinese government has continued to support the research and application of electric tractors. This includes launching national key research and development projects related to electric tractors, developing a promotion and evaluation outline for wheeled electric tractors, and providing subsidies for the purchase of high-power hybrid tractors. As shown in Table 6, the Chinese government has supported the development of electric tractors through policies, projects, and funding subsidies.

Table 5. Comparison between typical electric tractors in China and other countries around the world.

Countries	Electric Tractors			
	Models	Categories	Power	Autonomy
China	Lingong, 9E series	Hybrid	600 HP	/
China	Honghu T150	Pure	200 HP	Driverless
The United States of America	Monarch, MK-V	Pure	40 HP	Driverless
The United States of America	John Deere, Gridcon	Pure	400 HP	Driverless
Germany	Fendt, e100 Vario	Pure	67 HP	/

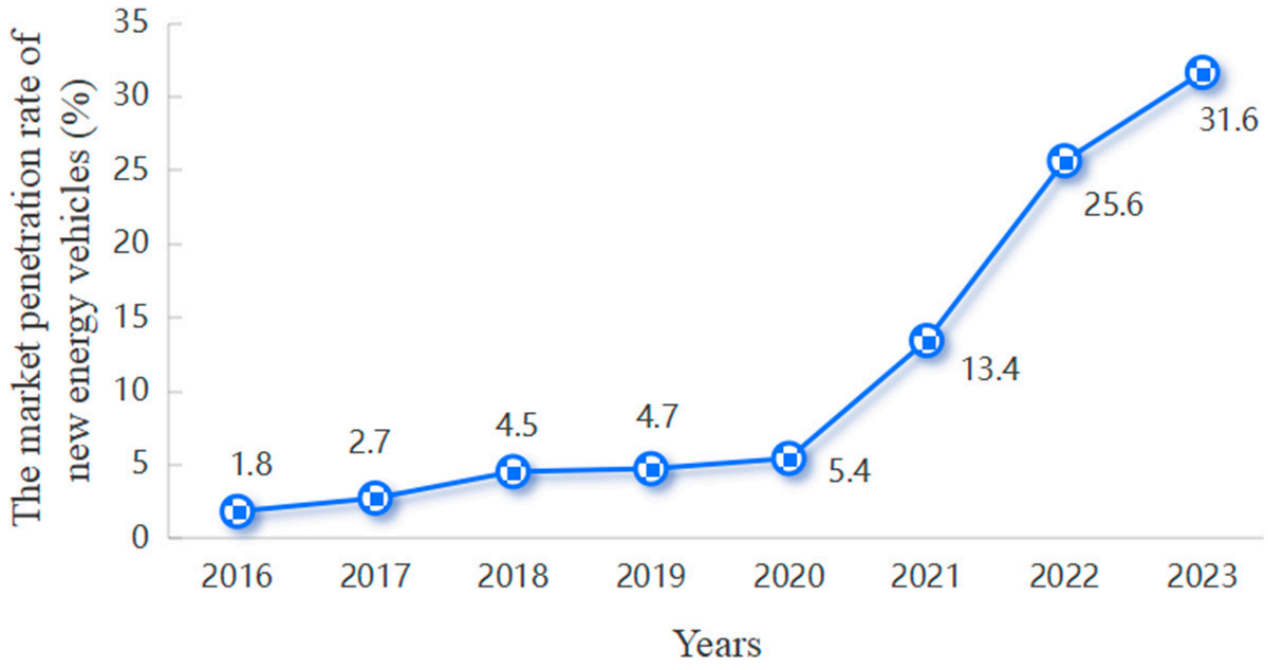

Figure 11. The market penetration rate of new energy vehicles in China.

Table 6. National policies and project support for electric tractors.

Types	Name	Start Year
National policy	The "Action Plan for the Development of agricultural machinery Equipment (2016–2025)"	2016
National project	Development of Intelligent Electric Tractor	2016
National project	Research and Demonstration of New Power System and Intelligent Control Unit Technology for Agricultural Machinery	2022

The main challenges are listed as follows:

(1) The application scenarios of tractors are significantly different from those of vehicles. In addition to road-driving functions, it is generally necessary to carry agricultural machinery for field operations. Tractors often require a large amount of power to operate in complex field environments, especially in the application scenarios of using electric tractors for plowing and excavating and harvesting underground crops. This is one of the challenges faced in the research and design of electric tractors.

(2) There is a lack of charging and swapping facilities around farmland. At present, China's charging infrastructure is mainly concentrated in large- and medium-sized cities, and these charging facilities are mainly used for electric vehicles. There are few charging facilities for electric vehicles or electric agricultural machinery in rural areas. In recent years, the government has also introduced policies to support the construction of charging infrastructure in rural areas, for example, the Guiding Opinions of the General Office of the State Council on Further Building a High-quality Charging Infrastructure System in 2023. This opinion clearly states the need to build effective coverage of rural charging networks. Overall, the construction of charging infrastructure in rural areas of China is still in its early stages, mainly constrained by the following reasons:

① Land in rural areas is protected, and private enterprises find it difficult to solve the problem of land attributes to build a large number of charging stations.

② The rural landmass is very large, the population is scattered, and the power grid density is low, making it difficult to meet the large-scale charging demand.

③ Due to the large area of rural areas, there is a shortage of offline maintenance personnel for charging infrastructure.

To solve the above problems, the government should conduct pilot projects in rural areas with good power grid infrastructure, and explore experience models for building charging and swapping infrastructure in rural areas. On the other hand, we should accelerate the improvement of rural power grid conditions and enhance power security. At the same time, we will strengthen the training of personnel for the operation and maintenance of charging and swapping infrastructure. It is also possible to consider the issue of rural charging infrastructure in the construction of high-standard farmland. We also need to fully utilize the current situation of wind and photovoltaic power generation in rural areas in China, and build an integrated charging and swapping infrastructure, as shown in Figure 12.

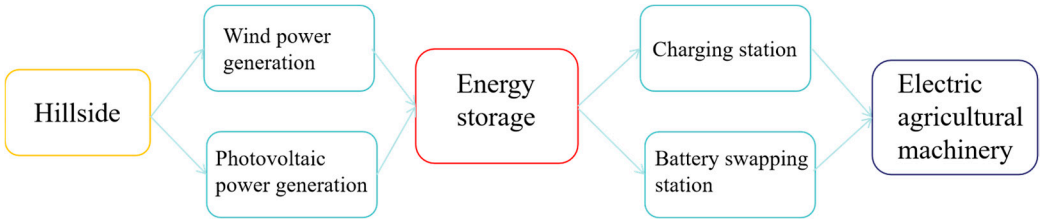

Figure 12. Schematic diagram of integrated charging and swapping infrastructure.

(3) At present, although there are some standards for electric tractors, these standards have not been systematized. Therefore, it is unable to effectively support the entire process of research and development, manufacturing, promotion, and application of electric tractors. According to the query on the National Public Service Platform for Standards Information, as shown in Table 7, there are currently only eight standards related to electric tractors in China (one industry standard and seven group standards). Compared to the 542 standards for electric vehicles (117 national standards, 76 industry standards, and 349 group standards), there is a significant gap in the number of standards. Although some standards related to electric vehicles can be used for electric tractors, there are still many aspects that need to be improved and supplemented, especially those standards that involve agricultural scenarios and have significant differences from electric vehicles.

Table 7. The current standards for electric tractors in China.

Standard Type	Standard Name	Standard Number	Release Date	Reference
Industry standards	Electric tractor	JB/T 15126-2025	9 May 2025	[123]
Group standards	Electric tractor—Walking system—Accelerated durability test method	T/CAAMM 345—2024	30 September 2024	[124]
	Electric tractors—Terminology	T/NJ 1318—2024	1 April 2024	[39]
	Pure electric tractors—Performance index calculation method	T/NJ 1309—2024	1 April 2024	[125]
	Electric tractors—Performance test method	T/NJ 1308—2024	1 April 2024	[126]
	Range-extended electric tractor-Part1: Terminology	T/CAAMM 210—2023	27 November 2023	[40]
	Electric tractor—Electric power train—Efficiency determination method	T/NJ 1256—2021	24 November 2021	[127]
	Electric tractor—Interface for electric power take-off	T/NJ 1177—2020	20 November 2020	[128]

(4) A systematic solution should be developed for the recycling and utilization of waste batteries. The issue of recycling used batteries has become one of the challenges facing the healthy development of the electric vehicle industry. This problem will inevitably be faced and solved by electric tractors in the near future. Only by addressing this issue can we ensure the healthy development of electric tractors in the future. Therefore, it is necessary to establish a multi-party collaboration mechanism. Not only should the producer responsibility system be implemented, but also a multi-party responsibility community of "battery producers + users + recyclers" should be built to thoroughly solve the problem of recycling waste batteries for electric tractors.

7. Conclusions

This study elucidates the classifications and characteristics of electric tractors in China. We summarized the research status of electric tractor motors and their transmission systems, batteries, and energy management technologies. We also analyzed some of the main opportunities and challenges facing the research and development around electric tractors in China. This research found that electric tractors in China are still in their early stages of development, with many still in the prototype stage. There is still a significant gap from development to industrial application. Meanwhile, the application scenarios of pure electric tractors are mostly in facilities such as greenhouses. Electric tractors with high power generally use hybrid modes.

Overall, China's active research around and applications of electric tractors are timely and of great significance in reducing labor intensity, fossil energy consumption, and carbon emissions in agricultural production.

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